# Growth, yield and quality of Easter lily as influenced by salinity level and growing media

**Amarin, Rasha.[1], Shawaqfeh, Samar[1*], Kafawin, Omar[2], Ayad, Jamal[3], Al-Zyoud, Firas [4], and Haddad, Nizar [5]**

[1,5] National Agricultural Research Center, Amman, Jordan.
[1*]Jerash University, Faculty of Agriculture, Dept. of Plant production and Protection, Jerash, Jordan.
[2,3] University of Jordan, School of Agriculture, Dept. Horticulture and Crop Science, Amman, Jordan.
[4] Mutah University, Faculty of Agriculture, Dept. of Plant Protection and IPM, Karak, Jordan.

## Abstract

Globally there is an increasing interest in growing ornamental plants as high value agricultural industries worldwide including Jordan. Soil salinity has significant constraints limiting growth and development of plants including ornamentals. The Easter lily, *Lilium longiflorum* Thunb. (Liliaceae) is a major ornamental plant in Jordan with different irrigation needs. Experiments were set up under greenhouse conditions at the School of Agriculture, the University of Jordan, Amman, Jordan during the 2019/2021 growing seasons to investigate the effect of different salinity levels and two growing media (soil and zeolitic tuff) on some quantity and quality characteristics of *L. longiflorum*. Results indicated that both salinity level and growing media have a significant impact on the plant characteristics (height, fresh and dry weights of the plant; dry weight, length, diameter and chlorophyll of inflorescence, stomata resistance and leaf greenness). Generally, the findings showed that increasing salinity level causes a significant reduction in most *L. longiflorum* characters tested. Furthermore, increased salinity level resulted in an increase in mineral concentrations in plant tissues. In addition, *L. longiflorum* grown in zeolitic tuff had better quantity and quality characteristics than those grown in soil. In conclusions, salinity influences almost all aspects of plant quantity and quality characteristics tested.

**Keywords:** *Lilium longiflorum*, salt stress ,zeolitic tuff, minerals, ornamental plants, Jordan.

## INTRODUCTION

Easter lily, *Lilium longiflorum* Thunb. (Liliaceae) is an important global cut flower with a high aesthetic and economic value (Fornaris *et al.*, 2011; Munafo and Gianfagna, 2011). Compared to other cut flowers, *Lilium* breeding proved to be effective to create genetic variation and development of new cultivars with higher resistance to adverse environmental conditions (Zhang *et al.*, 2012; Chung *et al.*, 2013). Nowadays, there is a growing interest in Jordan to improve cut flower cultivation, and the production is expected to increase in the coming years.

Salt stress is a major abiotic stress contributing to the loss of plant yields and productivity (Park *et al.,* 2018; Amarin *et al.,* 2020, 2021). Irrigating cut flower plants with saline water has negative impact on their aesthetic and economic values (Cassaniti *et al.*, 2009). *L. longiflorum* has been reported as a plant of low salinity tolerant (Zapryanova and Atanassova, 2009). Many quality and quantity characteristics of ornamental plants tend to be negatively affected by high salinity levels in irrigated water.

High saline-water levels decreased shoot and root elongation, leaf expansion and dry weight (Bhatt *et al.*, 2008), decreased flower number, length, fresh and dry weights, and plant diameter and height (Ahmad *et al.*, 2013). Many studies have shown the effects of salinity on plant growth as the result of water deficit due to low water potential, stress caused by toxic ions, and nutritional imbalance triggered by reduced nutrient uptake and transport (Akbarimoghaddam *et al.,* 2011; Oyiga *et al.,* 2016). Nutrient deficiency considered as one of the most crucial factors that reduces plant growth and crop productivity as both macro- and micro-nutrients are important constituents of enzymes, hormones and cellular structures (Rus *et al.*, 2004; Ashraf *et al.*, 2008). Abdi *et al.* (2006) stated increased amounts of N, P, K, Ca and Mg by increasing salts in the irrigation water.

Growing media may play a significant role in ornamental production. Ramesh *et al.* (2011) stated that the use of zeolites is a good growing medium due to their unique physical and chemical properties including ion exchange, dehydration-rehydration and adsorption properties made them useful in agricultural applications as zeolites were found to increase crop yield and promote nutrient use efficiency. Furthermore, Abdi *et al.* (2006) reported that zeolites increase the rate of photosynthesis due to availability of different elements and water for the plants. Safi *et al.* (2007) indicated higher carnation yield grown in tuff as a growing media. Applying zeolites to potting medium of chrysanthemums behaved like a slow-release K-fertilizer, yielding the same growth for the plants as if they are daily irrigated with Hoagland's solution (Milosevic and Milosevic, 2009). Furthermore, using zeolitic tuff as a plant growing media under different salinity levels improves the quantity and quality of clove pink (Amarin *et al.*, 2020) and chrysanthemum (Amarin *et al.*, 2021) as compared to soil.

Therefore, the present study aimed at investigating the impact of four salinity levels and two growing media on different quality and quantity characteristics of *L. longiflorum*.

## MATERIALS AND METHODS

### Plant materials, growth conditions and experimental treatments

The trails were set up under greenhouse conditions to investigate the impact of salinity and growing media on some quantity and quality characteristics of *L. longiflorum*. Corms of *L. longiflorum* were firstly grown in peat moss on and after 2 weeks the plants were transplanted into 10 L pots containing soil or zeolitic tuff as growing media. The plants were treated with pesticides to avoid infestation by pests, and were fertilized with NPK fertilizer (20: 20: 20). After 2 weeks under complete nutrient solution irrigation, saline treatments started. Soil water holding capacity, leaching requirements, and intervals between irrigations were Determined to set irrigation schedule. Saline solutions were prepared by adding NaCl and $CaCl_2$ at 85% and 15% (by weight) to the nutrient solution, respectively. Five levels (0, 2, 4, 6 and 8 $dS.m^{-1}$.) of irrigation water salinity were used. Irrigation water pH was adjusted to 6.5-7.0.

