Jordan Journal of Agricultural Sciences, Volume **16**, No.**3 2020**
DOI: https://doi.org/10.35516/jjas.v16i3.59

Effect of Saline Water Irrigation and Growing Media on Growth, Physiological and Mineral Parameters of Clove Pink Dianthus Caryophyllus

Amarin, R.[1], Kafawin, O.[2], Ayad, J.[3], Al-Zyoud, F.[4], Ghidan, A.[5]

[1] PhD in Horticulture, National Agricultural Research Center, Jordan.
[2] Prof. of Agronomy, Dept. of Horticulture and Crop Science, School of Agriculture, The University of Jordan, Amman, Jordan.
[3] Prof. of Plant Physiology, Dept. of Horticulture and Crop Science, School of Agriculture, The University of Jordan, Amman, Jordan.
[4] Prof. of Biological Control and IPM, Dept. of Plant Protection and IPM, Faculty of Agriculture, Mutah University, Karak, Jordan.
[5] PhD in Plant Protection, Amman, Jordan.

Received on 5/6/2020 and Accepted for Publication on 27/12/2020.

ABSTRACT

Soil salinity is one of the major environmental factors limiting plant growth and development; and it is considered a problem in arid and semiarid regions, where rainfall is insufficient to leach salts. The clove pink, Dianthus caryophyllus L. is a major product in Jordan with different irrigation needs and has the capacity to cope with water deficit. Consequently, the current study aimed at investigating the effect of salinity on certain growth, physiological and mineral parameters of two varieties of D. caryophyllus (Bizet Sagr and Grand Slam Hygr). The experiments were conducted under greenhouse conditions at the University of Jordan during the 2015/2016 growing season. The plants were grown in either soil or zeolitic tuff at five salinity levels. The results indicated that the growth parameters of both D. caryophyllus varieties vary significantly among the different salinity levels in both growing media. Increasing salinity caused a significant reduction in plant height, fresh and dry weights, flower length and diameter, and a delayed flowering time. Increasing salinity level caused also a significant reduction in leaf greenness, fluorescence yield, and relative water content, and increased stomatal resistance of both plant varieties in both growing media. Increasing salinity level caused a significant increase in Na and Cl, and a decrease in K, P, and N concentrations in plants of both tested varieties and media. In conclusion, salinity caused a significant effect on all tested growth, physiological and mineral parameters of D. caryophyllus. An appropriate irrigation regime should be used as a key to success in ornamentals' growth control.

Keywords: Clove pink, Dianthus caryophyllus, salinity, growing media, zeolitic tuff, growth.

INTRODUCTION

The supply of high-quality water has become increasingly limited in many areas of the world, especially in arid and semiarid regions. With a rapid increase in the urban population, the intense competition for high-quality water among agriculture, industry, and recreational users has promoted the use of alternative water sources for

Corresponding Author E-mail: rasha.amarin@yahoo.com

irrigation. These sources include recycled water and saline groundwater that contain relatively high levels of soluble salts. Soil salinity is a problem in arid and semiarid areas where irrigation is practiced (Niu and Cabrera, 2010). Over 50% of all irrigated lands are affected by salinity, yet the water used in these lands is seldom saline. Because low-quality is used for irrigation as a result of the limited supply of high-quality water, soil salinization is expected to increase in these areas, and plant production will be negatively affected (Niu and Cabrera, 2010; Niu and Rodriguez, 2010). As a part of the arid and semiarid areas, Jordan is considered one of the driest countries in the world. It is the fourth poorest country in the water. The average total rainfall quantity in Jordan is varying between 6,000 and 11,500 Million m3/year. About 85% of this quantity evaporates into the atmosphere, and the rest goes into rivers and wades as flood flow that will reach groundwater (Al-Jayyousi, 2003).

