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

Y.I. El-Nashar and Badreya A. Hassan

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

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, (T1= 40, T2= 60, T3= 80, and T4= 100% (control)) of field capacity) under five salinity levels (electrical conductivity (EC) of 0.63 dS m⁻¹ (control)), EC1= 1.6, EC2= 3.1, EC3= 6.3, and EC4= 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 EC3= 6.3 and EC4= 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 EC3 and EC4 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 Ca²⁺, Na⁺, and Cl⁻, was also determined. For both cultivars, Ca²⁺ content decreased as irrigation salinity increased, while Cl⁻ and Na⁺ contents increased as salinity increased in the plant tissue following irrigation.

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 freshwater 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 cm²) 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 (T1= 40, T2= 60, T3= 80, and T4= 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; EC0= 0.63), EC1= 1.6, EC2= 3.1, EC3= 6.3, and EC4= 9.4 dS m⁻¹ NaCl and CaCl₂) were determined with the amount of water held by the soil (Naik and Widholm, 1993). Salt solutions at different CaCl₂ and NaCl levels were prepared by dissolving CaCl₂ 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

| Chemical analysis | pH | EC (dS m⁻¹) | Ca²⁺ (meq l⁻¹) | Na⁺ (meq l⁻¹) | Mg²⁺ (meq l⁻¹) | K⁺ (meq l⁻¹) | Cl⁻ (ppm) | HCO₃⁻ (ppm) | SO₄²⁻ (ppm) | NO₃⁻ (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 (cm²) 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 °C for 72 h in an oven; thereafter, mass was immediately recorded.

**Gas exchange:**

The photosynthetic rate ($P_n$), stomatal conductance ($g_s$), intercellular CO₂ 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:

\[
\text{Chl. } a = 13.43 A^{663.8} - 3.47 A^{646.8} \quad (1)
\]
\[
\text{Chl. } b = 22.90 A^{663.8} - 5.38 A^{646.8} \quad (2)
\]
\[
\text{Total Chl. } (a + b) = 19.43 A^{663.8} - 8.05 A^{646.8} \quad (3)
\]

All chemical components ($\text{Ca}^{2+}$, $\text{Na}^+$, and $\text{Cl}^-$) 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 EC₄ 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 (cm²) | Shoot fresh mass (g) | Shoot dry mass (g) |
|-------------------|-----------------|------------------|-----------------|----------------|---------------------|------------------|
|                   |                 | Profusion         | Short Stuff     | Profusion       | Short Stuff         | Profusion         | Short Stuff       |
| T1 40% F.C.       | EC0             | 15.30±2.13       | 12.70±1.20      | 10.96±2.85      | 10.16±2.53          | 84.32±5.12        | 6.88±0.63         | 4.48±0.34         |
|                   | EC1             | 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         |
|                   | EC2             | 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         |
|                   | EC3             | 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         |
|                   | EC4             | 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         |
|                   | T1              | 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         |
|                   | T2 60% F.C.     | 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         |
|                   | T3 80% F.C.     | 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±0.41         | 8.01±1.63         | 2.89±0.37         | 1.69±0.29         |
|                   | T4 100% F.C.    | 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         | 1.35±0.70         |
|                   | (control)       | 13.00±1.83       | 10.78±1.05      | 14.70±2.66      | 17.06±1.96          | 79.00±5.85        | 51.65±5.20        | 7.33±0.64         | 7.37±0.58         | 2.52±0.55         | 1.54±0.27         |
|                   |                 | 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         |
|                   |                 | 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         |
|                   |                 | 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         |
|                   |                 | 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         |
|                   |                 | 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         |
|                   |                 | 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         |
|                   |                 | 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         |