## Data collection, measurements and analyses

Plant height was recorded from the level of growing medium to the top of the inflorescence at the flowering stage via 200±0.05 cm ruler using 5 randomly selected plants/plot. Five randomly selected plants were harvested/pot to measure the fresh plant weight (FW), and hereafter the plants were dried up at 70°C for 48 h for dry weight determination (DW). The impact of salinity on vase life of flowering shoots was measured in term of the relative loss of FW. Flowering shoots from the different salinity treatments were harvested and weighed in groups, each consisted of 3 shoots. Shoots were placed in an Erlenmeyer flask with a known volume of deionized water for rehydration and relative fresh weight (RFW) loss was recorded at 1, 4, 7 and 10 days. At fully opened flower heads, shoots were severed at the substrate surface. Flowers were washed in deionized water, blotted dry, kept in paper bags and dried in an oven at 70°C for constant DW. Length and diameter of flowering shoots of each plant were recorded and period to flowering was recorded. Leaf greenness (SPAD) was determined during flowering stage, and at the end of the experiment for both fully expanded young and old leaves using a chlorophyll meter (CCM-200 plus; OptiScience, NH, USA). Leaf chlorophyll fluorescence yield was measured at 3 days during the experiment on young and fully expanded leaves via a Pulse-Modulated Fluorimeter (OS1-FL Modulated Chlorophyll Fluorimeter, ADC Bio Scientific Ltd., Hertford, UK). Stomata resistance values were determined using Steady-State Porometer (AP4 Model, Delta T Devices) attached to the side of the leaves. Readings were taken on 3 fully expanded leaves situated at different position of the canopy. Fully expanded fresh leaves were then sampled from the middle of the plants to determine the relative water content (RWC). The FW was measured after harvesting (Wf). Hereafter, the leaves were floated on a Petri-dish filled with distilled water for 24 h in the dark, and weighed to obtain a fully turgid weight (Wt). Hereafter, the leaves were dried up at 70°C for 24 h and weighed to obtain the dry weight (Wd). The leaf RWC was calculated using the following equation according to Martinez *et al.* (2004). Salt accumulation in the root zone was monitored, leachate was collected from 3 pots/salinity level in both growing media after 30 days of the treatment and at the end of the experiment. The EC and pH of leachate were determined using an EC and pH meter. Representative fresh leaf, stem and root samples were taken at harvesting date, oven-dried at 70 C° for 48 h, grounded and stored for mineral analyses. Samples weighing 0.5 g DW were placed in a Muffle Furnace at 500°C for 6 h for total ash determination. The ash was wet with sulfuric and perchloric acid and diluted with distilled water for mineral analyses. Cl concentration was measured by titration using $AgNO_3$. Na and K concentrations were determined by flame photometry, while Ca concentration was determined by atomic absorption spectroscopy (Temminghoff and Houba, 2004).

**Statistical analysis**

The experimental treatments were a factorial arranged in a Randomized Complete Block Design (RCBD) with 5 replications. In order to affirm the basic assumptions of the data to be analyzed, they were firstly tested for the normal distribution and the homogeneity of variance using the Barlett-test (Kohler *et al.*, 2002). Analysis of variance (ANOVA) was conducted (Zar, 1999) through the Proc GLM of the Statistical Package SigmaStat version 22.0 (SPSS, 1997). Least significant differences (LSD) at a probability level of 0.05 was used to detect differences among means. (Abacus Concepts, 1991).

## RESULTS

**Plant growth**

The *L. longiflorum* plants grown in soil showed no significant differences in their height under different salinity levels (Fig. 1A). On contrast, increasing salinity level from 2 to 8 $dS.m^{-1}$ caused a significant ($P \leq 0.05$) reduction in *L. longiflorum* plant height grown in zeolitic tuff (Fig. 1A). According to the growing media, plants grown in zeolitic tuff had more height than those grown in soil. Similar trend of results was observed for both plant FW and DW weights (Fig. 1B and C). Plants grown in zeolitic tuff had the highest FW and DW under control treatment, and this was significantly (P≤0.05) different from FW and DW of plants grown under EC of 2 to 8 $dS.m^{-1}$. Moreover, results showed that increasing salinity level caused a significant (P≤0.05) reduction in FW and DW for plants grown in both growing media used. Subjecting *L. longiflorum* to salinity level of 8 $dS.m^{-1}$ resulted in a significant (P≤0.05) reduction in FW of 39% and 31% of plants grown in soil and zeolitic tuff, respectively, while the reduction in DW was 49% for plants grown in both growing media used as compared to the control.

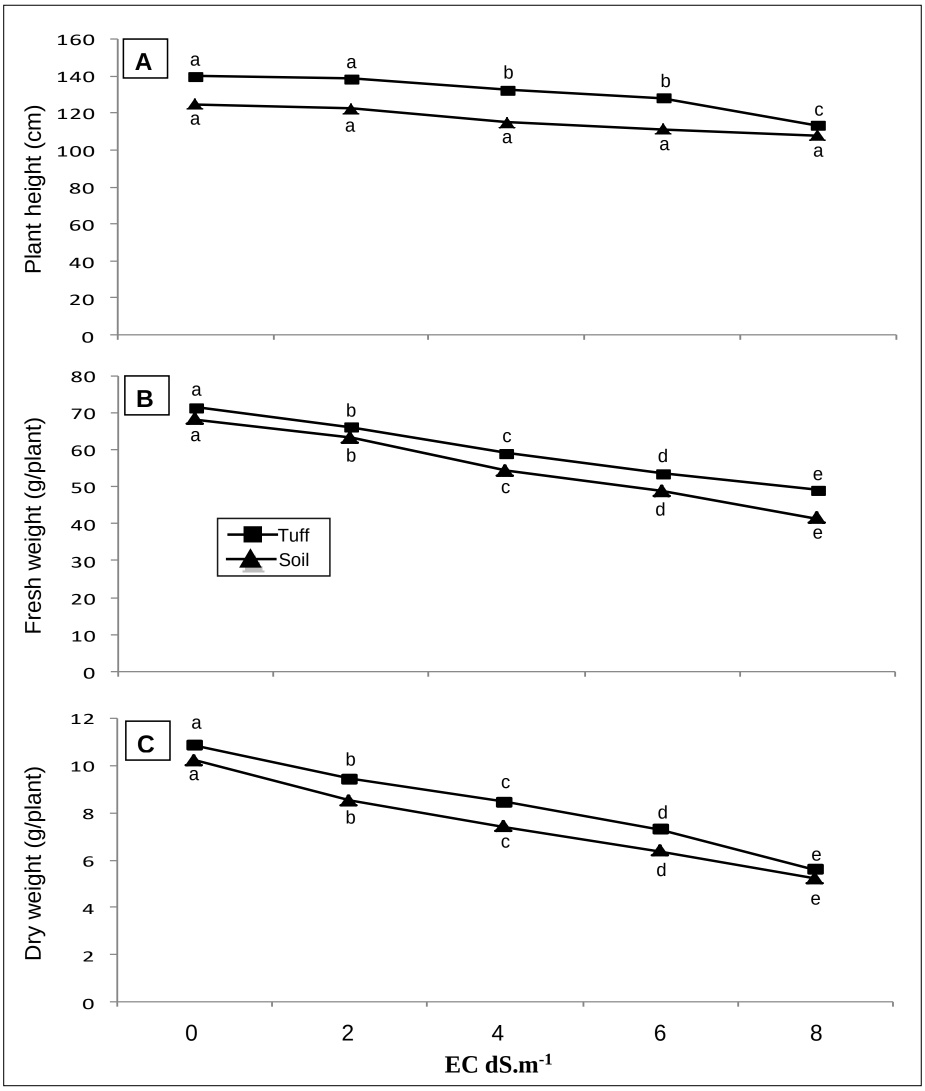


**Fig. 1. Mean plant height (cm) (A), fresh weight (g/plant) (B) and dry weight (g/plant) (C) of *Lilium longiflorum* grown at different salinity levels in soil ( ▲ ) and zeolitic tuff (■) growing media. [Different small letters above curves indicated significant differences among the different salinity levels within the same tested parameter and growing media at P≤0.05, one-factor analysis of variance].**

