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EFFECT OF SALINE IRRIGATION WATER LEVELS ON THE GROWTH OF TWO *ZINNIA ELEGANS* L. CULTIVARS

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ABSTRACT: The production and growth of ornamental plants are markedly affected by water deficiency. Therefore, enhancing their yield during the drought period has become the main goal in plant breeding. Two *Zinnia elegans* L. cultivars (Short Stuff and Profusion) were employed in this investigation to determine the effect of salinity and drought tolerance on plant growth for translation to a salinity and drought tolerance breeding program. Four irrigation treatments based on F.C. of medina used, (T_1= 40, T_2= 60, T_3= 80, and T_4= 100% (control) of field capacity) under five salinity levels (electrical conductivity (EC) of 0.63 dS m^{-1} (control)), EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4 dS m^{-1}) were imposed throughout a 120-day growing period using a drip irrigation system. The vegetative growth yield and the flowering characteristics were determined and gas exchange measurements were recorded. All flowering and vegetative characteristics decreased as the level of deficit irrigation water increased. Both cultivars treated with 40% under EC_3= 6.3 and EC_4= 9.4 dS m^{-1} did not flower. Nonetheless, significant differences were found between the two cultivars for all characteristics, indicating that they could be considered when adjusting for salinity and drought tolerance. Profusion cv. displayed better performance than Short Stuff cv., when grown under 80% and 100% irrigation treatments and the salinity levels, except for 40% with EC_3 and EC_4 which did not result in flower yield. Leaf chlorophylls content (chl. a, b, and total) reduced with the increase in the salinity level and with increasing deficit irrigation water treatments. Content of leaf minerals, such as Ca^{2+}, Na^{+}, and Cl^{-}, was also determined. For both cultivars, Ca^{2+} content decreased as irrigation salinity increased, while Cl^{-} and Na^{+} contents increased as salinity increased in the plant tissue following irrigation.

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Key words: Deficit irrigation, drought, flower yield, gas exchange, proline, mineral contents.

INTRODUCTION

Drought is one of the greatest important environmental stresses that limit crop productivity. Plant species adapt to this adverse condition via diverse strategies. A few of plants can (i) complete their life cycle under optimum conditions, (ii) decrease water loss by reducing their shoot size or stomatal pores, and (iii) continue their life cycle when the availability of water is limited (Bressan *et al*., 2002).

All plants undergo numerous stresses throughout their life cycle. However, their response is reliant on their species and the source of the stress. Currently, salinity serves as the major environmental factor that reduces plant productivity (Serrano, 1999). Owing to the worldwide constraints on fresh-water supplies, there has been a surge of

interest in the reusage of water (Shannon and Grieve, 1999). Salt stress can serve as a major challenge to agricultural production worldwide. More land spaces continue to be salinized by poor irrigation practices; hence, the impact of salinity is becoming increasingly a matter of concern (Winicov, 1998). As a result, there is increased demand for salt tolerant plants.

Salinization plays a main role in soil degradation as it affects 19.5% of irrigated land and 2.1% of the dry land utilized globally for agricultural purposes (FAO, 2000). The effects of salinity are more visible in arid and semi-arid areas as limited rainfall, high evapotranspiration, and high temperature, which are related with poor water and soil management; contribute to the issue of salinity, which becomes remarkably important for agricultural production in these regions.

Zinnia elegans, which belongs to the Asteraceae family, is native to Central America and Mexico zone. It is full-grown commercially as a bedding plant and cut flower and is well known for its tolerance to warm and dry conditions (Dole and Wilkins, 1999). Furthermore, Zinnia is a crop that has economic importance. Owing to its general tolerance of dry and saline conditions, Zinnia could be evaluated to elucidate its potential as a salt-tolerant cut flower crop.

The aims of the present study were to determine: (A) the feasibility of producing two Zinnia cultivars under conditions of increasing salinity and (B) the potential differences in plant growth and flowering yield when Zinnia plants are exposed to shortfall irrigation that is saturated with a chloride-based salt.

MATERIALS AND METHODS

Plant materials and treatments:

The present study was carried out in the nursery and grown under the net greenhouse conditions of the Plant Production Dep., College of Food and Agriculture Sciences, K.S.U., Saudi Arabia. Two commercial *Zinnia elegans* L. cultivars Profusion (Z) Coral Rose and Short Stuff (Group Flowers, Royal FloraHolland, Aalsmeer, Netherlands and HARRIS Seeds, Rochester, N.Y. USA) were used.

The seeds of two Zinnia cultivars were germinated in plastic pots (50×50 cm^2) on January 16th, 2018 (First season) and January 19th, 2019 (Second season). Twenty-four-day-old seedlings were transplanted into 15 cm diameter plastic pots for one seed per pot containing a combination of peat-moss and sand (1:1 by value). Deficit irrigation treatments began seven days after transplantation. Four irrigation treatments (T_1= 40, T_2= 60, T_3= 80, and T_4= 100% (control) of field capacity) were derived according to the amount of water detained by soils; this was calculated as the variance between dry and wet soil weight. Afterward determining the field capacity, control salt levels (tap water; EC_0= 0.63), EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4 dS m^{-1} NaCl and $CaCl_2$) were determined with the amount of water held by the soil (Naik and Widholm, 1993). Salt solutions at different $CaCl_2$ and NaCl levels were prepared by dissolving $CaCl_2$ and NaCl (1:1 by weight) in deionized water that was also used throughout the entire experimental period (Table, 1). The treatments included two commercial Zinnia cultivars (Profusion and Short Stuff), which were supplied with deficit irrigation and saline solutions. One month after planting, deficit irrigation

Table 1. Chemical analysis of the irrigation water used.

Chemical analysis	pH	EC (dS m^{-1})	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+} (meq l^{-1})	Cl^{-}	HCO_3^{-}	SO_4^{-}	NO_3^{-} (ppm)
Values	7.1	0.63	0.74	3.60	0.17	0.10	1.83	0.32	0.90	2.84

applications of the saline solutions were applied to the Zinnia plants using a manual irrigation water system that carried water to the surface of the soil. The pH and EC of each saline treatment were confirmed before each irrigation. Plants were sub-irrigated as needed. Irrigation intervals varied with treatments.

Experimental layout and data collection:

The experimental layout was a split-split-plot derived in a randomized complete block design in (RCBD) with three replications. Two Zinnia cultivars were planted as the main plots; four deficit irrigation water treatments were randomly allocated to the sub-main plots and five salt levels were derived to serve as the sub-sub-main plots. A random sample comprising of 6 plants from each sub-sub-plot was selected to determine the following vegetative growth traits: plant height (cm), number of leaves, leaf area (cm^2) of mature leaves, with the L1-3000 Model system (LI-COR, Inc., Germany). Shoot fresh and dry masses (g/plant), flowering date (day), number of inflorescences/plant, inflorescence diameter (cm), dry mass (g/plant) of the roots, and root length (cm) were also recorded. To obtain the dry mass, the samples were stored at 70 ℃ for 72 h in an oven; thereafter, mass was immediately recorded.

Gas exchange:

The photosynthetic rate (P_n), stomatal conductance (g_s), intercellular CO_2 concentration (C_i), and the transpiration rate (E) were determined using a gas exchange system (LI-COR Inc., LI-6400, Lincoln, NE, USA) between 10:15 and 11:15 am using fully expanded fifth blades. Measurements were performed at light saturating intensity on a sunlit day with active photosynthetic radiation ~650 µmol m^{-2} s^{-1}, relative humidity ~45%, and air temperature of ~25°C, on a fully expanded top leaf found on the major axis of the plant.

Chemical components:

At the end of the first season 120 days letter, an analysis of the following chemical component was carried out. To determine chlorophyll (chl. a, b, and total (a + b)) content (mg/g), we extracted chl. from fresh leaf samples using *N, N*-dimethylformamide (DMF) according to the method described by Porra *et al*. (1989). The levels of chl. *a*, *b*, and total (*a* + *b*) were calculated with the equations below:

Chl. $a = 13.43\ A^{663.8} - 3.47\ A^{646.8}$ (1)

Chl. $b = 22.90\ A^{663.8} - 5.38\ A^{646.8}$ (2)

Total Chl. $(a + b) = 19.43\ A^{663.8} - 8.05\ A^{646.8}$ (3)

All chemical components (Ca^{2+}, Na^{+}, and Cl^{-}) were determined in the sample solution using the A.O.A.C. (1992) process. Proline content (mg/g) was determined in dry leaf samples according to the method of Bates *et al*. (1973).