Growing ornamental plants became one of the important high-value agricultural industries worldwide. Ornamentals are grown for their aesthetic value and national income, which has a growing interest in the last few decades. In the past, most of the ornamentals used in Jordan were imported, but nowadays Jordan produces a large range of ornamentals. Moreover, the local production of ornamentals covers all the needs of the local market with oversupply during certain times of the year, and the production is expected to increase in the coming years (Jordan Statistical Yearbook, 2016). In Jordan, which is considered a semi-arid environment, about 72% of annual water demand goes for agricultural uses. Jordanian soils contain high levels of calcium carbonate (15-35%), and low soil organic matter which leads to nutrient deficiency (Owais et al., 2013). Soil salinity is one of the major environmental factors limiting plant growth and development; and it is considered a common problem in arid and semiarid regions, where rainfall is insufficient to leach salts and excess sodium ions out of the rhizosphere. The use of saline irrigation water in floriculture production may be inevitable in the long run since the freshwater supply is decreasing over time. Many floriculture species are sensitive to salt accumulation in the root zone. Irrigation with saline water can have detrimental effects on plant growth and development (Ashraf et al., 2008). Due to limited water resources, a challenge for agriculture is represented by the extreme difficulty to sustain high consumption levels of water required by growers. The high demand for irrigation water increases the salinity and reduces water quality for irrigating the ornamental plants; it also increases the need for groundwater as a supplemental source for irrigation besides the surface water. The increase in water abstraction of groundwater and the decrease of groundwater recharge increased water salinity to intolerable levels in Jordan (Mohsen, 2007).

The local environmental conditions increase the interest to search for ornamental plants that tolerate drought and high salinity rates. In some areas, the scarcity of water increased the dimension to use treated wastewater for irrigation purposes (Navarro et al., 2008; McCammon et al., 2009). As more low-quality water is used for ornamental plants irrigation, demand for salt-tolerant species will increase. This makes it urgent to study the effect of salinity on ornamental plants' growth and to identify tolerable species that stand high salinity and drought conditions. Therefore, exploring potential alternative ornamental crops which can tolerate salinity stresses; and the use of low-quality water for irrigation purposes, become more necessary in various parts of the world to deal with this problem.

Salt tolerant plant species can minimize the detrimental effects of salinity by producing anatomical, morphological and physiological adaptations (Ashraf et al., 2008). The clove pink, Dianthus caryophyllus L. is a major ornamental plant in Jordan, therefore, the current study aimed at investigating the effect of salinity on certain growth, physiological and mineral parameters of two varieties of D. caryophyllus planted in two different media. It is hoped that this research could provide an opportunity to explore the potential use of low-quality water on ornamental plants that might create new dimensions in the expansion of the ornamental plants business in Jordan.

MATERIALS AND METHODS

Plant material, growth conditions, and experimental treatments: The experiments were conducted under greenhouse conditions at the Faculty of Agriculture, University of Jordan, Amman, Jordan during the 2015/2016 growing season. Two varieties of D. caryophyllus (Bizet Sagr and Grand Slam Hygr) were used to run the experiments, and they were obtained from a local nursery in Amman, Jordan. The plants were grown in early September 2015 in 10-liter pots and were fertilized with NPK fertilizer (20: 20: 20) at the end of October. The plants were allowed to establish for 1-2 weeks under irrigation with a complete nutrient solution before the initiation of saline treatments. Saline solutions were prepared by adding NaCl and CaCl2 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. The plants were grown in either soil or zeolitic tuff at the above-mentioned five salinity levels. There was five plants/salinity level, which was randomly placed on greenhouse benches.

Data collection, measurements, and analysis: Plant height was recorded from the growing media level to the top of inflorescence at the flowering stage by using a 200±0.05 cm ruler from five randomly selected plants from each plot, and the average plant height was calculated. Five randomly selected plants were harvested from each pot to measure fresh plant weight, and then they were dried at 70°C for 48 h for dry weight determination. The effect of salinity on the vase life of flowering shoots was measured in terms of relative loss of fresh weight (FW). Flowering shoots from the different salinity treatments were harvested and weighed in groups of three shoots. Then, one set of shoots, with three replications, was placed in an Erlenmeyer flask with a known volume of deionized water for rehydration, after which the relative fresh weight (RFW) loss was recorded at 1, 4, 7, 10, and 14 days. When most of the flower heads/buds are fully opened, shoots were severed at the substrate surface. Flowers were washed in deionized water, blotted dry, placed in paper bags and dried in an oven at 70°C to reach constant weight. Dry weight, length, and diameter of flowering shoots on each plant were recorded. Also, the effect of salinity on the time to the flower of plants was recorded.