## Flower quantity and quality

Increasing salinity resulted in a shorter period until *L. longiflorum* flowering (Fig. 2A). The highest number of days to flowering was obtained for *L. longiflorum* plants grown under control treatment in both soil and zeolitic tuff. *L. longiflorum* started flowering after 68.0 and 86.75 days in the control treatment, and it was fastened by about 20.50 and 20.75 days once growing plants under 8 $dS.m^{-1}$ in soil and zeolitic tuff, respectively. Inflorescences FW was decreased as salinity level in irrigation water increased in both soil and zeolitic tuff (Fig. 2B). Under control treatment, inflorescence FW was 8.5 g and 8.94 g which was significantly

($P \leq 0.05$) reduced at 8 $dS.m^{-1}$ to 4.59 g and 5.60 g in soil and zeolitic tuff, respectively. There were significant ($P \leq 0.05$) differences in inflorescence DW between plants grown in soil and zeolitic tuff under different salinity levels. However, this was not significantly different for plants grown under EC of 0, 2 and 4 $dS.m^{-1}$in soil. Moreover, plants grown in zeolitic tuff showed significant ($P \leq 0.05$) reduction in inflorescence DW when irrigated with increasing salt concentrations (Fig. 2C). In general, inflorescence DW and FW of *L. longiflorum* plants weather grown in soil or in zeolitic tuff were significantly reduced with increasing salinity level in irrigated water from 2 to 8 $dS.m^{-1}$.

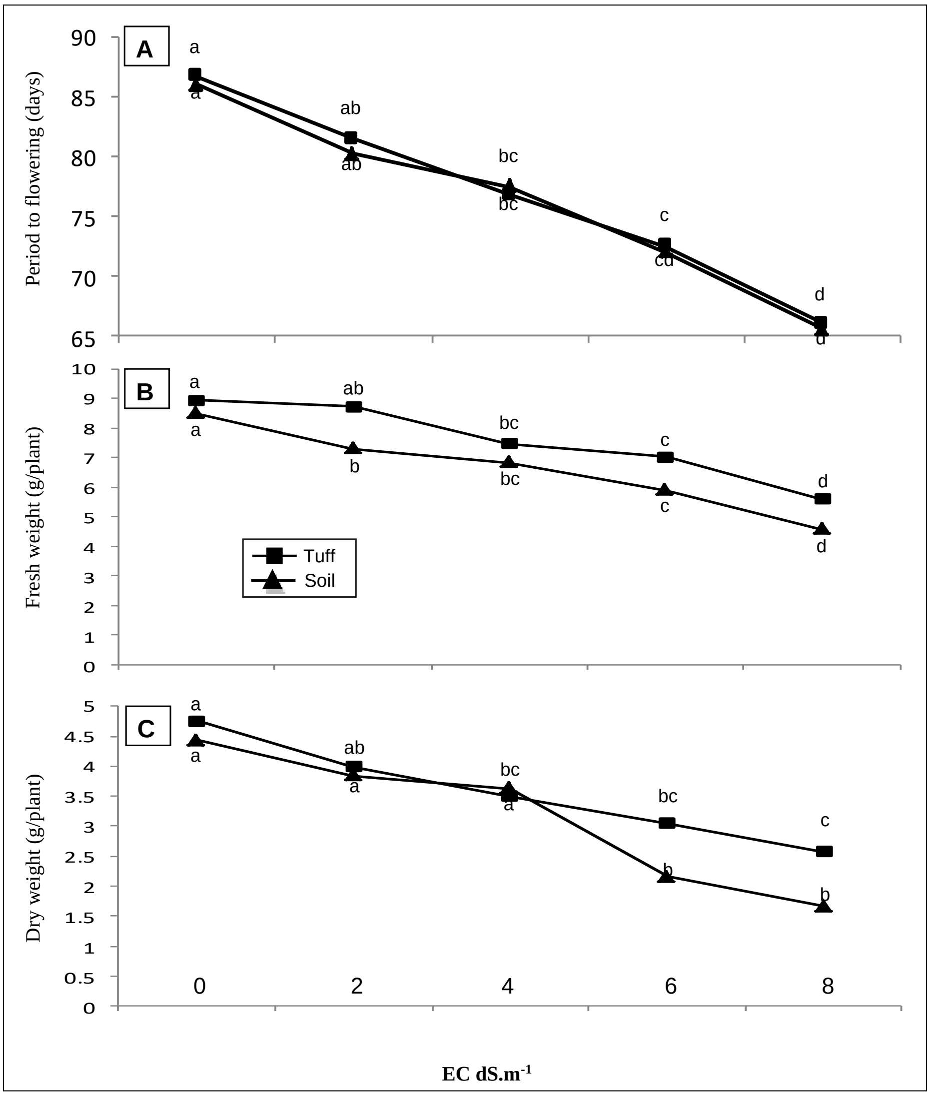


**Fig. 2. Mean period to flowering (days) (A), inflorescence fresh weight (g/plant) (B) and inflorescence dry weight (g/plant) (C) of *Lilium longiflorum* plants grown at different salinity levels in soil (▲) and zeolitic tuff ( ■ ) growing media. [Different small letters above curves indicated significant differences among the different salinity levels within the same tested parameter and growing media at P≤0.05, one-factor analysis of variance].**

In addition, both length and diameter of inflorescence were significantly ($P \leq 0.05$) affected by salinity (Fig. 3A and B). There were significant ($P \leq 0.05$) differences in inflorescences length of plants grown in both soil and zeolitic tuff among the different salinity levels. However, this was not significantly different for plants grown under EC of 0, 2 and 4 $dS.m^{-1}$ in soil. Moreover, plants grown in zeolitic tuff showed a significant ($P \leq 0.05$) reduction in inflorescence length when irrigated with increasing concentrations of salt. In general, inflorescence length of *L. longiflorum* plants weather grown in soil or in zeolitic tuff was significantly ($P \leq 0.05$) reduced with increasing salinity level of irrigated water from 2 to 8 $dS.m^{-1}$. Results showed that *L. longiflorum* grown in zeolitic tuff had the widest diameter (148.93 mm) under control treatment (Fig. 3B). However, plants grown in soil had the highest inflorescence diameter in the control treatment, and there was a significant ($P \leq 0.05$) reduction in the inflorescence diameter with increasing EC up to 8 $dS.m^{-1}$. As compared to the control treatment, the reduction in diameter was 22% and 40% for plants grown in zeolitic tuff and soil, respectively. The RFW of shoots harvested from plants grown in both soil and zeolitic tuff was significantly ($P \leq 0.05$) different among the different salinity levels (Fig. 4A and B). The highest RFW was recorded for the control treatment, while the lowest was reported at 8 $dS.m^{-1}$. Loss in RFW recorded after 4, 7 and 10 days was significant for shoots harvested from soil and zeolitic tuff.