Irrigation water content: EC0= 0.63, EC1= 1.6, EC2= 3.1, EC3= 6.3, and EC4= 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 (cm²) | Shoot fresh mass (g) | Shoot dry mass (g) |
|-------------------|-----------------|-------------------|------------------|-----------------|----------------------|---------------------|
|                   | EC0              | Short Stuff       | Profusion        | Short Stuff     | Short Stuff          | Short Stuff         |
| T₁ 40% F.C.       | 1.98±0.21        | 11.86±4.01        | 11.03±3.58       | 13.21±2.69      | 81.18±5.61           | 60.29±4.68          |
|                   | 1.61±0.26        | 12.46±4.56        | 8.64±2.46        | 7.82±1.94       | 64.78±4.65           | 48.08±5.64          |
|                   | 0.49±0.08        | 0.91±0.17         | 1.85±0.53        | 1.56±0.06       | 1.85±0.53            | 0.45±0.05           |
|                   | 2.56±0.50        | 3.83±0.46         | 8.34±1.49        | 2.52±0.34       | 1.98±0.21            | 1.61±0.26           |
|                   | 2.45±0.21        | 3.01±0.32         | 10.67±1.34       | 11.03±2.69      | 81.18±5.61           | 60.29±4.68          |
|                   | 1.23±0.08        | 2.73±0.05         | 1.93±0.48        | 0.91±0.17       | 2.52±0.34            | 1.61±0.26           |
|                   | 0.47±0.05        | 0.45±0.05         | 1.85±0.53        | 0.45±0.05       | 1.85±0.53            | 0.45±0.05           |
|                   | 1.13±0.08        | 0.86±0.08         | 4.82±0.61        | 2.34±0.64       | 4.82±0.61            | 2.34±0.64           |
|                   | 1.13±0.08        | 0.86±0.08         | 4.82±0.61        | 2.34±0.64       | 4.82±0.61            | 2.34±0.64           |
|                   | 3.58±0.81        | 3.40±0.96         | 9.30±0.38        | 3.40±0.96       | 9.30±0.38            | 3.40±0.96           |
|                   | 11.23±2.31       | 8.78±1.21         | 7.95±1.48        | 6.19±0.49       | 2.85±0.12            | 2.48±0.16           |
| T₂ 60% F.C.       | 15.80±2.84       | 12.46±4.56        | 11.61±2.18       | 86.76±6.82      | 63.71±6.61           | 3.83±0.46           |
|                   | 15.73±1.56       | 11.08±1.82        | 11.46±2.16       | 52.21±5.78      | 7.12±1.23            | 2.56±0.50           |
|                   | 13.43±2.55       | 10.74±1.52        | 10.25±1.46       | 9.23±1.10       | 7.72±1.31            | 2.56±0.50           |
|                   | 13.60±1.84       | 9.88±1.63         | 8.01±1.75        | 8.66±0.86       | 5.64±1.16            | 2.56±0.50           |
|                   | 7.03±1.54        | 4.83±1.64         | 7.65±1.59        | 2.34±0.64       | 4.82±0.61            | 2.34±0.64           |
|                   | 16.29±1.51       | 13.32±1.78        | 14.25±2.64       | 3.49±0.96       | 3.49±0.96            | 3.49±0.96           |
|                   | 13.86±1.25       | 12.25±2.57        | 12.42±1.95       | 60.62±6.62      | 7.92±0.29            | 3.49±0.96           |
|                   | 14.56±2.88       | 10.38±2.81        | 13.07±3.44       | 10.02±2.07      | 7.79±0.29            | 3.49±0.96           |
|                   | 13.79±3.10       | 8.70±0.89         | 10.46±1.67       | 9.37±1.86       | 7.44±0.97            | 3.29±0.15           |
|                   | 10.30±2.67       | 8.67±1.64         | 8.15±1.09        | 8.48±1.52       | 3.57±0.68            | 2.52±0.76           |
|                   | 18.13±3.33       | 15.62±1.85        | 13.91±1.31       | 7.63±1.71       | 3.04±0.27            | 1.25±0.13           |
|                   | 16.33±1.30       | 13.42±2.15        | 10.12±1.88       | 2.33±0.48       | 1.25±0.13            | 1.25±0.13           |
|                   | 12.26±2.50       | 10.74±1.97        | 11.34±2.37       | 9.07±1.83       | 5.19±0.62            | 1.50±0.34           |
|                   | 10.70±2.64       | 10.07±1.83        | 9.90±1.24        | 6.32±0.67       | 4.34±0.32            | 1.36±0.28           |
|                   | 11.23±2.31       | 8.78±1.21         | 7.95±1.48        | 6.19±0.49       | 2.85±0.12            | 2.48±0.16           |

**Significant at 0.01 level of probability, *Significant at 0.05 level of probability, N.S Not-significant.

Irrigation water content: EC₀ = 0.63, EC₁ = 1.6, EC₂ = 3.1, EC₃ = 6.3, and EC₄ = 9.4, respectively.