Statistical analysis:

Data were statistically analyzed by analysis of variance (ANOVA) (Steel *et al*., 1997) using the SAS Ver. 9.1 software (SAS Institute Inc., 1985, Cary, North Carolina, USA). Means for the different sources of variation were applied by the least significance difference (LSD) test at $P < 0.05$.

RESULTS AND DISCUSSION

Vegetative growth parameters:

The vegetative growth and flower yield of the Zinnia varieties (Profusion and Short Stuff) and the deficits in irrigation water and salinity are presented in Tables 2 - 5, including the results of statistical analysis. In both seasons, Profusion and Short Stuff achieved their highest height in control irrigation and control salinity, while the shortest plants were obtained in 40% deficit irrigation and EC_4 salinity level, respectively. Plant height decreased when salinity increased, as well as with decreased with low levels of irrigation (40% and 60%). When the varieties were compared, the Short Stuff variety was demonstrated to be more sensitive to salinity than Profusion (Tables, 2 and 3).

Table 2. Mean performance of the vegetative parameters of *Zinnia elegans* L. cvs. Short Stuff and Profusion plants grown under different salinity deficit irrigation water during first season.

Irrigation regime	Salinity levels	Plant height (cm)		Number of leaves		Leaf area (cm^2)		Shoot fresh mass (g)		Shoot dry mass (g)	
		Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff
T_1 40% F.C.	EC_0	15.30±2.13	12.70±1.20	10.96±2.85	10.16±2.53	84.32±5.12	61.00±5.27	6.88±0.63	4.48±0.34	2.50±0.61	1.28±0.34
	EC_1	12.29±1.89	12.27±1.32	10.28±1.58	10.04±2.32	77.01±4.36	51.32±6.54	6.87±0.53	4.32±0.38	2.41±0.48	1.05±0.32
	EC_2	12.57±1.35	10.79±2.03	11.09±1.86	9.21±2.24	75.00±6.25	49.67±8.24	5.28±0.24	3.89±0.27	1.85±0.74	0.96±0.24
	EC_3	10.71±1.04	8.18±1.13	9.59±2.64	9.49±1.02	62.33±7.21	38.01±8.59	4.70±0.62	2.03±0.52	1.31±0.73	0.92±0.15
	EC_4	6.91±0.52	6.52±0.78	8.35±1.58	7.14±1.52	56.29±6.89	37.00±4.51	3.53±0.82	2.89±0.61	1.14±0.49	0.90±0.24
T_2 60% F.C.	EC_0	15.50±1.30	13.13±1.26	15.92±3.21	11.89±2.04	91.31±8.56	73.00±5.69	9.20±0.57	8.39±1.53	2.60±0.51	1.52±0.28
	EC_1	14.57±2.11	11.43±1.56	14.49±2.25	11.72±0.98	89.35±5.79	71.66±7.58	10.11±0.35	7.80±1.29	3.16±0.47	1.51±0.34
	EC_2	15.27±2.95	10.74±2.05	13.56±3.59	10.52±2.30	84.33±7.58	71.04±4.36	9.10.421±	8.01±1.63	2.89±0.37	1.69±0.29
	EC_3	12.70±1.23	9.15±1.03	11.08±3.58	9.71±1.55	79.00±5.85	51.65±5.20	7.330.64±	7.37±0.58	2.52±0.55	1.54±0.27
	EC_4	7.67±0.74	9.30±1.12	10.95±1.89	9.72±1.24	67.68±6.25	49.02±4.58	6.48±0.34	5.91±0.67	2.17±0.50	1.17±0.15
T_3 80% F.C.	EC_0	15.63±2.72	13.58±1.50	15.65±1.58	18.25±1.48	88.36±8.52	73.00±6.25	11.47±0.24	9.53±0.83	2.80±0.58	2.51±0.53
	EC_1	14.03±1.93	12.75±0.36	14.32±3.57	16.91±2.57	88.30±6.58	71.68±5.30	11.36±0.68	8.20±0.95	2.67±0.61	2.35±0.70
	EC_2	13.00±1.83	10.78±1.05	14.70±2.66	17.06±1.96	79.66±8.69	71.04±4.25	9.71±0.74	8.11±1.03	2.66±0.69	2.20±0.43
	EC_3	12.60±1.75	9.78±0.85	13.32±3.60	14.28±1.57	81.29±8.47	69.66±8.23	8.55±0.58	6.28±0.65	2.76±0.80	1.64±0.15
	EC_4	9.63±0.51	8.95±0.56	12.82±2.68	15.71±2.64	74.00±6.41	67.35±4.69	5.30±0.65	5.18±0.86	1.35±0.67	1.49±0.27
T_4 100% F.C. (control)	EC_0	17.47±2.68	15.32±1.04	16.20±3.41	16.79±1.83	97.03±7.23	74.30±5.41	13.59±0.89	10.07±1.27	3.28±0.42	2.66±0.23
	EC_1	14.41±2.35	13.16±1.50	15.01±3.58	14.97±2.57	81.64±6.55	72.33±5.20	11.89±0.73	9.11±1.52	3.82±0.74	2.49±0.35
	EC_2	12.87±1.79	10.81±0.41	16.17±3.72	12.01±2.67	84.67±5.23	73.00±6.81	11.14±0.64	9.29±1.32	3.64±0.43	2.54±0.19
	EC_3	11.01±1.37	8.38±0.34	14.96±2.89	12.62±2.05	76.01±5.47	69.29±4.23	10.37±0.52	6.01±1.22	3.39±0.34	1.40±0.27
	EC_4	10.00±0.96	8.51±0.31	14.99±3.47	11.62±1.81	68.65±7.36	67.33±3.57	9.53±0.48	5.92±0.55	2.75±0.53	1.31±0.21
C * I * S		**		*		**		*		N.S	
Cultivars (C)		**		**		*		**		*	
Irrigation (I)		N.S		**		**		*		N.S	
Salinity (S)		**		**		**		**		**	
C * I		**		*		N.S		*		*	
C * S		**		**		N.S		**		**	
I * S		**		**		**		**		N.S	

Irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.
Means ± SDs are given for each treatment group; as indicated by split-split-plot, ANOVA followed by LSD test.
****Significant at 0.01 level of probability, *Significant at 0.05 level of probability, $^{N.S}$ Not-significant.**

Table 3. Mean performance of the vegetative parameters of *Zinnia elegans* L. cvs. Short Stuff and Profusion plants grown under different salinity deficit irrigation water during second season.