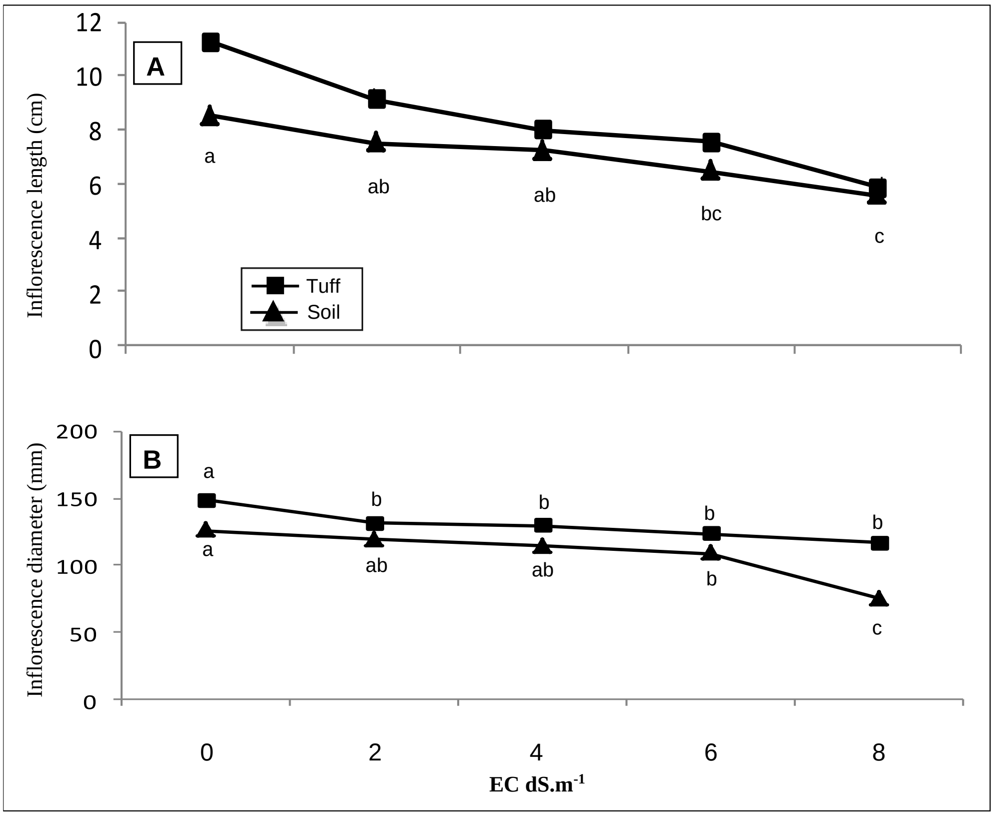


**Fig. 3. Mean inflorescence length (cm) (A) and inflorescence diameter (mm) (B) of *Lilium longiflorum* plants grown at different salinity levels in soil (▲) and zeolitic tuff (■) growing media. [Different small letters above curves indicated significant differences among the different salinity levels within the same tested parameter and growing media at P≤0.05, one-factor analysis of variance].**

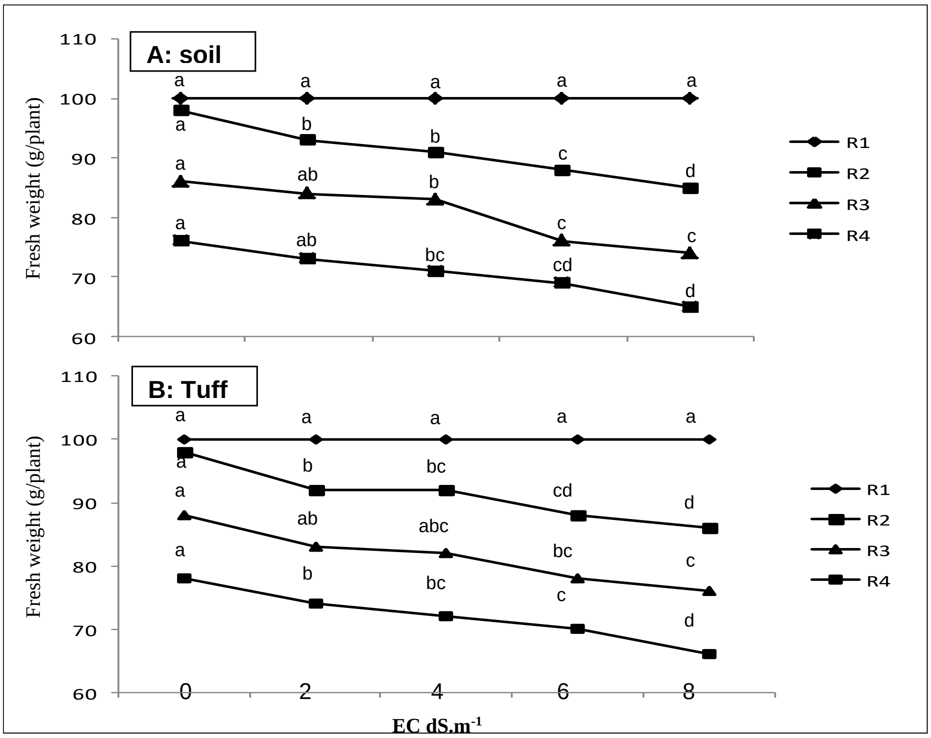


**Fig. 4. Mean relative fresh weight (RFW) (g/plant) of *Lilium longiflorum* plants grown at different salinity levels in soil (A) and zeolitic tuff (B) growing media. R1, R2, R3 and R4 representing the RWF at the 1st, 4th, 7th and 10th days, respectively. [Different small letters above curves indicated significant differences among the different salinity levels within the same tested day and growing media at P≤0.05, one-factor analysis of variance].**

**Plants physiological characteristics**

Leaf (SPAD), stomata resistance, chlorophyll fluorescence and leaf RWC were significantly ($P \leq 0.05$) affected by salinity level (Fig. 5A, B, C and D). Results indicated that the highest SPAD was significantly obtained from plants grown in soil and zeolitic tuff under control treatment. Increasing salinity level caused a significant reduction in SPAD. Reductions under salinity level of 8 $dS.m^{-1}$ were 32% and 28% in soil and zeolitic tuff, respectively, as compared to control treatment. Plants grown in zeolitic tuff showed higher SPAD than those grown in soil (Fig. 5A). Plants grown in soil under EC of 8 $dS.m^{-1}$ showed significantly ($P \leq 0.05$) higher stomata resistance compared to the other 4 treatments (Fig. 5B). In zeolitic tuff, there was a significant ($P \leq 0.05$) decrease of stomata resistance with decreasing the salinity level. However, plants grown in soil showed higher stomata resistance than those grown in zeolitic tuff at all salinity level tested.

Furthermore, plants grown in both soil and zeolitic tuff had the highest chlorophyll fluorescence (0.73 and 0.71, respectively) under control treatment. Increasing salinity level from 2 $dS.m^{-1}$ to 8 $dS.m^{-1}$ caused a significant ($P \leq 0.05$) reduction in chlorophyll fluorescence of *L. longiflorum* grown in both media (Fig. 5C). As compared to control treatment, there were reductions of 25% and 27% in plants grown in soil and zeolitic tuff at 8 $dS.m^{-1}$, respectively. Increasing salinity level in irrigated water resulted in a significant ($P \leq 0.05$) reduction in RWC for plants grown under 8 $dS.m^{-1}$ (Fig. 5D). Under the control treatment in soil, *L. longiflorum* had the highest RWC (91.14). However, this was not significantly different for plants grown under EC of 2 $dS.m^{-1}$ and 4 $dS.m^{-1}$. Moreover, increasing salinity level in irrigated water resulted in a significant reduction in RWC of plants grown under 6 and 8 $dS.m^{-1}$. Plants grown in zeolitic tuff had the lowest RWC when irrigated with salinity level of 8 $dS.m^{-1}$. Subjecting plants grown in soil and zeolitic tuff to a high salinity level caused 40% and 34% reduction in RWC, respectively, compared to the control treatment.