Means ± SDs are given for each treatment group; as indicated by split-split-plot, ANOVA followed by LSD test.
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 | Profusion | Short Stuff |
| T1 40% F.C. | EC0 | 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 |
|                 | EC1 | 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 |
|                 | EC2 | 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 |
|                 | EC3 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
|                 | EC4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| T2 60% F.C. | EC0 | 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 |
|                 | EC1 | 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±1.04 | 1.21±0.19 | 15.43±1.60 | 18.08±1.35 |
|                 | EC2 | 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 |
|                 | EC3 | 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 |
|                 | EC4 | 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 |
| T3 80% F.C. | EC0 | 87.00±6.34 | 77.00±5.32 | 4.00±0.83 | 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 |
|                 | EC1 | 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 |
|                 | EC2 | 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 |
|                 | EC3 | 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 |
|                 | EC4 | 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 |
| T4 100% F.C. (control) | EC0 | 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 |
|                 | EC1 | 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 |
|                 | EC2 | 91.66±8.85 | 68.65±5.19 | 2.71±0.71 | 1.70±0.33 | 3.27±0.37 | 3.48±0.67 | 1.06±0.17 | 1.14±0.15 | 11.76±1.82 | 16.31±2.64 |
|                 | EC3 | 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 |
|                 | EC4 | 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 ** NS ** NS NS
Cultivars (C) ** NS ** NS NS NS
Irrigation (I) ** NS ** NS NS
Salinity (S) ** NS ** NS NS

Irrigation water content: EC0 = 0.63, EC1 = 1.6, EC2 = 3.1, EC3 = 6.3, and EC4 = 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 | Cultivars (C) | Irrigation (I) | Salinity (S) | C * I * S | C * I | C * S | I * S |
|-------------------|----------------|---------------|----------------|---------------|----------|------|------|------|
|                   |                | Profusion     | Short Stuff    | Profusion     | Short Stuff | Profusion     | Short Stuff | Profusion | Short Stuff |
| **T1** 40% F.C.   | EC0            | 97.3±3.25     | 78.6±5.94     | 2.23±0.64     | 1.7±0.16    | 2.7±0.17     | 3.37±0.31   | 1.68±0.20 | 1.18±0.11   |
|                   | EC1            | 98.0±5.16     | 80.3±4.25     | 1.90±0.52     | 1.2±0.17    | 3.20±0.28    | 4.47±0.21   | 1.56±0.18 | 1.27±0.12   |
|                   | EC2            | 99.0±6.95     | 78.6±6.58     | 2.06±0.34     | 1.1±0.12    | 3.23±0.42    | 3.85±0.25   | 0.48±0.05 | 0.63±0.08   |
|                   | EC3            | 0.0           | 0.0           | 0.0           | 0.0         | 0.0           | 0.0         | 0.0       | 0.0         |
|                   | EC4            | 0.0           | 0.0           | 0.0           | 0.0         | 0.0           | 0.0         | 0.0       | 0.0         |
| **T2** 60% F.C.   | EC0            | 88.3±6.58     | 81.3±7.82     | 4.26±0.28     | 1.6±0.16    | 3.97±0.53    | 3.52±0.21   | 1.57±0.16 | 2.14±0.29   |
|                   | EC1            | 94.0±4.62     | 81.0±5.58     | 4.19±0.29     | 2.4±0.19    | 4.65±0.84    | 3.28±0.27   | 1.32±0.27 | 1.98±0.24   |
|                   | EC2            | 87.0±8.29     | 74.3±6.18     | 3.43±0.31     | 1.6±0.14    | 4.15±0.51    | 3.91±0.24   | 1.70±0.17 | 1.60±0.25   |
|                   | EC3            | 90.2±4.59     | 68.3±5.61     | 2.65±0.26     | 1.3±0.12    | 3.24±0.31    | 0.76±0.16   | 0.21±0.01 | 0.68±0.20   |
|                   | EC4            | 59.3±6.27     | 0.0           | 0.69±0.16     | 0.0         | 0.54±0.09    | 0.0         | 0.13±0.02 | 0.75±0.09   |
| **T3** 80% F.C.   | EC0            | 91.0±5.95     | 75.0±4.95     | 3.86±0.13     | 1.6±0.10    | 3.56±0.86    | 5.32±0.19   | 1.83±0.23 | 2.30±0.39   |
|                   | EC1            | 85.6±6.21     | 74.3±5.24     | 4.33±0.21     | 2.6±0.21    | 3.69±0.61    | 4.48±0.15   | 1.96±0.26 | 1.79±0.16   |
|                   | EC2            | 93.3±7.11     | 82.0±3.25     | 3.40±0.16     | 1.6±0.11    | 4.01±0.89    | 3.54±0.19   | 1.62±0.24 | 2.32±0.28   |
|                   | EC3            | 94.0±4.52     | 82.6±7.16     | 2.73±0.14     | 1.2±0.08    | 3.17±0.56    | 4.00±0.34   | 0.99±0.13 | 1.58±0.16   |
|                   | EC4            | 96.3±5.27     | 0.0           | 2.30±0.08     | 0.0         | 2.64±0.23    | 0.0         | 0.47±0.06 | 0.83±0.10   |
| **T4** 100% F.C.  | EC0            | 87.6±6.16     | 78.0±7.89     | 6.86±0.79     | 1.9±0.18    | 3.54±0.38    | 5.04±0.81   | 1.77±0.17 | 2.28±0.27   |
|                   | EC1            | 91.2±3.18     | 82.6±5.64     | 4.06±0.51     | 1.2±0.24    | 3.89±0.26    | 2.34±0.41   | 1.63±0.13 | 1.29±0.20   |
|                   | EC2            | 90.3±4.18     | 81.0±5.16     | 3.30±0.34     | 2.1±0.29    | 3.80±0.34    | 3.81±0.31   | 1.67±0.18 | 1.75±0.14   |
|                   | EC3            | 96.3±4.52     | 81.8±4.83     | 3.16±0.27     | 0.7±0.07    | 2.52±0.16    | 0.97±0.02   | 1.28±0.12 | 0.94±0.07   |
|                   | EC4            | 95.6±6.49     | 0.0           | 1.63±0.14     | 0.0         | 2.24±0.24    | 0.0         | 1.06±0.10 | 0.89±0.06   |