Leaf greenness (SPAD) (or relative chlorophyll content) was measured using a handheld chlorophyll meter (measured as the optical density). SPAD reading was done at the end of the experiment for all survived plants on both fully expanded young and old leaves. Leaf chlorophyll fluorescence yield was measured on three days during the experiment on young and fully expanded leaves by using a Pulse-Modulated Fluorimeter (OS1-FL modulated chlorophyll fluorimeter, ADC Bio Scientific Ltd., Hertford, UK). Stomata resistance values were determined using a steady-state Porometer (AP4 model, Delta T devices) attached to the side of the leaves. Readings were taken on three fully expanded leaves situated at different positions of the canopy. Fully expanded fresh leaves were sampled from the middle of the plant to determine relative water content (RWC). The FW was measured after harvest (Wf). Hereafter, the leaves were floated on a Petri-dish filled with distilled water for 24 h in the dark, then weighed to obtain a fully turgid weight (Wt). After that, the leaves were dried 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): RWC = (Wf-Wd) / (Wt-Wd) * 100.

To analyze the mineral concentrations, 3-shoots/treatment were randomly collected at harvest date, oven-dried at 70°C for 48 h, grounded to pass a 40-mesh screen, and stored for analysis. Sodium (Na), chloride (Cl), potassium (K) phosphorous (P), and Nitrogen (N) were analyzed according to standard soil and plant analysis procedures (Temminghoff and Houba, 2004). Samples weighing 0.5 g dry weight were placed in a muffle furnace at 500°C for 6 h for total ash determination. The ash was wetted with sulfuric and perchloric acid and diluted with distilled water for mineral analyses. Sodium and potassium concentrations were determined by flame photometry, and chloride was measured by titration using AgNO3. To monitor salt accumulation in the root zone, leachate was collected from three pots/salinity level 30 days post-treatment and at the end of the experiments. The EC and pH of leachate were determined using an EC and pH meter, respectively.

Statistical analysis

The experimental treatments were a factorial experiment arranged in a Randomized Complete Block Design (RCBD) with five replications. The statistical analysis was performed using the proc General Linear Model (GLM) (SPSS 19.0, SPSS Inc. Chicago, IL, USA) (SPSS, 1997). The data were analyzed using a one-way analysis of variance (ANOVA) to detect the differences in the tested parameters (Zar, 1999). When significant differences were detected, means were separated using the Least Significant Differences (LSD) test at 0.05 probability level (Abacus Concepts, 1991).

RESULTS

Effect of salinity on plant growth parameters:

D. caryophyllus grown in both growing media showed significant differences in their height under different salinity levels (Table 1). Both varieties (Bizet Sagr and Grand Slam Hygr) grown in soil have the tallest plants under control and EC of 2 dS.m-1 treatments. Increasing salinity level from 2 to 8 dS·m-1 caused a significant reduction in plant height. Reduction in plant height varied between varieties; Bizet Sagr reduced by 27%, while V2 reduced by 32% compared to the control grown in soil. In zeolitic tuff, the plant height reduced by 36% for Bizet Sagr and 33% for Grand Slam Hygr. D. caryophyllus grown in soil and zeolitic tuff showed a significant reduction in FW under different salinity levels (Table 1). FW was reduced by 42% and 45% for Bizet Sagr compared to 57% and 52% in Grand Slam Hygr in soil and zeolitic tuff, respectively. The highest Wd was obtained from Bizet Sagr plants in the control treatment in the soil. However, plants grown in soil in the control treatment were significantly different in their Wd from plants grown in soil under EC of 4, 6, and 8 dS.m-1. Under the EC of 8 dS.m-1, the Wd was the lowest for both verities in both growing media. Subjecting Grand Slam Hygr grown in soil to the highest salinity level caused a 46% reduction in Wd when compared to control treatment (Table 1).