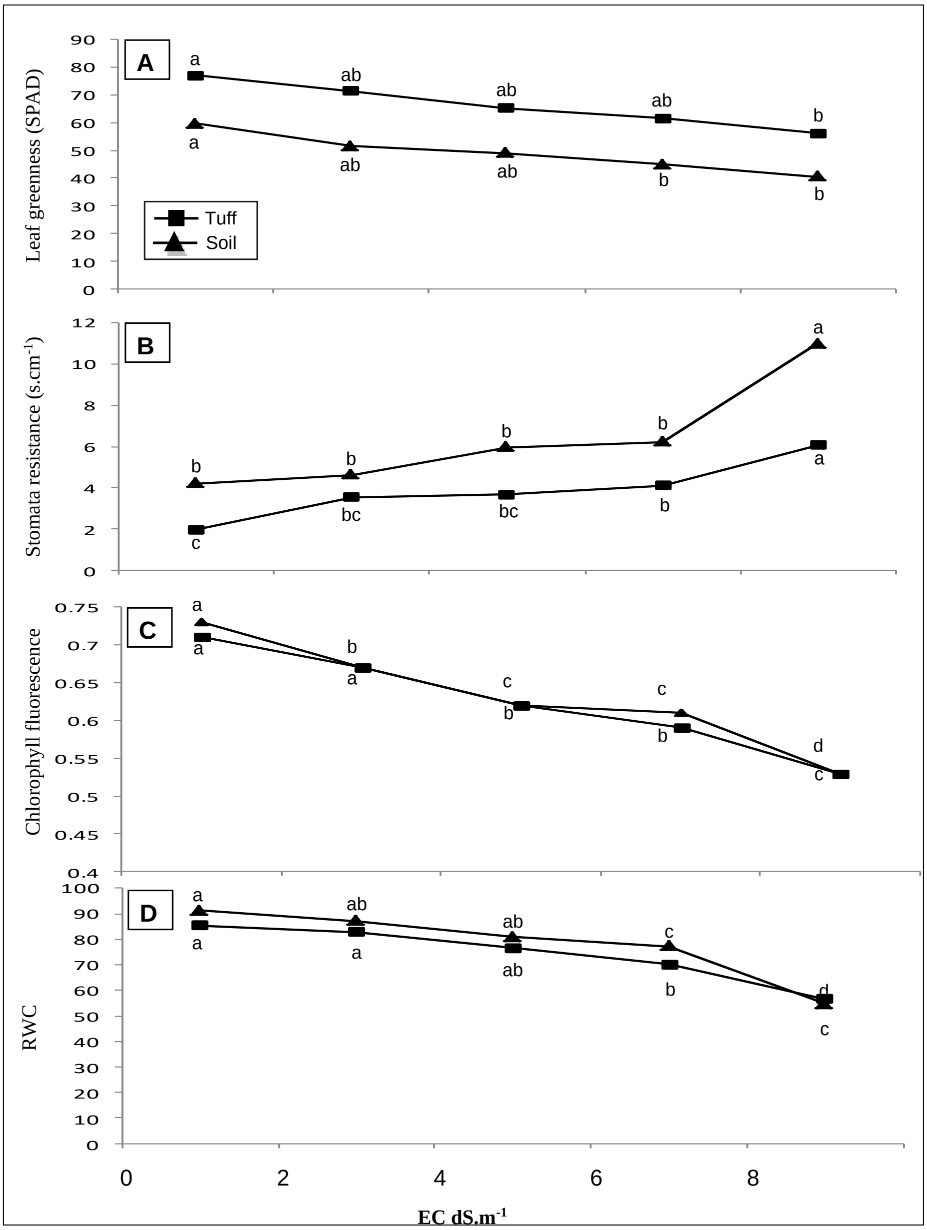


**Fig. 5. Mean leaf greenness (SPAD) (A), stomata resistance ($s.cm^{-1}$) (B), chlorophyll fluorescence (C) and relative water content (RWC) (D) of *Lilium longiflorum* plants grown at different salinity levels in soil (▲) and zeolitic tuff (■) growing media. [Different small letters above curves indicated significant differences among the different salinity levels within the same tested parameter and growing media at P≤0.05, one-factor analysis of variance].**

## Plant mineral contents and interactions

The concentrations of Na, Cl, K, P and N were significantly (P≤0.05) affected by salinity level (Fig. 6A-E). The highest Na concentration was obtained in plants grown in soil (1.61%) at 8 $dS.m^{-1}$ (Fig. 6A). The same trend of results was obtained in case of Cl concentration (Fig. 6B). A significant (P≤0.05) increase in Cl concentration was reported by increasing salinity level up to 8 $dS.m^{-1}$ in both growing media used. Plants grown in soil had the highest K concentration under the control treatment (Fig. 6C). Increasing salinity level caused a significant ($P \leq 0.05$) reduction in K concentration in plants grown in both media. There was a reduction of 12% and 26% in K concentration grown in soil and zeolitic tuff, respectively when irrigated with salinity level of 8 $dS.m^{-1}$ compared to the control treatment. Increasing salinity level caused a significant ($P \leq 0.05$) increase in P concentration in plants grown under both growing media. In addition, plant N concentration grown in both media decreased significantly ($P \leq 0.05$) with increasing salinity level up to 8 $dS.m^{-1}$ (Fig. 6E).