**Significant at 0.01 level of probability, *Significant at 0.05 level of probability, N.S Not-significant.**

Irrigation water content: EC0= 0.63, EC1= 1.6, EC2= 3.1, EC3= 6.3, and EC4= 9.4, respectively.

Means ± SDs are given for each treatment group; as indicated by split-split-plot, ANOVA followed by LSD test.
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 T4 control irrigation but under EC4 salinity, these values were low in the T2 and T1 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 T4 control irrigation; however, at the EC4 salinity, a low shoot fresh mass was found at T1 and T2.

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 in 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 (Álvarez 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 (EC₁ and EC₄), fewer than 40% deficit irrigation was required to halt flower production. Conversely, Short stuff could not produce flowers under EC₄ 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; Álvarez 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 H₂O, 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 CO₂ concentration of Profusion and Short Stuff cvs. zinnia plants grown under different salinity deficit irrigation water. Deficit irrigation water treatments: T₁= 40, T₂= 60, T₃= 80, and T₄= 100% F.C.; irrigation water content: EC₀= 0.63, EC₁= 1.6, EC₂= 3.1, EC₃= 6.3, and EC₄= 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 (Munnène-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 (EC3 and EC4), 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 (T1 (40%) and T2 (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, EC3 and EC4, 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 CaCl2 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: T1 = 40, T2 = 60, T3 = 80, and T4 = 100% F.C.; irrigation water content: EC0 = 0.63, EC1 = 1.6, EC2 = 3.1, EC3 = 6.3, and EC4 = 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: T1 = 40, T2 = 60, T3 = 80, and T4 = 100% F.C.; irrigation water content: EC0 = 0.63, EC1 = 1.6, EC2 = 3.1, EC3 = 6.3, and EC4 = 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: T1= 40, T2= 60, T3= 80, and T4= 100% F.C.; irrigation water content: EC0= 0.63, EC1= 1.6, EC2= 3.1, EC3= 6.3, and EC4= 9.4, respectively.
NaCl, thereby donating to the increase in leaf tissue Ca content in all taxa. Kaya and Higgs (2002) reported that Ca(NO₃)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-

**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.
REFERENCES

A.O.A.C. (1992). Official Methods of Analysis, 12th (ed). Association of Official Analytical Chemists: Washington DC, USA., 702 p.

Aghamohammadi, M.; Naderi, R. and Hadavi, E. (2016). Evaluation of drought stress on vegetative and reproductive characteristics of Zinnia elegans L. Elixir. Int. J., 97: 42195-42197.

Ahir, M.P. and Alka, S. (2017). Effect of different levels of irrigation water on growth and yield of gladiolus cv. American Beauty. Trends. Bio., 10: 9011-9013.

Ahir, M.P.; Alka, S. and Patil, S.J. (2017). Response of different salinity levels on growth and yield of tuberose cv. Prajwal. Int. J. Chem. Stud., 5: 2150-2152.

Álvarez, S.; Alejandra, N.; Sebastián, B. and Sánchez-Blanco, M.J. (2009). Regulated deficit irrigation in potted Dianthus plants: Effects of severe and moderate water stress on growth and physiological responses. Sci. Hort., 122: 579–585.

Augé, R.M.; Stodola, A.J.W.; Moore, J.L.; Klingeman, W.E. and Duan, X. (2003). Comparative dehydration tolerance of foliage of several ornamental crops. Sci. Hort., 98:511-516.