Irrigation regime	Salinity levels	Plant height (cm)		Number of leaves		Leaf area (cm^2)		Shoot fresh mass (g)		Shoot dry mass (g)	
		Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff
T_1 40% F.C.	EC_0	14.23±3.64	11.86±2.01	11.03±3.58	13.21±2.69	81.18±5.61	60.29±4.68	7.21±1.62	5.64±1.22	2.52±0.34	1.98±0.21
	EC_1	13.23±3.21	11.84±1.58	10.45±2.31	12.20±0.98	80.76±6.88	59.27±6.62	7.01±1.62	4.50±0.64	2.42±0.20	1.61±0.26
	EC_2	12.96±3.15	10.48±2.45	8.69±2.64	9.53±2.56	77.36±7.64	53.63±5.59	6.26±1.64	3.72±0.74	2.44±0.16	1.23±0.08
	EC_3	9.70±2.05	7.51±2.32	8.12±2.46	7.82±1.94	64.78±4.65	48.08±5.64	2.73±0.95	1.93±0.48	0.91±0.17	0.49±0.08
	EC_4	7.76±1.64	5.89±2.54	6.64±2.36	5.78±1.81	59.05±5.96	41.82±3.58	1.56±0.62	1.85±0.53	0.45±0.05	0.47±0.05
T_2 60% F.C.	EC_0	15.80±2.84	12.46±1.56	10.62±2.34	11.61±2.18	86.76±6.82	63.71±6.61	10.02±1.37	8.34±1.49	3.83±0.46	2.56±0.50
	EC_1	15.73±1.56	11.08±1.82	10.77±1.95	11.46±2.16	78.23±5.68	52.21±5.78	10.67±1.34	7.13±1.23	3.01±0.32	2.45±0.43
	EC_2	13.43±2.55	10.74±1.52	9.01±3.50	10.25±1.46	76.08±8.62	50.80±6.98	9.23±1.10	7.72±1.31	2.62±0.31	2.32±0.48
	EC_3	13.60±1.84	9.88±1.63	7.95±2.61	8.01±1.75	72.89±5.32	47.02±8.62	8.66±0.86	5.64±1.16	2.75±0.53	1.27±0.31
	EC_4	7.03±1.54	8.48±1.64	6.24±2.64	7.65±1.59	68.93±4.23	49.87±5.69	2.34±0.64	4.82±0.61	0.86±0.08	1.13±0.08
T_3 80% F.C.	EC_0	16.29±1.51	13.32±1.78	11.60±1.89	14.25±2.64	89.33±6.96	63.71±4.79	9.80±0.58	9.30±0.38	3.40±0.96	3.58±0.81
	EC_1	13.86±1.25	12.25±2.57	10.91±1.85	12.24±1.95	86.98±5.97	60.62±6.62	10.02±2.07	7.79±0.29	3.70±0.91	2.74±0.61
	EC_2	14.56±2.88	10.38±2.81	11.27±1.73	13.07±3.44	83.04±5.37	59.27±8.95	9.37±1.86	7.44±0.97	3.29±1.05	2.73±0.21
	EC_3	13.79±3.10	8.70±0.89	9.30±1.59	10.46±1.67	83.14±6.31	48.04±5.79	8.48±1.52	5.37±0.68	2.52±0.76	1.62±0.17
	EC_4	10.30±2.67	8.67±1.64	8.15±1.09	9.04±1.97	65.31±7.62	48.08±6.51	7.63±1.71	3.04±0.27	2.33±0.48	1.25±0.13
T_4 100% F.C. (control)	EC_0	18.13±3.33	15.62±1.85	11.32±2.71	13.91±1.31	98.83±3.95	69.15±5.26	12.85±2.10	7.93±0.98	4.24±0.51	2.63±0.79
	EC_1	16.33±1.30	13.42±2.15	10.12±1.88	10.20±1.32	93.93±8.64	67.15±4.26	9.48±1.79	7.04±1.04	3.88±0.67	2.57±0.65
	EC_2	12.26±2.50	10.74±1.97	11.34±2.37	10.61±0.88	88.28±6.79	66.91±3.85	9.07±1.83	5.19±0.62	3.68±0.43	1.50±0.34
	EC_3	10.70±2.64	10.07±1.83	8.90±2.12	9.62±1.24	83.89±5.69	54.51±6.78	6.32±0.67	4.34±0.32	2.36±0.08	1.36±0.28
	EC_4	11.23±2.31	8.78±1.21	7.95±1.48	8.29±0.64	74.87±7.86	50.15±4.98	6.19±0.49	2.85±0.12	2.48±0.16	1.14±0.19
C * I * S		**		*		*		**		N.S	
Cultivars (C)		**		**		**		**		**	
Irrigation (I)		**		N.S		**		**		*	
Salinity (S)		**		**		**		**		**	
C * I		N.S		**		**		**		**	
C * S		**		**		N.S		**		**	
I * S		**		**		**		**		*	

Irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.
Means ± SDs are given for each treatment group; as indicated by split-split-plot, ANOVA followed by LSD test.
****Significant at 0.01 level of probability, *Significant at 0.05 level of probability, $^{N.S}$ Not-significant.**

Table 4. Mean performance of the flower parameters of *Zinnia elegans* L. cvs. Short Stuff and Profusion plants grown under different salinity deficit irrigation water during first season.

Irrigation regime	Salinity levels	Flowering date (day)		Number of flowers		Flowering diameter (cm)		Root dry mass (g)		Root length (cm)	
		Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff
T_1 40% F.C.	EC_0	98.67±5.50	79.62±6.98	1.71±0.57	1.30±0.43	3.11±0.30	3.30±0.61	1.45±0.33	1.11±0.09	15.94±1.71	13.38±1.58
	EC_1	96.66±7.63	80.69±6.51	1.35±0.51	1.04±0.38	3.37±0.41	4.94±0.53	1.76±0.11	1.20±0.05	10.60±1.85	14.15±2.64
	EC_2	97.31±7.76	79.00±5.23	1.66±0.46	1.00±0.40	2.63±0.35	3.66±0.49	0.67±0.07	0.78±0.11	9.25±1.11	15.56±1.79
	EC_3	0.00	0.00	0.00	0.00	0.00	0.00	0.34±0.07	0.26±0.02	5.43±1.34	9.93±1.52
	EC_4	0.00	0.00	0.00	0.00	0.00	0.00	0.22±0.15	0.14±0.02	4.27±0.98	7.13±2.37
T_2 60% F.C.	EC_0	87.01±3.60	82.01±7.19	3.32±0.38	1.69±0.34	4.26±0.71	3.19±0.38	1.88±0.26	2.26±0.34	17.14±1.35	19.51±1.75
	EC_1	95.33±2.51	82.33±8.22	3.69±0.57	1.66±0.39	4.50±0.53	3.42±0. 17	1.32±0.14	1.21±0.19	15.43±1.60	18.08±1.35
	EC_2	91.30±5.23	75.03±5.35	3.71±0.49	1.32±0.41	4.05±0.37	3.68±0.49	1.49±0.22	1.19±0.14	15.37±1.27	17.22±1.96
	EC_3	88.02±2.64	74.25±6.57	2.33±0.50	1.05±0.71	3.61±0.28	1.10±0.12	1.20±0.10	0.29±0.01	11.47±2.19	9.59±1.73
	EC_4	83.29±4.96	0.00	0.35±0.41	0.00	0.94±0.38	0.00	1.54±0.18	0.16±0.13	5.80±1.88	10.35±1.72
T_3 80% F.C.	EC_0	87.00±6.34	77.00±5.32	4.00±0.38	2.34±1.07	3.92±0.43	4.82±0.27	1.17±0.25	1.26±0.17	13.43±1.68	19.03±2.49
	EC_1	92.36±8.11	73.65±6.71	3.67±0.38	1.61±0.53	3.96±0.31	4.62±0.25	1.28±0.21	1.53±0.14	9.37±1.27	32.01±4.67
	EC_2	94.33±5.36	80.68±4.28	3.33±0.69	1.59±0.52	3.54±0.38	3.47±0.31	1.75±0.16	1.26±0.11	12.57±1.61	12.72±1.88
	EC_3	94.67±5.87	84.30±4.12	2.31±0.41	1.02±0.46	3.24±0.16	3.92±0.52	1.56±0.17	0.98±0.08	8.66±1.38	9.51±1.72
	EC_4	95.01±4.98	0.00	1.66±0.71	0.00	2.48±0.27	0.00	0.67±0.05	0.83±0.07	5.77±1.02	10.92±2.48
T_4 100% F.C. (control)	EC_0	88.65±6.87	83.00±4.62	6.29±1.83	2.31±1.21	3.98±0.19	4.78±0.73	1.19±0.21	1.57±0.21	12.60±1.98	25.59±3.72
	EC_1	91.00±5.63	81.29±4.71	3.64±1.07	1.04±0.60	3.54±0.23	2.51±0.43	1.13±0.18	1.16±0.12	9.50±1.64	14.69±2.58
	EC_2	91.66±6.85	68.65±5.19	2.71±0.71	1.70±0.33	3.27±0.37	3.48±0.67	1.08±0.17	1.14±0.15	11.76±1.82	16.31±2.64
	EC_3	94.69±4.87	66.57±4.28	2.33±0.72	0.34±0.11	2.58±0.34	0.74±0.13	0.90±0.19	0.88±0.24	8.63±2.16	11.45±2.19
	EC_4	96.02±5.32	0.00	1.29±0.51	0.00	2.37±0.20	0.00	0.75±0.12	0.64±0.08	6.97±0.65	6.59±1.57
C * I * S		**		**		N.S		N.S		N.S	
Cultivars (C)		**		**		N.S		*		*	
Irrigation (I)		**		**		N.S		*		N.S	
Salinity (S)		**		**		**		**		**	
C * I		**		**		N.S		N.S		N.S	
C * S		**		**		N.S		*		N.S	
I * S		**		**		N.S		**		N.S	

Irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.
Means ± SDs are given for each treatment group; as indicated by split-split-plot, ANOVA followed by LSD test.
****Significant at 0.01 level of probability, *Significant at 0.05 level of probability, $^{N.S}$ Not-significant.**

Table 5. Mean performance of the flower parameters of *Zinnia elegans* L. cvs. Short Stuff and Profusion plants grown under different salinity deficit irrigation water during second season.