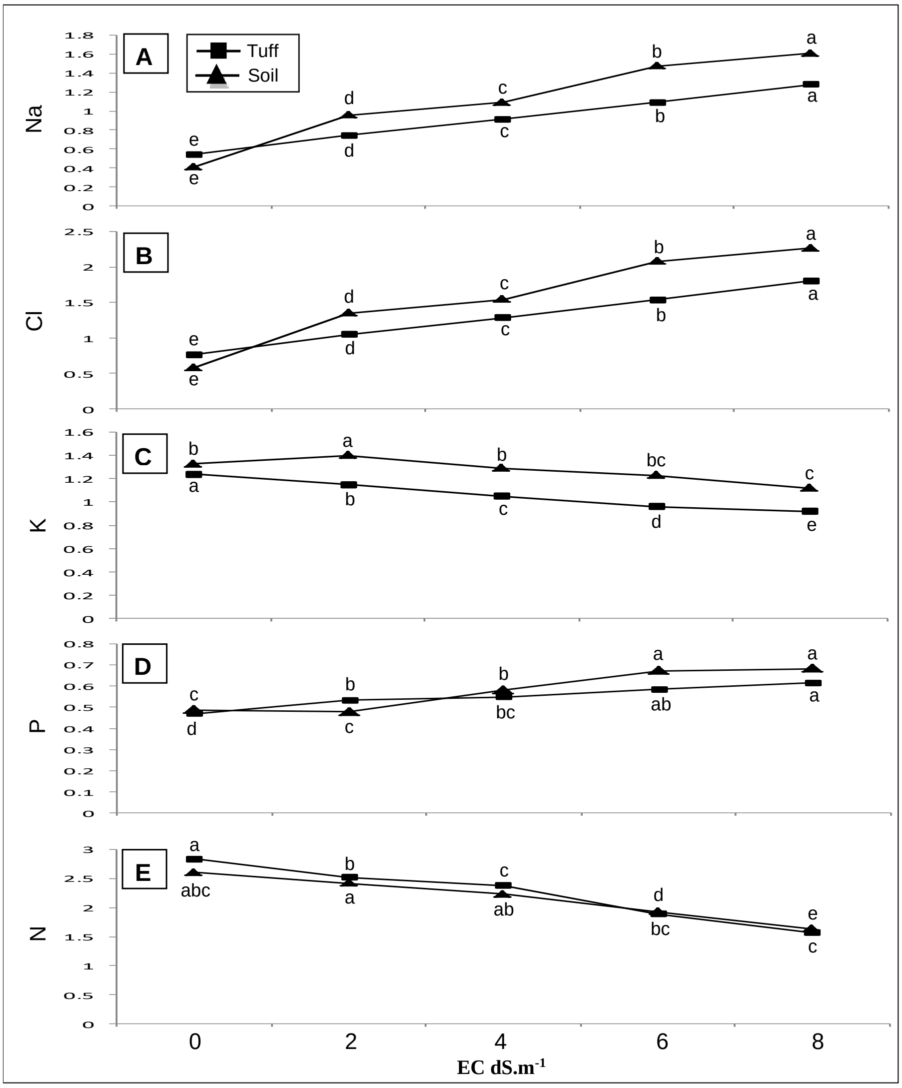


**Fig. 6. Mean concentration percentage (%) of Na (A), Cl (B), K (C), P (D) and N (E) of Lilium longiflorum plants grown at different salinity levels in soil (▲) and zeolitic tuff (■) growing media. [Different small letters above curves indicated significant differences among the different salinity levels within the same tested mineral and growing media at P≤0.05, one-factor analysis of variance].**

The results indicated that increasing salinity level caused a significant (P≤0.05) reduction in K/Na, K/Cl, P/Na, N/Na, P/Cl and N/Cl ratios in plant tissues (Fig. 7A-F). The highest K/Na ratio was recorded in plants grown in soil under the control treatment (7.865%), and the lowest ratio was recorded for plants grown also in soil at the highest used salinity treatment. Similar results were obtained for K/Cl ratio in plants in both growing media. The highest ratio was recorded for plants grown in soil at the control treatment. Increasing salinity level caused a significant (P≤0.05) reduction in P/Na ratio in plant tissues. Also, P/Na ratio in plants was significantly (P≤0.05) and negatively correlated with salinity. A reduction of 3.44% in the control treatment and 0.5% at EC of 2 dS.m-1 was reported. Increasing salinity level caused a significant (P≤0.05) reduction in P/Cl ratio in plants tissues. Moreover, P/Cl ratio was reduced by salinity in both growing media. Reduction reached 45% in plants grown in zeolitic tuff in the control treatment compared to those irrigated with 8 dS.m-1. Similar reduction was obtained for N/Na ratio in plants grown in soil and zeolitic tuff, and a significant (P≤0.05) reduction was reported by increasing salinity level to 8 dS.m-1. Plants grown in zeolitic tuff showed the highest N/Na ratio in their tissues under control treatment (5.24%), while the lowest ratio of K/Cl was recorded for plants grown in soil at the highest used salinity level (1.01%). Increasing salinity level caused a significant (P≤0.05) reduction in N/Cl ratio in plant tissues. Moreover, N/Cl ratio was strongly reduced by salinity in plants grown in both media. Reductions exceeded 78% and 77% in plants grown in soil and zeolitic tuff, respectively by increasing salinity to 8 dS.m-1.

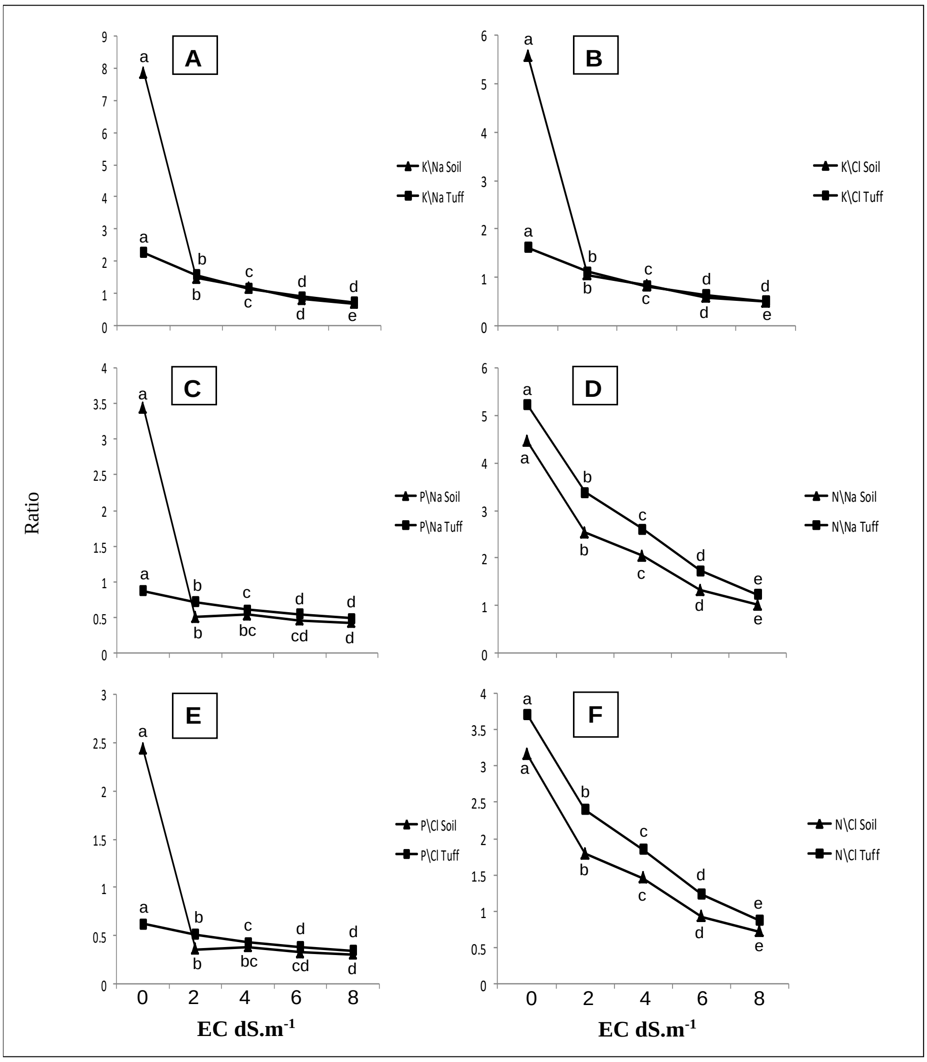


**Fig. 7. Ratios of K/Na (A), K/Cl (B), P/Na (C), N/Na (D), P/Cl (E) and N/Cl (F) of *Lilium longiflorum* plants grown at different salinity levels in soil (▲) and zeolitic tuff (■) growing media. [Different small letters above curves indicated significant differences among the different salinity levels within the same tested mineral ratio and growing media at P≤0.05, one-factor analysis of variance].**