Azza, A.M.; Mazhar, Mon.; Mahgoub, H. and Abd El-Aziz, G. (2011). Response of Schefflera arboricola L. to gypsum and sulphur application irrigated with different levels of saline water. Austria. J. Basic App. Sci., 5(10): 121-129.

Bañón, S.; Conesa, E.; Valdés, R.; Miralles, J.; Martínez, J.J. and Sánchez Blanco, M.J. (2012). Effect of saline irrigation on phytohormone-treated chrysanthemum plants. Acta hort., 937: 307-312.

Bass, R.; Nijsen, H.M.C.; Van Den Berg, T.J.M. and Warmenhoven, M.G. (1995). Yield and quality of carnation (Dianthus caryophyllus L.) and gerbera (Gerbera jamasunii L.) in a closed nutrient system as affected by sodium chloride. Sci. Hort., 61: 273-284.

Bates, L.S.; Waldren, R.P. and Teare, I.D. (1973). Rapid determination of free proline for water stress studies. Plant Soil, 39: 205-207.

Bellinger, Y.; Bensaoud, A. and Larher, F. (1991). Physiological significance of proline accumulation, a trait of use to breeding for stress tolerance. In: Acevedo, E.; Conesa, A.P.; Monneveux P.; and Srivastava, J.P. (eds.), Physiology – Breeding of Winter Cereals for Stressed Mediterranean Environment. INRA, Paris, pp. 449-458.

Blum, A. (1986). Salinity resistance. In: Blum, A. (ed.), Plant Breeding for Stress Environments, CRC Press, Boca Raton, pp. 1163-1169.

Boursiac, Y.; Chen, S. and Luu, D.T. (2005). Early effects of salinity on water transport in Arabidopsis roots: Molecular and cellular features of aquaporin expression. Plant Physiol., 139: 790–805.

Bressan, R.A.; Hasegawa, P.M. and Locy, R.D. (2002). Stress physiology. In: Taiz, L. and Sunderland, Z.E. (eds.), Plant Physiology, 3ed ed., Sinauer Associates Inc., MA., pp. 591-623.

Cabrera, R.I. (2003). Mineral nutrition. In: Roberts, A.V.; Debener, T. and Gudin, S. (eds.), Encyclopedia of rose science, Academic Press, Oxford, UK, pp. 573-580.

Cameron, R.; Harrison-Murray, R.; Fordham, M.; Wilkinson, S.; Davies, W.; Atkinson, C. and Else, E. (2008). Regulated irrigation of woody ornamentals to improve plant quality and precondition against drought stress. Ann. App. Bio., 153: 49-61.

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. Bio., 81: 435-443.
Cassaniti, C.; Leonardi, C. and Flower, T.J. (2009). The effect of sodium chloride on ornamental shrubs. Sci. Hort., 122: 586-593.

Cerqueira, L.; Fadigas, F.D.S.; Pereira, F.A.; Gloaquen, T.V. and Costa, J.A. (2008). Growth of _Heliconia psittacorum_ and _Gladiulus hortulanus_ irrigated with treated domestic waste water. Revista Brasileira de Engenharia., 12(6):606-613.

Chaves, M.M. and Oliveira, M.M. (2004). Mechanisms underlying plant resilience to water deficits—Prospects for water-saving agriculture. J. Exp. Bot., 55: 2365-2384.

Chyliński, W.K.; Łukaszewska, A.J. and Kutnik, K. (2007). Drought response of two bedding plants. Acta Physiol. Plant, 29: 399-406.

Dale, J.E. (1988). The control of leaf expansion. Annu. Rev. Plant Physiol. Plant Mol. Biol., 39:267–295.

Dhanda, S.S.; Behl, R.K. and Elbassam, N. (1995). Breeding wheat genotypes for water deficit environments. Land Volk., 45: 159-167.

Djanaguiraman, M.; Sheeba, J.A.; Shankar, A.K.; Devi, D.D. and Ban-Garusamy, U. (2006). Rice can acclimate to lethal level of salinity by pretreatment with sublethal level of salinity through osmotic adjustment. Plant and Soil., 284(1):363–373.

Dole, J.M. and Wilkins, H.F. (1999). Floriculture Principles and Species. Prentice Hall, Upper Saddle River, N.J., USA, 1048 p.

FAO (2000). Global network on integrated soil management for sustainable use of salt-affected soils, http://www.fao.org/ag/AGL/agII/spush/intro.htm.

Grattan, S.R. and Grieve, C.M. (1998). Salinity–mineral nutrient relations in horticultural crops. Sci. Hort., 78: 127–157.