Irrigation regime	Salinity levels	Flowering date (day)		Number of flowers		Flowering diameter (cm)		Root dry mass (g)		Root length (cm)	
		Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff	Profusion	Short Stuff
T_1 40% F.C.	EC_0	97.33±3.25	78.65±5.94	2.23±0.64	1.70±0.16	2.70±0.17	3.37±0.31	1.68±0.20	1.18±0.11	16.59±4.01	15.15±3.67
	EC_1	98.00±5.16	80.32±4.25	1.90±0.52	1.23±0.17	3.20±0.28	4.47±0.21	1.56±0.18	1.27±0.12	10.97±3.58	12.71±4.95
	EC_2	99.02±6.95	78.66±6.58	2.06±0.34	1.10±0.12	3.23±0.42	3.85±0.25	0.48±0.05	0.63±0.08	6.63±1.53	11.59±3.45
	EC_3	0.00	0.00	0.00	0.00	0.00	0.00	0.44±0.05	0.27±0.11	5.60±1.85	6.20±1.81
	EC_4	0.00	0.00	0.00	0.00	0.00	0.00	0.32±0.03	0.23±0.07	4.51±1.23	6.88±2.16
T_2 60% F.C.	EC_0	88.31±6.58	81.36±7.82	4.26±0.28	1.63±0.16	3.97±0.53	3.52±0.21	1.57±0.16	2.14±0.29	18.13±5.64	20.18±2.92
	EC_1	94.04±4.62	81.02±5.58	4.19±0.29	2.43±0.19	4.65±0.84	3.28±0.27	1.32±0.27	1.98±0.24	15.76±3.92	19.74±3.69
	EC_2	87.00±8.29	74.33±6.18	3.43±0.31	1.63±0.14	4.15±0.51	3.91±0.24	1.70±0.17	1.60±0.25	15.73±5.25	18.22±2.48
	EC_3	90.28±4.59	68.31±5.61	2.65±0.26	1.36±0.12	3.24±0.31	0.76±0.16	0.21±0.01	1.68±0.20	11.94±3.12	8.92±1.65
	EC_4	59.33±6.27	0.00	0.69±0.16	0.00	0.54±0.09	0.00	0.13±0.02	0.75±0.09	6.06±1.52	10.02±3.19
T_3 80% F.C.	EC_0	91.03±5.95	75.05±4.95	3.86±0.13	1.63±0.10	3.56±0.86	5.32±0.19	1.83±0.23	2.30±0.39	13.86±3.58	31.34±7.85
	EC_1	85.69±6.21	74.33±5.24	4.33±0.21	2.60±0.21	3.69±0.61	4.48±0.15	1.96±0.26	1.79±0.16	9.60±2.85	20.43±3.26
	EC_2	93.35±7.11	82.04±3.25	3.40±0.16	1.63±0.11	4.01±0.89	3.54±0.19	1.62±0.24	2.32±0.28	12.82±1.64	16.55±2.58
	EC_3	94.01±4.52	82.68±7.16	2.73±0.14	1.26±0.08	3.17±0.56	4.00±0.34	0.99±0.13	1.58±0.16	9.03±2.47	14.05±3.59
	EC_4	96.33±5.27	0.00	2.30±0.08	0.00	2.64±0.23	0.00	0.47±0.06	0.83±0.10	6.26±1.75	9.84±2.25
T_4 100% F.C. (control)	EC_0	87.66±5.16	78.00±7.89	6.86±0.79	1.96±0.18	3.54±0.38	5.04±0.81	1.77±0.17	2.28±0.27	12.39±3.68	23.92±3.25
	EC_1	91.29±3.18	82.67±5.64	4.06±0.51	1.23±0.24	3.89±0.26	2.34±0.41	1.63±0.13	2.19±0.20	12.43±3.95	15.69±1.58
	EC_2	90.38±4.18	81.00±5.16	3.30±0.34	2.13±0.29	3.80±0.34	3.81±0.31	1.67±0.18	1.75±0.14	9.86±2.58	16.64±2.04
	EC_3	96.03±4.52	68.10±4.83	3.16±0.27	0.76±0.07	2.52±0.16	0.97±0.02	1.28±0.12	0.94±0.07	9.41±2.07	10.75±2.16
	EC_4	95.67±6.49	0.00	1.63±0.14	0.00	2.24±0.24	0.00	1.06±0.10	0.89±0.06	9.13±1.79	10.63±1.48
C * I * S		**		**		**		**		**	
Cultivars (C)		**		**		**		**		**	
Irrigation (I)		**		**		**		**		**	
Salinity (S)		**		**		**		**		**	
C * I		**		**		**		**		*	
C * S		**		**		**		**		**	
I * S		**		**		**		*		*	

Irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.
Means ± SDs are given for each treatment group; as indicated by split-split-plot, ANOVA followed by LSD test.
****Significant at 0.01 level of probability, *Significant at 0.05 level of probability, $^{N.S}$ Not-significant.**

Based on the interactions in both seasons, plant height, flowering date and number of flowers under the levels of deficit irrigation and salinity were found to statistically differ with P values ≤ 0.05, while the number of leaves statistically differed with P values ≤ 0.01. For the interaction among the three factors in both seasons, no differences were found in the flowering diameter, root dry mass and root length (the first season only), and shoot dry mass.

In both seasons, the number of leaves and leaf area were markedly reduced by successive decreases in the amount of irrigation water and increases in salinity levels. Furthermore, the rate of response was found to vary among the studied characteristics. Under control salinity, the Profusion variety had high leaf number and leaf area in the T_4 control irrigation but under EC_4 salinity, these values were low in the T_2 and T_1 regions. When the irrigation water was reduced, the physiological processes were affected; thus, plants were experiencing drought stress, which is reflected by the low water absorption and transmission to different parts of the plant.

The growth of plants, which was estimated as its shoot fresh mass, was greatly influenced by deficit irrigation and high salinity level. Hence, significant differences were found in the shoot fresh mass after treatment with diverse levels of irrigation and salinity. No significant differences were found in shoot dry mass of plants exposed to both deficit irrigation and saline water (Tables, 2 and 3). Under control salinity, the Profusion and Short Stuff varieties had high shoot fresh mass in the T_4 control irrigation; however, at the EC_4 salinity, a low shoot fresh mass was found at T_1 and T_2.

In both seasons and cultivars, the growth parameters for the dry mass of Zinnia root were not significantly affected by the different levels of salinity with deficit irrigation. Although root length was significantly affected by different treatments, it was reduced by successive increases in salinity levels (Tables, 4 and 5).

The reduction in plant vegetative growth is a communal phenomenon that occurs when plants are grown under stresses of deficit irrigation and increased salinity, and is commonly referred to as underdeveloped plant growth. The first response of plants to deficit irrigation and salinity is a decrease in their growth rate. This is due to a deficit in water and the osmotic effect of salts around the zone of the roots, which lead to a decrease in the water supply to plant cells as clarified by earlier studies (Blum, 1986; Boursiac *et al*., 2005). Previously, Shannon and Grieve (1999) demonstrated the inhibition of root growth and its function when there is a high exterior salt concentration. Munns and Tester (2008) also stated that the mechanism of salt tolerance in plants may result in limited cell extension because of an increase in EC. A decrease in the division and elongation of plant cells decreases their final size, consequently leading to a decrease plant height, the leaves number, leaf area, shoot fresh mass, and root length growth, as reported previously (Cabrera, 2003; Cassaniti, *et al.*, 2009; Ahir *et al*., 2017). A decrease in growth parameters in different ornamental plants owing to salinity has also been mention in gladiolus (Cerquera *et al*., 2008; Ahir and Alka, 2017), marigold (Valdez-Aguilar *et al*., 2009), and Zinnia (Zivder *et al*., 2011). The drought-induced reduction in the enlargement and division of cells can account for the reduction in individual leaf area and number of leaves (Dale, 1988). With severe drought conditions, plants with leaves adopt a spindle shape, and their leaf area is remarkably decrease (Chaves and Oliveria, 2004). Thus, a minor leaf area can be considered as a benefit for decreasing water consumption (Ālvarez *et al*., 2009). This special mechanism too enables plants to resistance water stress. Increasing stomatal resistance and a low stomatal density can also decrease the transpiration (Parsons, 1982).

An increase in the growth of roots can increase drought tolerance in plants (Dhanda *et al*., 1995). However, root length can be

decreased by a little water supply (Passioura, 1982; Dhanda *et al*., 1995). In the present investigation, length of root was found to be significantly affected, with "Profusion" displaying a reduced length relative to Shot Stuff. This reduction in the roots growth may be owing to the phenotypic plasticity (Kuldeep *et al*., 2011) that occurs during stress-induced irrigation and is important for avoiding the effect of drought stress (Chylinski *et al*., 2007).