# DISCUSSION

Salinity affects many morphological, physiological and biochemical processes including seed germination, plant growth, and water and nutrient uptake (Akbarimoghaddam *et al.*, 2011; Park *et al.*, 2016). Due to salinity some physiological changes may occur in stomatal resistance, transpiration, photosynthesis, chlorophyll content and root and leaf activity (Kucukahmetler, 2000). The present results indicated that the growth of *L. longiflorum* decreases by increasing salinity, probably in response to limited cell expansion resulting from osmotic stress (Munns and Tester, 2008). Our data showed significant reductions in *L. longiflorum* plant height as salinity level in the irrigation water increased up to EC 8 dS.m$^{-1}$. In this regard, Zapryanova and Atanassova (2009) reported that *L. longiflorum* is a sensitive ornamental plant, thus it could not tolerate salt concentration more than 2 $dS.m^{-1}$. The present results indicated that salinity significantly affected *L. longiflorum* growth in terms of shoot FW and DW. Increasing salinity level from control up to 8 $dS.m^{-1}$ caused a significant reduction in FW of *L. longiflorum* in the two different growing media and the reduction in shoot DW was 48% as compared to the control treatment. Our results agreed with the findings of Kang *et al.* (2021) who stated that saline conditions decrease plant height, shoot length, leaf area, FW and DW of *Lilium*.

Proper management of water and nutrients is necessary for ornaments' production as their excessive application may lead to reduced growth, yield and poor quality (Oki and Lieth, 2004). Plants grown under saline conditions have retarded growth and less FW caused by disturbance to water and ion balance, membrane permeability, stomatal conductivity and photosynthesis (Navarro *et al.*, 2003; Cabanero *et al.*, 2004). Our results showed a significant reduction in number of flowers produced by plant by increasing salinity level in both growing media compared to the control. Plants grown at 2.5 $dS.m^{-1}$ produced taller plants with higher flower yield plant (Ahmad *et al.*, 2013). This agreed with what we found in *L. longiflorum* grown in zeolitic tuff, as the reduction in the average number of flowers produced/plants was not significant for plant grown under EC of 2 $dS.m^{-1}$. Our findings indicate a delay in flowering as a result of irrigation with highly saline water and these findings are in agreement with the findings of Kang *et al.* (2021) in cut lilies, Fornes *et al.* (2007) in *Calceolaria* plants, and Shillo *et al.* (2002) in *Trachelium*. Moreover, a significant reduction in flower size was noticed in the current study with increasing salinity. The present results indicated that at high salinity level, *L. longiflorum* has higher stomata resistance value as compared to control. These results are in agreement with Eisa *et al.* (2012), who stated that stomata resistance is increased with increasing salinity in irrigated water. In the present study the reduction in chlorophyll content was 45-65% at 8 $dS.m^{-1}$ compared to control., this significant reduction in RWC of *L.*

*longiflorum* in response to the increased salinity levels. Salt stress causes reduction in growth and photosynthesis of plants, so using photosynthetic parameters such as chlorophyll fluorescence yield can assist to determine salt tolerance of plants. The current results indicated that the chlorophyll fluorescence yield decreased with increased salinity level. The reduction in chlorophyll fluorescence with increasing salt concentration may be attributed to the effect of salt on the reaction centers of photosystem II (Lazar, 2006; Redondo-Gomez *et al.*, 2007).

The present data indicated that increased salinity level resulted in increased amounts of minerals in *L. longiflorum* leaves. This agreed with the findings of Amarin *et al.* (2020) who reported that Na concentration in *Dianthus caryophyllus* grown in soil increased by 48-55% at salinity level of 8 dS.m$^{-}$1 compared to control. In tested plants K content was decreased by 13% and 26% for *L. longiflorum* grown in soil and zeolitic tuff, respectively. Our data indicated that P content in *L. longiflorum* decreased by 29% and 24% compared to control treatment in plants grown in soil and zeolitic tuff, respectively. Total phosphorus and total sulfur concentration most likely decreased because of the interaction of P and sulfates with the increasing external concentration of Ca, producing insoluble forms of P and sulfur (Abdi *et al.* 2006). Salt stress tolerance has been strongly correlated with the maintenance of a higher K/Na ratio in cell compartments (Maathius and Amtmann 1999). Our data indicated that K/Na ratio in *L. longiflorum* was significantly decreased as salinity level increased > 2 dS.m$^{-1}$, in addition to a reduction in P/Na and P/Cl ratios in all tested plants by increasing salinity level up to 8 dS.m$^{-1}$ compared to the control treatment. Regarding the growing media, *L. longiflorum* grown in zeolitic tuff performed better than in those grown soil, which is in full agreement with the findings of Amarin *et al.* (2020) on clove pink and Amarin *et al.* (2021) on chrysanthemum. So, it is recommended to grow *L. longiflorum* in zeolitic tuff rather than in soil medium when saline water is used for irrigation. Furthermore, Safi *et al.* (2005) indicated that higher carnation yield is obtained from the zeolitic tuff experiment. Ramesh *et al.* (2011) found that using zeolitic tuff is better due to their unique physical and chemical properties and adsorption properties made them useful in agricultural applications to increase crop yield and to promote nutrient use efficiency.

## CONCLUSIONS

In conclusions, salt stress significantly negatively affects *L. longiflorum* cut flower growth and flower development. Increasing salinity inhibited plant growth and caused a decrease in plant height, number of leaves, FW, DW and RWC. Increased salinity levels resulted in increased amounts of minerals in the plant tissues. It is suggested to use zeolitic tuff instead of soil as a growing medium to for *L. longiflorum*. Further studies on *L. longiflorum* are needed under various growing media mixtures.

## REFERENCES

Abacus Concepts. 1991. SuperAnova User's Manual. Version 1.11, Berkeley, CA.

Abdi, G.H., Khosh-Khui, M. and Eshghi, S. 2006. Effect of natural zeolite on growth and flowering of strawberry *Fragaria ananassa* Duch. ***Int. J. Agric. Res.,*** 1: 384–389.

Ahmad, I., Khan, M.A., Qasim, M. and Ahmad, R. 2013. Growth, yield and quality of *Rosa hybrida* L. as influenced by NaCl salinity. ***J. Ornam. Hort. Pl.,*** 3: 143–153.

Akbarimoghaddam, H., Galavi, M., Ghanbari, A. and Panjehkeh, N. 2011. Salinity effects on seed germination and seedling growth of bread wheat cultivars. ***Trakia J. Sci.,*** 9: 43–50.

Amarin, R., Kafawin, O., Ayad, J., Al-Zyoud, F. and Ghidan, A. 2020. Effect of saline water irrigation and growing media on growth, physiological and mineral parameters of clove pink *Dianthus caryophyllus*. ***Jor. J. Agric. Sci.,*** 16: 55–62.