Iturbe-Ormaetxe, I.; Escuredo, P.R. and Arrese-Igor, C. (1998). Oxidative damage in pea plants exposed to water deficit or paraquat. Plant Physiol., 116: 173-181.

Kang, S.; Shi, W. and Zhang, J. (2000). An improved water-use efficiency for maize grown under regulated deficit irrigation. Field Crops Res., 67: 207–214.

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

Kiarostami, K.H.; Mohseni, R. and Saboora, A. (2010). Biochemical changes of _Rosmarinus officinalis_ L. under salt stress. J. Stress Physiol. Biochem., 6: 114-122.

Kuldeep, T.; Park, M.R.; Lee, H.J.; Lee, C.A.; Rehman, S.; Steffenson, B. and Yun, S.J. (2011). Fertile Crescent region as source of drought tolerance at early stage of plant growth of wild barley (_Hordeum vulgare_ L. ssp. spontaneum). Pak. J. Bot., 43: 475-486.

Kundu, P.B. and Paul, N.K. (1997). Effects of water stress on chlorophyll, proline and sugar accumulation in rape (_Brassica campestris_ L.). Bangla. J. Bot., 26: 83-85.

Lacramioara, O.; Grigore, M.N. and Vochita, G. (2015). Impact of saline stress on growth and biochemical indices of _Calendula officinalis_ L. seedlings. Rom. Biotech. Let., 20: 11007-11017.

Liu, Q.; Sun, Y.; Niu, G.; Altland, J.; Chen, L. and Jiang, L. (2017). Morphological and physiological responses of ten ornamental taxa to saline water irrigation. HortScience, 52: 1816–1822.

Lutts, S.; Kinet, J.M. and Bouharmont, J. (1996). Effects of salt stress on growth, mineral nutrition and proline accumulation in relation to osmotic adjustment in rice (_Oryza sativa_ L.) cultivars differing in salinity resistance. J. Plant Growth Regular., 19: 207–218.
Mafakheri, A.; Siosemardeh, A.; Bahramnejad, B.; Struik, P.C. and Sohrabi, Y. (2010). Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. Aust. J. Crop Sci., 4: 580-585.

Manivannan, P.; Abdul Jaleel, C.A.; Sankar, B.; Kishorekumar, A.; Somasundaram, R.; Lakshmanan, G.A. and Panneerselvam, R. (2007). Growth, biochemical modifications and proline metabolism in *Helianthus annuus* L. as induced by drought stress. Colloids and Surfaces B. Bio., 59(2): 141-149.

Mathur, D.; Wattal, P.N. and Mathur, D. (1995). Influence of water stress on seed yield of Canadian rape at flowering and role of metabolic factors. Plant Phys. Bioche. New Delhi, 22: 115-118.

Mazhar, A.A.M.; Mahgoub, M.H. and Abd El-Aziz, N.G. (2011). Response of *Schefflera arboricola* L. to gypsum and sulphur application irrigated with different levels of saline water. Aust. J. Basic. App. Sci., 5: 121-129.

Molinari, H.B.C.; Marur, C.J.; Daros, E.; De Campos, M.K.F.; De Carvalho, J.F.R.P.; Filho, J.C.B.; Pereira, L.F.P. and Vieira, L.G.E. (2007). Evaluation of the stress-inducible production of proline in transgenic sugarcane (*Saccharum* spp.): osmotic adjustment, chlorophyll fluorescence and oxidative stress. Phys. Plan., 130: 218-229.

Moore, K.; Wajsbrot, C.; Burgart, C. and Fisher, L. (2019). A test method to evaluate salt tolerance of ornamentals. HortTechn., 29: 434-437.

Mott, J.J. and McComb, A. (1975). Effects of moisture stress on the growth and reproduction of three annual species from an arid region of Western Australia. J. Eco., 63(3), 825-834.

Munns, R. and Tester, M. (2008). Mechanism of Salinity Tolerance. An. Rev. Plant Biol., 59: 651-681.

Munnè-Bosch, S.; Noguès, S. and Alegre, L. (1999). Diurnal variations of photosynthesis and dew absorption by leaves in two evergreen shrubs growing in Mediterranean field conditions. New Phytol., 144: 109–119.

Nabil, M. and Coudret, A. (1995). Effects of sodium chloride on growth, tissue elasticity and solute adjustment in two *Acacia nilotica* subspecies. Phys. Plan., 93: 217–224.

Nahed, A.G.; Mahgoub, M.H. and Mazhar, A.M. (2011). Influence of using organic fertilizer on vegetative growth, flowering and chemical constituents of *Matthiola incana* L. plant grown under saline water irrigation. World J. Agric. Sci., 7: 47-54.