Flowering Parameters:

In both seasons, flowering parameters (flowering date, number of flowers/plant, and flower diameter) were significantly influenced by salinity levels with deficit irrigation. While averaged overall shape treatments, the flowering date and number of flowers increased in response to the increase in deficit irrigation with the highest values recorded in salinity levels. Flowering and growth parameters were markedly reduced after irrigation treatment with concentrations greater than 3.3 dS m^{-1}. Short Stuff Zinnia plants seemed to be more sensitive to salinity than the Pro-fusion plants. For the Profusion plants treated with saline water (EC_3 and EC_4), fewer than 40% deficit irrigation was required to halt flower production. Conversely, Short stuff could not produce flowers under EC_4 when all of the deficit irrigation treatments were employed (Tables, 4 and 5).

A delay in flowering due to the mechanism that alters the growth stage of flowering is known to result from multiple stresses (cellular toxicity, nutritional deficit, and osmotic imbalance) exerted by salinity (Stanton *et al*., 2000; Cameron *et al*., 2006). A reduction in root biomass owing to salinity has been indicated to impede flowering by affecting energy reserves (Van Zandt and Mopper, 2002). Thus, irrigation with saline water reduces growth of crops and the production in sensitive species crops (Volkmar *et al*., 1998) owing to the harmful effects on element relations, biomass partitioning, and irrigation water. The response of ornamental plants to salinity depends on growth conditions and cultivar (Bass *et al*., 1995; Sonneveld *et al*., 1999).

Flower characteristics (flowering date, number of flowers, and flower diameter) were reduced by gradually decreases in the amount of deficit irrigation and increased by the level of salinity in water. The increase in salinity level under deficit irrigation negatively affected the initial performance of flowers, including their development and growth.

As drought stress significantly affected the number of flowers/plant in both cultivars, plants can survive despite a lack of water and avoid losses in flower number. The number of flowers may thus be typical as cultivar has a greater influence on this number than drought. Nevertheless, water deficit may influence flowering parameters by inhibiting vegetative growth in ornamental plants (Cameron *et al*., 2006; Ālvarez *et al*., 2009). In general, plants have a tendency to produce flowers under deficit irrigation owing to the stress created by the deficiency in needs water principals. This for the plant to usage all of its resources for flowering, which results in early flowering (Mott and McComb, 1975), nonetheless lower flowers number to save the components required for survival (Augé *et al*., 2003; Riaz *et al*., 2013).

Salt tolerance is a polygenic characteristic and plants tend to differ according to Na tolerance and salt tolerance. Plants display optimal production when Na and salt concentrations are minor; thus, growers must strive to use irrigation water sources that have traces of Na and salts (Raudales and Dickson, 2019). Based on the guidelines for the quality of water used for irrigation, plants are not exposed to risks once the Na level is lower than 60-69 mg l^{-1}; however, a moderate risk to their growth is expected when Na level exceeds 120-210 mg l^{-1} (Peterson, 1996; Rolfe *et al*., 2000).

Gas exchange measurements:

The P_n, g_s, C_i, and E of the plants are shown in Figs. 1 and 2. In the Short Stuff,

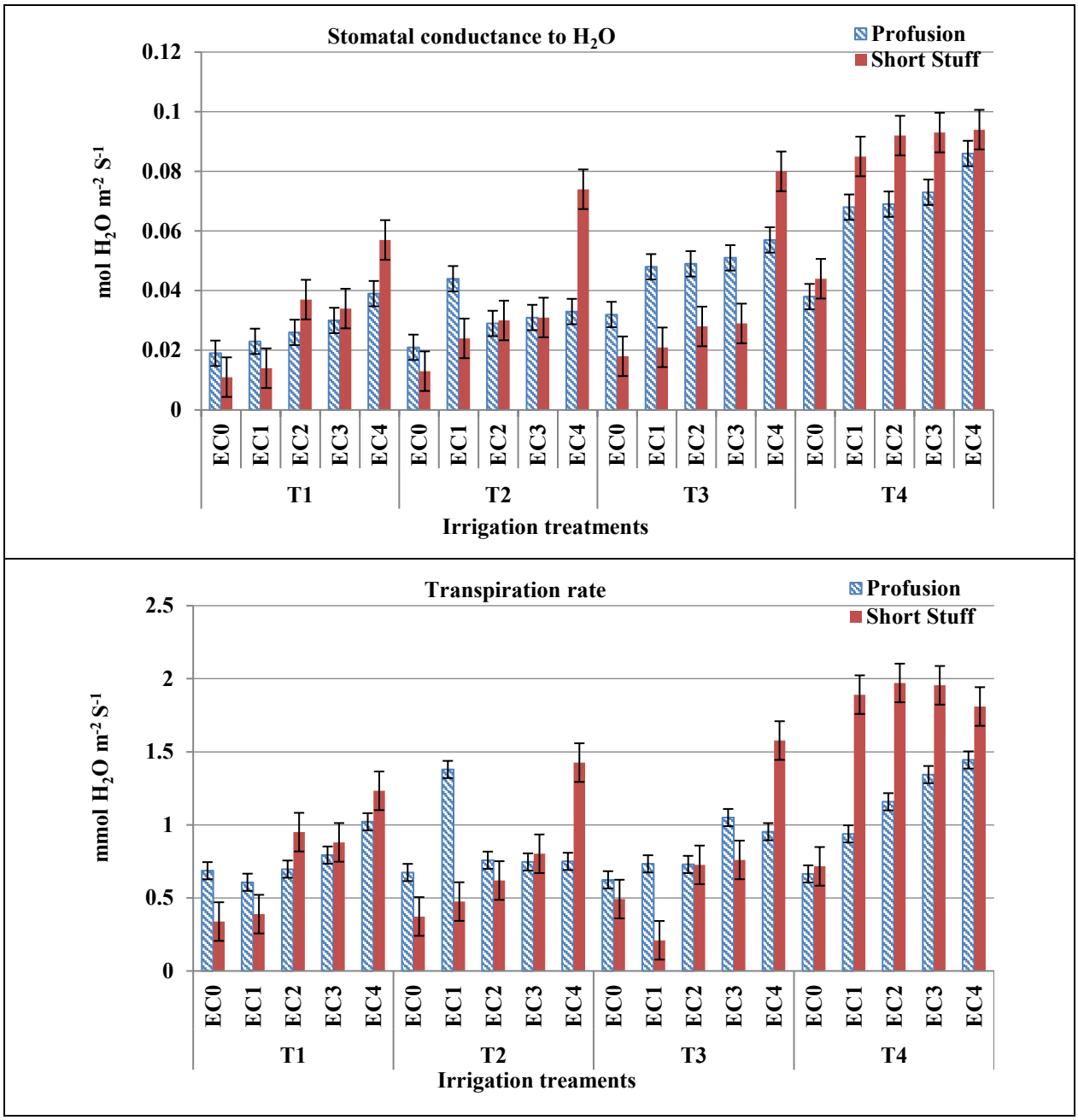

Fig. 1. Stomatal conductance to H_2O, and transpiration rate of Profusion and Short Stuff cvs. zinnia plants grown under different salinity deficit irrigation water. Deficit irrigation water treatments: T_1= 40, T_2= 60, T_3= 80, and T_4= 100% F.C.; irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.