Amarin, R., Kafawin, O., Ayad, J., Al-Zyoud, F., Haddad, N. and Amarin, A. 2021. Performance of chrysanthemum *Chrysanthemum morifolium* Ramat (CV. Balady) in different saline water irrigated soils and growing media. ***Jor. J. Agric. Sci.,*** 17: 85–99.

Ashraf, M., Athar, H.R., Harris, P.J.C. and Kwon, T.R. 2008. Some prospective strategies for improving crop salt tolerance. ***Adv. Agron.,*** 97: 45–110.

Bhatt, M.J., Patel, A.D., Bhatti, P.M. and Pandey, A.N. 2008. Effect of soil salinity on growth, water status and nutrient accumulation in seedlings of *Ziziphus mauritiana* (Rhamnaceae). ***J. Fruit Ornam. Plant Res.,*** 16: 383–401.

Cassaniti, C., Leonardi, C. and Flower, T. 2009. The effect of sodium chloride on ornamental shrubs. ***Scientia Hortic.,*** 122: 586–593.

Chung, M.Y., Chung, J.D., Ramanna, M., Van Tuyl, J.M. and Lim, K.B. 2013. Production of polyploids and unreduced gametes in *Lilium auratum* × *L. henryi* hybrid. ***Int. J. Biol. Sci.,*** 9: 693–701.

Eisa, S., Hussin, S., Geissler, N. and Koyro, H.W. 2012. Effect of NaCl salinity on water relations, photosynthesis and chemical composition of Quinoa *Chenopodium quinoa* as a potential cash crop halophyte. ***AJCS,*** 6: 357–368.

Fornaris, A., Chiavazza, P.M. and Devecchi, M. 2011. The importance of *Lilium* in garden design: history and future. **Acta Hort.,** 900: 59–64.

Fornes, F., Belda, R.M., Carrion, C., Noguera, V., Garcia-Agustin, P. and Abad, M. 2007.Pre-conditioning ornamental plants to drought by means of saline water irrigation as related to salinity tolerance. ***Scientia Hort.,*** 113: 52–59.

Kang, Y.I., Choi, Y.J., Lee, Y.R., Seo, K.H., Suh, J.N. and Lee, H.R. 2021. Cut flower characteristics and growth traits under salt stress in lily cultivars. **Plants,** 10: 1–12.

Kohler, W., Schachtel, W. and Voleske, P. 2002. Biostatistik. Springer-Verlag, Berlin, pp 301.

Kucukahmetler, O. 2000. The effects of salinity on yield and quality of ornamental plants and cut flowers. ***Proc. Int. Symp. Technol. Con. Sali. Hortic. Prod.,*** 573: 407–414.

Lazar, D. 2006. The polyphasic chlorophyll a fluorescence rise measured under high intensity of exciting light. ***Funct. Plant Biol.,*** 33: 9–30.

Maathius, F.J.M. and Amtmann, A. 1999. K nutrition and Na toxicity: the basis of cellular K/Na ratios. ***Ann. Bot.,*** 84: 123–133.

Milosevic, T. and Milosevic, N. 2009. The effect of zeolite, organic and inorganic fertilizers on soil chemical properties, growth and biomass yield of apple trees**. *Plant Soil Environ.,*** 55: 528–535.

Munafo, J.P. and Gianfagna, T.J. 2011. Quantitative analysis of steroidal glycosides in different organs of Easter lily (*Lilium longiflorum* Thunb.) by LC-MS/MS. ***J. Agric. Food Chem.,*** 59: 995–1004.

Munns, R. and Tester, M. 2008. Mechanisms of salinity tolerance. ***Annu. Rev. Plant Biol.,*** 59: 651–681.

Navarro, A., Banon, S., Conejero, W. and Sanchez-Blanco, M.J. 2008. Ornamental characters, ion accumulation and water status in *Arbutus unedo* seedlings irrigated with saline water and subsequent relief and transplanting. ***Environ. Exp. Bot.,*** 62: 364–370.

Oki, L.R. and Lieth, J.H. 2004. Effect of changes in substrate salinity on the elongation of *Rosa hybrida* L. Kardinal stems. ***Scientia Hortic.,*** 101: 103–119.

Oyiga, B.C., Sharma, R., Shen, J., Baum, M., Ogbonnaya, F., Léon, J. and Ballvora, A. 2016. Identification and characterization of salt tolerance of wheat germplasm using a multivariable screening approach. ***J. Agron. Crop Sci.,*** 202: 472–485.

Park, H.J., Kim, W.Y. and Yun, D.J. 2016. A new insight of salt stress signaling in plant. ***Mol. Cells,*** 39: 447–459.

Park, Y.G., Muneer, S., Kim, S., Hwang, S.J. and Jeong, B.R. 2018. Foliar or subirrigational silicon supply modulates salt stress in strawberry during vegetative propagation. ***Hortic. Environ. Biotechnol.,*** 59: 11–18.

Ramesh, K., Damodar-Reddy, D., Kumar-Biswas, A. and Subba-Rao, A. 2011. Four zeolites and their potential uses in agriculture. ***Adv. Agron.,*** 113: 215–236.

Redondo-Gomez, S., Mateos-Naranjo, E., Davy, A.J., Fernandez-Munoz, F., Castellanos, E.M., Luque, T. and Figuero, M.E. 2007. Growth and photosynthetic responses to salinity of the salt-marsh shrub *Atriplex portulacoides*. ***Ann. Bot.,*** 100: 555–563.

Rus, A., Lee, B.H., Muñoz-Mayor, A., Sharkhuu, A., Miura, K., Zhu, J.K. and Hasegawa, P.M. 2004. AtHKT1 facilitates $Na^+$ homeostasis and $K^+$ nutrition in plants. ***Plant Physiol.,*** 136: 2500–2511.

Safi, M.I., Bulad, A. and Blawenah, A. 2007. Flower yield and quality of *Lilium aziatische* irrigated with different types of water. ***Bulg. J. Agric. Sci.,*** 13: 51–54.

Safi, M.I., Fardous, A., Muddaber, M., El-Zuraiqi, S., Al-Hadidi, L. and Bashabsheh, I. 2005. Effect of treated saline water on flower yield and quality of roses *Rosa hybrida* and carnation *Dianthus caryophyllus*. ***Sci. Asia,*** 31: 335–339.

Shillo, R., Ding, M., Pasternak, D. and Zaccai, M. 2002. Cultivation of cut flower and bulb species with saline water. ***Scientia Hortic.,*** 92: 41–54.

SPSS (Statistical Product and Service Solutions INC). 1997. SIGMASTAT 2.03: SigmaStat statistical software user's manual, Chicago, United States.

Temminghoff, E.E. and Houba, V.J. 2004. Plant analysis procedures. Vol. 179, Dordrecht, Kluwer Academic Publishers.

Zapryanova, N. and Atanassova, B. 2009. Effects of salt stress on growth and flowering of ornamental annual species. ***Biotechnol. Equip.,*** 23: 177–179.

Zhang, X., Ren, G., Li, K., Zhou, G. and Zhou, S. 2012. Genomic variation of new cultivars selected from distant hybridization in *Lilium*. ***Plant Breed.,*** 131: 227–230.