Naik, P.S. and Widholm, J.M. (1993). Comparison of tissue culture and whole plant responses to salinity. Plant Cell Tissue Organ. Cult., 33: 273-280.

Parsons, L.R. (1982). Plant responses to water stress. In: Christiansen, M.N. and Lewis C.F. (eds.), Breeding Plants for Less Favorable Environments, Springer-Verlag, New York, USA, pp. 175-192.

Passioura, J.B. (1982). The role of root system characteristics in the drought resistance of crop plants. Proceeding of IRRI symposium “Drought Resistance in Crops with the Emphasis on Rice”, 4-8 May, 1981, Los Banos, Philippines, pp. 71-82.

Pereira, J.S. and Chaves, M.M. (1993). Plant water deficits in Mediterranean ecosystems. In: Smith, J.A.C. and Griffiths, H. (eds.), Water Deficits Plant Responses from Cell to Community, Bios Scientific Publishers Ltd., Oxford, UK, pp. 237-251.

Peterson, F.H. (1996). Water testing and interpretation. In: Reed, D.W. (ed.), A Grower's Guide to Water, Media, and Nutrition for Greenhouse Crops. Ball Publications, USA, pp. 31-49.

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.

Raudales, R.E. and Dickson, R. (2019). The roads that lead to salty water. Grower Talks., 82: 54–57.

Riaz, A.; Martin, P.; Riaz, S.; Younis, A. and Hameed, M. (2013). Comparative performance of two zinnia (\textit{Zinnia elegans} L.) cultivars under high-temperature and limited water conditions in Pakistan. Acta hort., 980: 69-78.

Riaz, A.; Younis, A.; Taj, A.R.; Karim, A.; Tariq, U.; Munir, S. and Riaz, S. (2013). Effect of drought stress on growth and flowering of marigold (\textit{Tagetes erecta} L.). Pak. J. Bot., 45: 123-131.

Rise, I. and Shank, M. (1990). Influence of \( \text{Cl}^{−}, \text{Na}^{+} \) and \( \text{SO}_4^{2−} \) in irrigation water on the growth of azaleas. Gartenbauwissenschaft, 55: 252-258.

Rolfè, C.; Yiasoumi, W. and Keskula, E. (2000). Managing Water in Plant Nurseries, 2\textsuperscript{nd} ed. NSW Agriculture, Orange, NSW Australia, 279 p.

SAS, Institute Inc., (1985). Statistical Analysis System User’s Guide: Statistics. SAS Inst., Cary, North Caroline, USA.

Serrano, R. (1999). A glimpse of the mechanism of ion homeostasis during salt stress. J. Exp. Bot., 50: 1023-1036.

Shannon, M.C. and Grieve, C.M. (1999). Tolerance of vegetable crops to salinity. Sci. Hort., 78: 35-38.

Sonneveld, C.; Baas, R.; Nijssen, H.M.C. and De Hoog, J. (1999). Salt tolerance of flower crops grown in soilless culture. J. Plant Nutr., 22: 1033-1048.

Stanton, M.L.; Roy, B.A. and Thiede, D.A. (2000). Evolution in stressful environments, I. Phenotypic variability, phenotypic selection and response to selection in five distinct environmental stresses. Evolution., 54: 93-111.

Steel, R.G.D.; Torrie, J.H. and Dicky, D.A. (1997). Principles and Procedures of Statistics: A Biometric Approach. McGraw Hill, Inc., New York, USA, 666 p.

Taiz, L. and Zeiger, E. (2002). Plant Physiology. 3\textsuperscript{rd} ed. Sinauer Associates, Inc., Sunderland, M.A., 690 p.

Valdez-Aguilar, L.A.; Grieve, C.M. and Poss, J. (2009). Salinity and alkaline pH of irrigation water affect marigold plants, I. Growth and shoot dry mass partitioning. HortSci., 44: 1719-1725.

Van Zandt, P.A. and Mopper, S. (2002). Delayed and carryover effects of salinity on flowering in \textit{Iris hexagona}. Amer. J. Bot., 89: 1847-1851.

Vanlal, R.; Anand, P.; Kumar, G. and Tiwari, A.K. (2019). Effect of saline stress on growth and biochemical indices of chrysanthemum (\textit{Chrysanthemum morifolium} Ramat.) germplasm. India J. Agri. Sci., 89: 41-45.

Vartanian, N.; Hervochoin, P.; Marcotte, L.; Larher, F. and Gif-Sur-Yvette, C. (1992). Proline accumulation during drought rhizogenesis in \textit{Brassica napus} var. \textit{Oleifera}. J. Plant Phys., 140: 623-628.