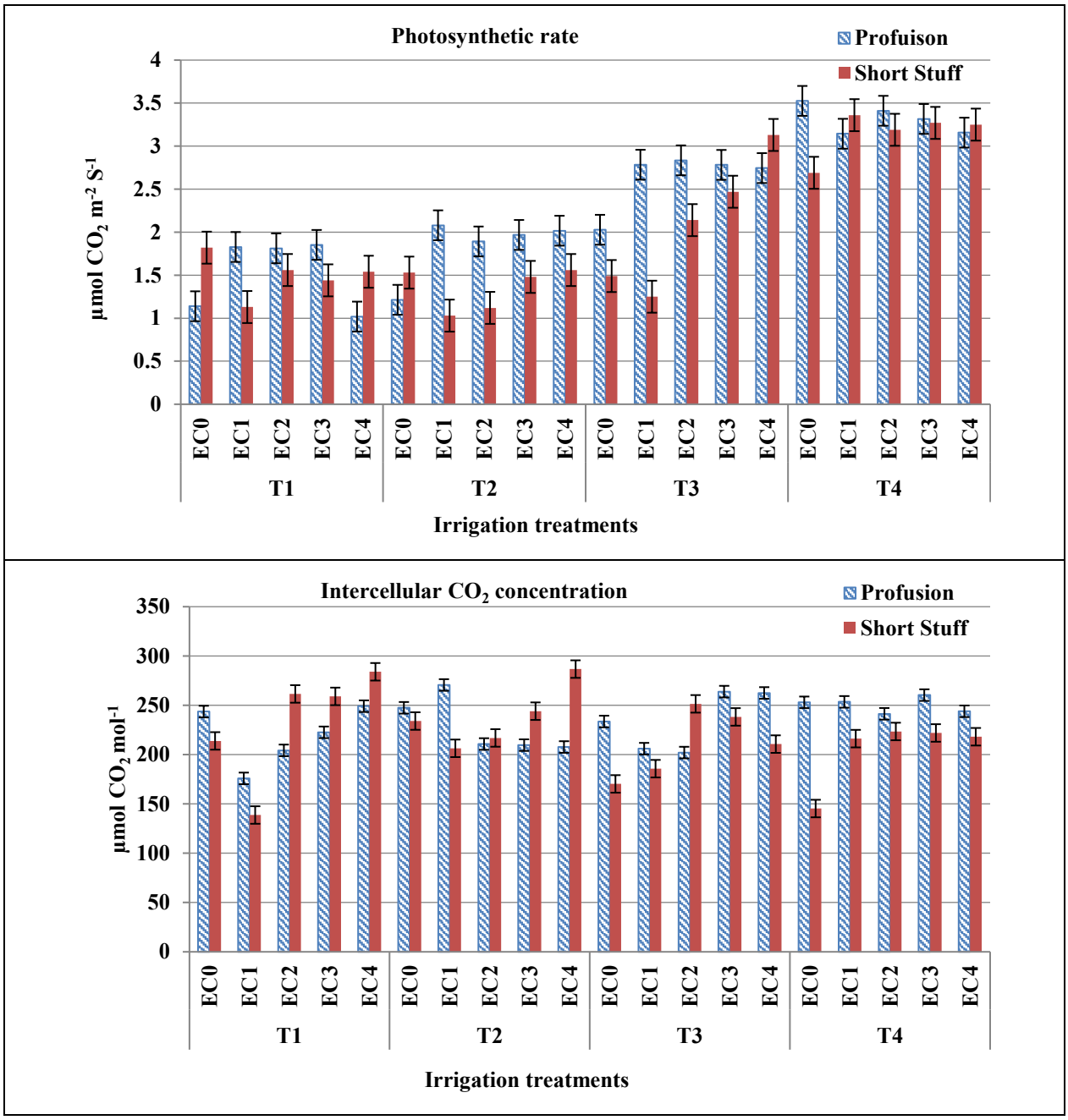

Fig. 2. Photosynthetic rate and intercellular CO_2 concentration of Profusion and Short Stuff cvs. zinnia plants grown under different salinity deficit irrigation water. Deficit irrigation water treatments: T_1= 40, T_2= 60, T_3= 80, and T_4= 100% F.C.; irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.

value of recorded number was higher than Profusion at g_s and E. All parameters increased with an increase in salinity but reduced in the plants subjected to deficit irrigation compared to the control; this finding was despite the greater reductions in g_s and E (Fig., 1) than in P_n and C_i (Fig., 2).

A reduction in leaf water potential owing to deficit irrigation with saline water could be the reason of the reduction in g_s and other physiological adaptations, such as inferior leaf area growth, which might contribute to the reduction in total irrigation water ingesting (Kang *et al*., 2000). Previously, shortfall irrigation water was demonstrated to decrease daytime g_s, thereby leading to a reduction in the leaf water potential (Munnè-Bosch *et al*., 1999; Moore *et al*., 2019).

Photosynthetic pigments:

Photosynthetic efficiency is thought to depend on photosynthetic pigments, such as chl. a and chl. b, which play a significant role in the photochemical responses involved in photosynthesis (Taiz and Zeiger, 2002). Stresses induced by drought and salinity can inhibit photosynthesis in plants by affecting chlorophyll content, which results in changes in the chl. components (chl. a, b and total a + b) and damages in the photosynthetic apparatus of plants (Iturbe-Ormaetxe *et al*., 1998; Riaz *et al*., 2013). Incremental in salinity level under deficit irrigation could significantly reduce the photosynthetic pigments in both Zinnia cultivars (Fig., 3). Likened to the performance of plants in the non-saline condition, when plants were treated with saline (EC_3 and EC_4), the maximum decrease in chl. a and b contents were first observed in Profusion and then Short Stuff. Furthermore, compared to the performance of plants in a non-drought condition, when deficit irrigation (T_1 (40%) and T_2 (60%)) was performed, a high reduction in chl. a and b contents were observed in Short Stuff followed by Profusion. Chyliński *et al*. (2007) reported that the reduced concentration of chl. a and chl. b in the leaves of Impatiens was significantly dependent on drought-induced stress. Djanaguiraman *et al*. (2006) stated that the reduction in chl. content when there is a high salt level under deficit irrigation might be related to the disturbance in cellular functions and damages to the photosynthetic electron transport chain or membrane worsening. Previously, the leaf chlorophyll content of Chrysanthemum was found to increase with low salt concentration, but decrease with an increase in salt levels (Vanlal *et al*., 2019). Moreover, Nahed *et al*., (2011) mentioned the effect of salinity on the reduction of photosynthesis in *Matthiola incana*. An increase in enzyme activity during salt stress was found to be associated to a reduction in photosynthetic pigments and chlorophyll content, which were observed in *Rosmarinus officinalis* (Kiarostami *et al*., 2010).

Mineral contents:

By analyzing the mineral contents in the Zinnia cvs. plant tissues, significant interactions were found among the cultivars, deficit irrigation, and salinity composition, including Ca^{2+}, Na^{+}, and Cl^{-}. For both cultivars, the plant tissue content of Ca^{2+} decreased as irrigation salinity increased. Conversely, the plant tissue Cl^{-} and Na^{+} contents increased as salinity increased and decreased according to the content of deficit irrigation (Fig., 4 and 5). Short Stuff cv. had higher buildup of Ca^{2+} and Cl^{-} in leaf tissue than "Profusion". Granny plants salinity levels, EC_3 and EC_4, increased the Na^{+} and Cl^{-} contents of all plant tissues under deficit irrigation. However, Ca^{2+} content was found to reduce with the same treatments.

Maintaining adequate content of Ca^{2+} is essential to avert any negative influences on plant performance, which may arise because of a lack of Ca^{2+} as is often identified under non-saline of conditions. The factors affecting the ability of plant tissue to obtain Ca^{2+} include Ca^{2+} source, the nature of the counter-ions, the ratio of Ca^{2+} to other cations in the substrate, and substrate pH (Grattan and Grieve, 1998). Previously, Liu *et al*. (2017) found that $CaCl_2$ was supplied as one of the salinizing agents in addition to

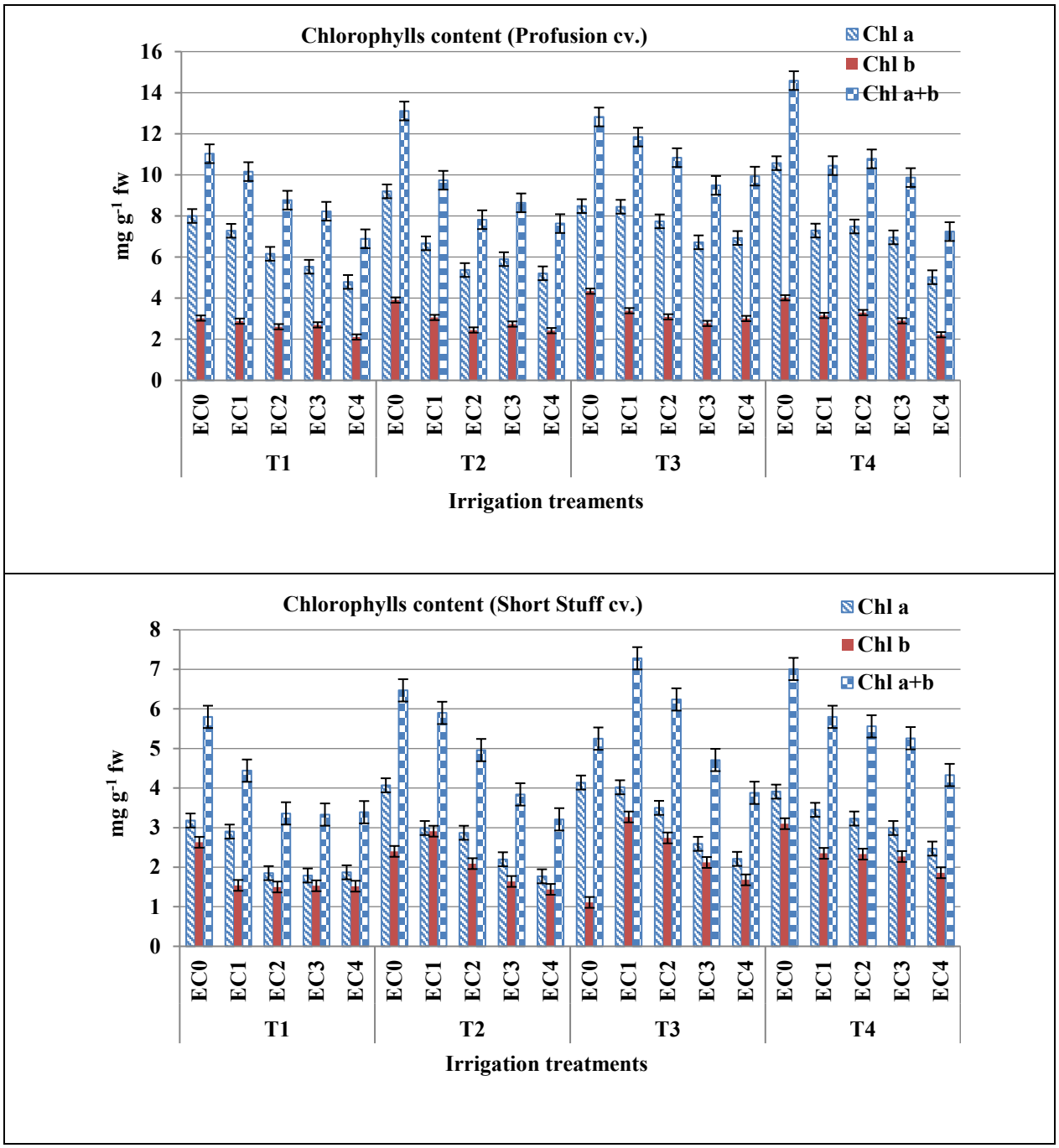

Fig. 3. Chlorophylls content of zinnia plants (Profusion and Short Stuff cvs.) grown under different salinity deficit irrigation water. Deficit irrigation water treatments: T_1= 40, T_2= 60, T_3= 80, and T_4= 100% F.C.; irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.

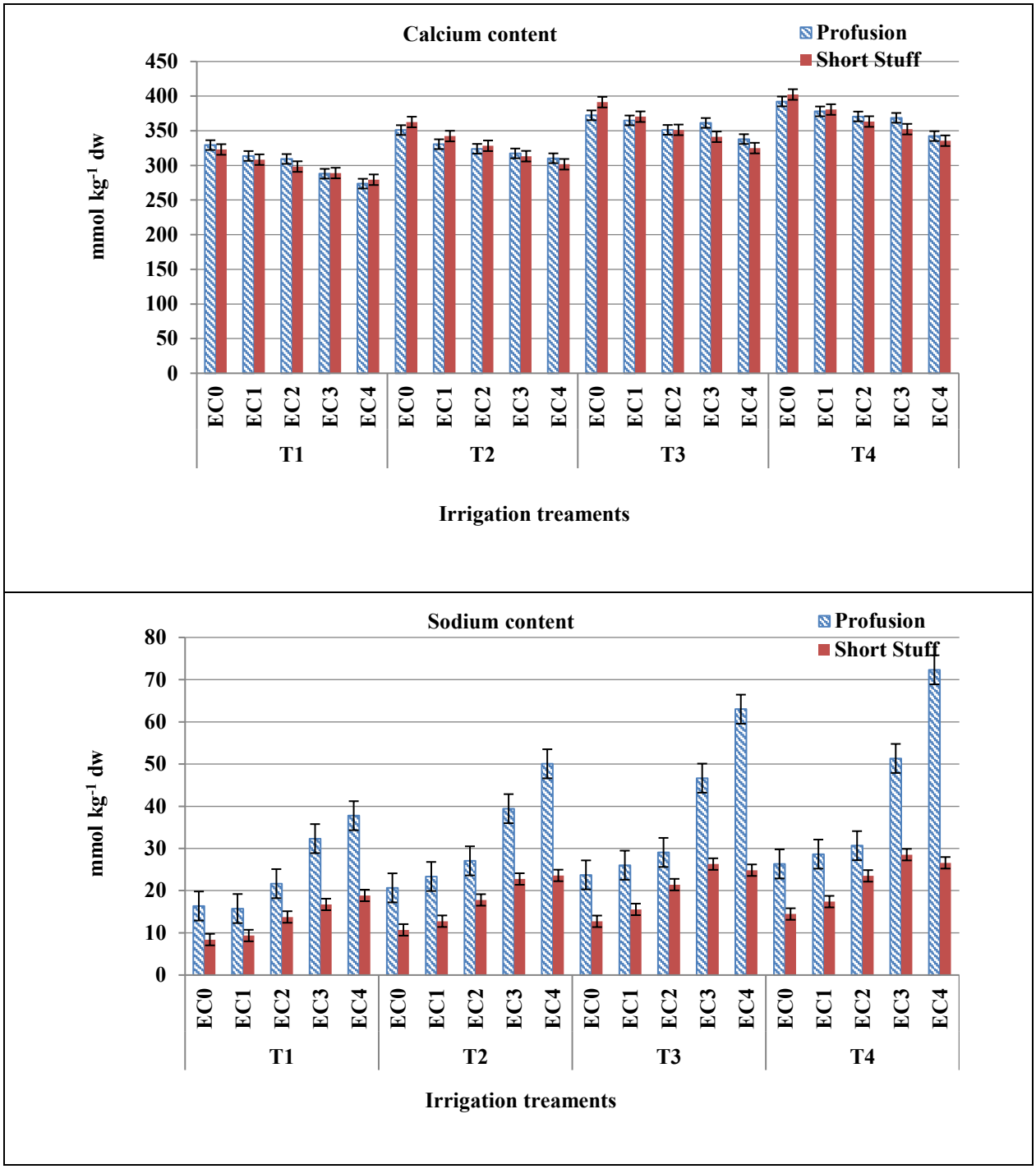

Fig. 4. Nutrients content calcium and sodium of Profusion and Short Stuff cvs. zinnia plants grown under different salinity deficit irrigation water. Deficit irrigation water treatments: T_1= 40, T_2= 60, T_3= 80, and T_4= 100% F.C.; irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.