Volkmar, K.M.; Hu, Y. and Steppihn, H. (1998). Response physiologique des plantes a la salinité: Mise au point bibliographique. Can. J. Plant Sci., 78: 19-27.

Winicov, I. (1998). New molecular approaches to improving salt tolerance in crop plants. Ann. Bot., 82: 703-710.

Worku, M. and Astatkie, T. (2010). Dry matter partitioning and physiological responses of \textit{Coffea arabica} L. varieties to soil moisture deficit stress at the seedling stage in Southwest Ethiopia. Afric. J. Agri. Res., 5: 2066-2072.

Zivder, S.; Khaleghi, E. and Dehkordi, F.S. (2011). Effect of salinity and temperature on seed germination indices of \textit{Zinnia elegans} L. J. App. Hort., 13: 48-51.
تأثير مستويات مياه الري المالحة على نمو صنفين من نبات الزيينة (Zinnia elegans L.)

ياسر إسماعيل النشار، بدرية أحمد حسن

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

تأثر نباتات الزيينة بشكل ملحوظ بنقص المياه. لذلك، أصبح تعزيز مصاوماتها خلال فترة الجفاف الهدف الرئيسي في تربية النباتات. تم استخدام صنفين من الزيينة (Profusion Short Stuff) في تربية النباتات. تم استخدام مصاومات مختلفة من مياه الري، بدءًا من نسبة ملحية 0.01% (كونترول) إلى نسبة ملحية 0.04% و 0.06% و 0.08% و 0.1% (1T ، 2T ، 3T ، 4T ) في برنامج تربية نباتات النجمية. نمت النباتات في فترة الثقيلة من مياه الري، تحت خمسة مصاومات ملحية (التصويل الكهربائي 0.01% لكونترول)، تم تحديد النباتات لمستويات مختلفة من ملحية ماء الري وهي: EC = 3.6 مللي إير، EC2 = 4.3 مللي إير، EC3 = 3.1 مللي إير، EC4 = 9.4 مللي إير.

عدد 120 يومًا تم إجراؤها في نظام الري بالانتظار. تم تقدير صفات النمو الخضري وخصائص النزهير وسجلت قياسات تبادل الغازات. ونتيجة لذلك، نجح نبات الزينة في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة بالوسط. وكلا الصنفين المعالجين بـ 0.04% سعة حقلية تحت تأثير 3T = 6.3 مللي إير، 6.4 مللي إير، تم الانتظار في جميع صفات النزهير مع نقص مستوى الرطوبة.

تحدد درجة الملحية وتحلل جفاف مما يبدو أنه يمكن أن يكون أداة أفضل من الصنف وتفاءل في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة. ومع ذلك، نجح نبات الزينة في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة، وتحدد درجة الملحية وتحلل جفاف مما يبدو أنه يمكن أن يكون أداة أفضل من الصنف وتفاءل في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة.

الكاسيدوم مع زيادة ملحية الري، بينما زادت محتويات الكالسيوم و الصوديوم مع زيادة الملحية في نسبتهاأ苦恼. PRF 100% عند 3T = 4.4 مللي إير، 4.6 مللي إير، نمت النباتات في فترة الثقيلة من مياه الري، تحت خمسة مصاومات ملحية (التصويل الكهربائي 0.01% لكونترول)، تم تحديد النباتات لمستويات مختلفة من ملحية ماء الري وهي: EC = 3.6 مللي إير، EC2 = 4.3 مللي إير، EC3 = 3.1 مللي إير، EC4 = 9.4 مللي إير.

عدد 120 يومًا تم إجراؤها في نظام الري بالانتظار. تم تقدير صفات النمو الخضري وخصائص النزهير وسجلت قياسات تبادل الغازات. ونتيجة لذلك، نجح نبات الزينة في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة بالوسط. وكلا الصنفين المعالجين بـ 0.04% سعة حقلية تحت تأثير 3T = 6.3 مللي إير، 6.4 مللي إير، تم الانتظار في جميع صفات النزهير مع نقص مستوى الرطوبة.

تحدد درجة الملحية وتحلل جفاف مما يبدو أنه يمكن أن يكون أداة أفضل من الصنف وتفاءل في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة. ومع ذلك، نجح نبات الزينة في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة، وتحدد درجة الملحية وتحلل جفاف مما يبدو أنه يمكن أن يكون أداة أفضل من الصنف وتفاءل في جميع صفات النزهير والنمو الخضري مع نقص مستوى الرطوبة.