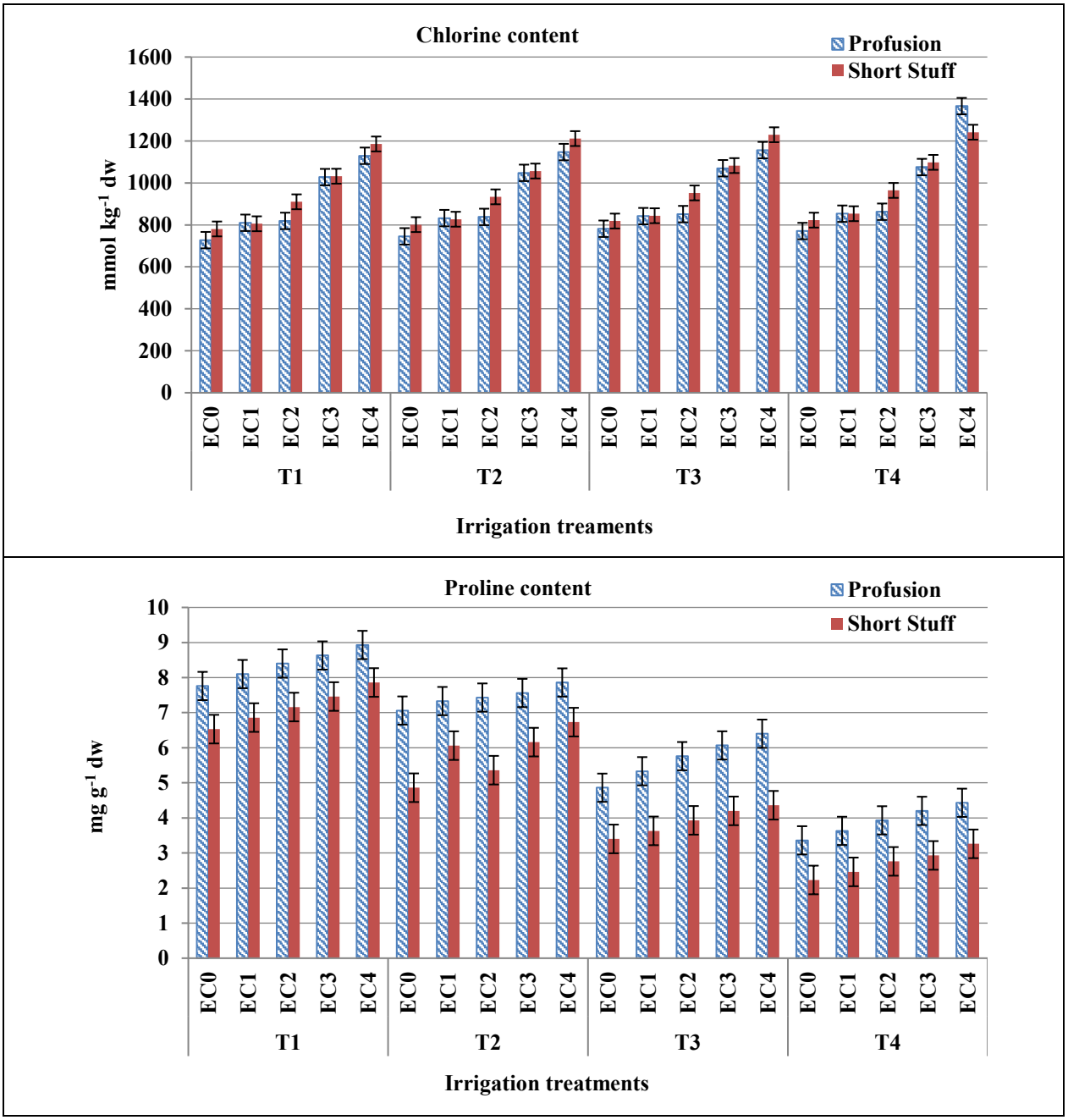

Fig. 5. Nutrient content chlorine and proline content of Profusion and Short Stuff cvs. zinnia plants grown under different salinity deficit irrigation water. Deficit irrigation water treatments: T_1= 40, T_2= 60, T_3= 80, and T_4= 100% F.C.; irrigation water content: EC_0= 0.63, EC_1= 1.6, EC_2= 3.1, EC_3= 6.3, and EC_4= 9.4, respectively.

NaCl, thereby donating to the increase in leaf tissue Ca content in all taxa. Kaya and Higgs (2002) reported that $Ca(NO_3)_2$ supplementation increased the dry mass then cucumber yield in a soil containing high levels of NaCl.

Plants routinely tolerate salt stress by evading the uptake of Na^+ and Cl^- or enduring high contents of these minerals in the plant tissue (Munns and Tester, 2008; Liu *et al*., 2017). In the present investigation, the leaf Zinnia plant had the highest Cl^- and Na^+ content among the two cultivars and displayed acceptable visual quality. Such findings indicate that Zinnias could tolerate high Cl_- and Na_+ contents. Moreover, Liu *et al*. (2017) reported that *Chaenomeles speciosa* and *Diervilla rivularis* plants had comparatively high Cl^- and Na^+ contents in their leaf tissue; however, these plants displayed severe foliar salt damage or died during the investigation. Such finding demonstrates the low tolerance of Cl^- and Na^+ buildup and the poor capacity of the plants to exclude the ions from their leaves and stem.

Proline content:

As demonstrated by data, deficit irrigation water with saline-water has a significant effect on proline content at a significance level of 5%. Proline content during deficit irrigation increased with an increase in salinity-induced stress levels compared to that of upon irrigation with control water (Fig., 5). In zinnia cv. Profusion leaves, proline content increased when the level of irrigation salinity increased to a level greater than that of Short Stuff cultivar. Generally, proline content accumulates in various plant species in response to stresses like drought and salinity. Though the role of proline content in plant osmo-tolerance remains contentious, the detoxification of responsive oxygen species owing to proline content is supposed to contribute to osmotic adjustment and the protection of membrane integrity (Molinari *et al*., 2007). Drought-induced stress increases the proline content then glycine-betaine, free amino acids, and the activity of γ- glutamyl kinase; however, because of deficit irrigation with saline water, the activity of proline oxidase decreased (Manivannan *et al*., 2007). Mathur *et al*. (1995) identified that metabolic factors, like free proline, were significantly increased owing to the severe stress induced by deficit irrigation in the tissues of leaves. Moreover, Kundu and Paul (1997) found that stress induced by drought resulted in a higher proline accumulation in the leaves of the Brassica plant at the generative growth stages. Vartanian *et al*. (1992) than Azza *et al*. (2011) found that higher proline accumulation through stresses caused by irrigation water, reaching up to 4.5% of the total dry mass. Thus, proline buildup during water stress is an adaptive reply that augments survival and the water status of tissues (Bellinger *et al*., 1991; Aghamohammadi *et al*., 2016). Vanlal *et al*. (2019) also discovered the significant association between salt tolerance and proline buildup in Chrysanthemum plant.

CONCLUSION

In the present study, we demonstrated that Zinnia cultivars (Short Stuff and Profusion) plants may exhibit moderate sensitivity to salinity. When irrigation was performed with saline water, we identified a significant reduction in the biochemical, plant growth, and flower production parameters. Furthermore, when a concentration greater than 3.3 dS m^{-1} was employed for irrigation, the flowering and growth parameters were found to markedly reduce. Compared to the Profusion Zinnia plant, cv. Short Stuff appeared to be more sensitive to salinity and deficit irrigation. Altogether, our findings reveal that Profusion exhibited better physiological performance and morphological attributes than Short Stuff, which contribute to its acceptable quality and its beauty at field capacity and EC of 60% and 3.3 dS m^{-1}, respectively.

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تأثير مستويات مياه الري المالحة على نمو صنفين من نبات الزينيا (*Zinnia elegans* L.)

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يتأثر إنتاج ونمو نباتات الزينة بشكل ملحوظ بنقص المياه. لذلك، أصبح تعزيز محصولها خلال فترة الجفاف الهدف الرئيسي في تربية النباتات. تم استخدام صنفين من الزينيا (Short Stuff وProfusion)، وقد استخدمت في هذا البحث توليفات تتحمّل الملوحة والجفاف لتحديد أثر الملوحة والجفاف على نمو النبات من أجل استخدامها في برنامج لتربية نباتات تتحمل الملوحة والجفاف. لذلك استخدمت أربع معالجات للري (T_1 = ٤٠، T_2 = ٦٠، T_3 = ٨٠، T_4 = ١٠٠٪ (كنترول) من السعة الحقلية)، تحت خمسة مستويات ملوحة (التوصيل الكهربائي EC = ٠,٦٣ (كونترول))، وتم تعريض النباتات لمستويات مختلفة من ملوحة ماء الري وهي: EC_1 = ١,٦ ، EC_2 = ٣,١، EC_3= ٦,٣ و EC_4 = ٩,٤ ديسيسيمنز م$^{-1}$) لمدة ١٢٠ يوماً تم إجراؤها في نظام الري بالتنقيط. تم تقدير صفات النمو الخضري وخصائص التزهير وسُجلت قياسات تبادل الغازات. ودلت النتائج أن هناك إنخفاض في جميع صفات التزهير والنمو الخضري مع نقص مستوى الرطوبة بالوسط. وكلا الصنفين المعالجين بـ ٤٠٪ سعة حقلية تحت EC_3= ٦,٣ و EC_4= ٩,٤ ديسيسيمنز م$^{-1}$ لم يزهروا. ومع ذلك، وجدت فروق ذات دلالة إحصائية بين الصنفين لجميع الخصائص، مما يشير إلى أنه يمكن أخذها في الإعتبار عند تحديد درجة الملوحة وتحمل الجفاف لهما. والصنف Profusion أظهر أداء أفضل من الصنف Short Stuff، مع معاملات الري ٨٠ و ١٠٠٪ ومستويات الملوحة، باستثناء ٤٠٪ مع EC_3 و EC_4 التي لم ينتج عنها محصول زهري. إنخفض محتوى الكلوروفيل في الأوراق (الكلوروفيل أ ، ب ، والكلي) مع زيادة مستوى الملوحة تحت معاملات الري المختلفة. تم أيضاً تحديد محتوى العناصر في الأوراق مثل (Ca^{+2} و Na^{+} و Cl^{-}) لكلا الصنفين، وقد إنخفض محتوى الكالسيوم مع زيادة ملوحة الري، بينما زادت محتويات الكلوريد والصوديوم مع زيادة الملوحة في أنسجة النبات بعد الري.