The longest period until plant flowering was obtained when increasing the salinity level in both soil and zeolitic tuff (Table 2). In Bizet Sagr grown in soil, a delay of 37 days was recorded as plants grown under EC of 8 dS.m-1 compared to the control treatment. The highest number of days to flowering was obtained when the salt level was the highest in irrigation water in both soil and zeolitic tuff. Bizet Sagr plants started flowering after 160.4 days in the control but after 197.4 days in the highest used salinity level. This was almost the same for plants grown in zeolitic tuff as there was about 35 days delay. Grand Slam Hygr plants grown in zeolitic tuff started flowering after 156.8 in the control treatment and it was delayed by about 25 days once growing under 8 dS.m-1 in soil and tuff. These findings indicated that increasing salinity resulted in delayed flowering. Flower fresh and dry weights were affected by salinity treatments (Table 2). Increasing salinity levels from 2 up to 8 dS.m-1 caused a significant reduction in flower FW at all salinity levels for both varieties. As compared to the control treatment, the reduction reached 51% for Grand Slam Hygr plants grown in soil and 48% for plants grown in zeolitic tuff. A similar trend was observed for the effect of salinity on flower Wd. Significant reductions were reported in flowers Wd as it was 52% and 55% for Bizet Sagr as well as 48% and 58% for Grand Slam Hygr in plants grown at 8 dS.m-1 in soil and zeolitic tuff, respectively.

Flowers' length and diameter were also affected by salinity (Table 3). In general, flower length was decreased as the salinity level of irrigation water increased in both soil and zeolitic tuff. Flower length in Bizet Sagr plants was reduced from 53.93 to 23.77 cm and from 53.81 to 24.41 cm in response to increasing salinity from zero to 8 dS.m-1 once grown in soil and tuff, respectively. Flower length in Grand Slam Hygr was reduced from 52.90 to 27.42 cm and from 55.92 to 31.39 cm by subjecting plants to high salinity levels compared to the control treatment in soil and zeolitic tuff, respectively. Increasing salinity decreased significantly flower diameter for both Bizet Sagr and Grand Slam Hygr in both growing media (Table 3). After 4 days, plants of both varieties start losing their RFW significantly (Table 4). The highest RFW was recorded for the control treatment, while the lowest occurred at EC 8 dS.m-1. Loss in RFW was significant for shoots grown under EC of 2 dS.m-1 on days 7 and 10. For plants grown in zeolitic tuff, no significant differences were recorded by comparing shoots grown under EC of 2 dS.m-1 and 8 dS.m-1.

Effect of salinity on plants' physiological responses: SPAD, stomata resistance, chlorophyll fluorescence, and leaf RWC were significantly affected by salinity (Table 5). The highest chlorophyll content (SPAD) was obtained from Grand Slam Hygr grown in zeolitic tuff under control treatment. Increasing salinity levels in irrigation water caused a significant reduction in SPAD for both varieties in both growing media. This reduction reached 64% for Bizet Sagr grown in soil under a salinity level of 8 dS.m-1 (16.4) as compared to the control treatment (45.7). Plants grown in zeolitic tuff showed higher chlorophyll content than soil. Plants grown under EC of 8 dS.m-1 showed higher stomata resistance (6.17 and 5.0 s.cm-1 for Grand Slam Hygr grown in soil and zeolitic tuff, respectively). Stomata resistance varied between the two varieties in both growing media. The results showed that both varieties are grown in soil and zeolitic tuff has the highest fluorescence yield under control treatment. Increasing salinity level from 2 up to 8 dS.m-1 caused a significant reduction in fluorescence yield for both varieties grown in both media. Increasing salinity levels in water resulted in a significant reduction in RWC for plants grown under 8 dS.m-1. Subjecting plants are grown in soil and zeolitic tuff to high salinity level caused about 40% reduction in RWC when compared to control treatment.

Effects of salinity on plant mineral content: Ion concentrations of Na, Cl, K, P ,and N in the plant were significantly affected by salinity (Table 6). Na concentration in both varieties was significantly increased with increasing salinity levels. The highest concentration of Na was obtained in Grand Slam Hygr grown in zeolitic tuff when irrigated with the highest salinity level. However, Bizet Sagr showed higher Na concentration when planted in soil at a high salinity level, while Grand Slam Hygr had higher Na content in plants grown in zeolitic tuff at higher salinity levels. Increasing salinity level caused a significant increase in Cl concentration in plants of both tested varieties. Results showed that increasing salinity levels caused a significant decrease in K concentration for both plant varieties grown in both media. Bizet Sagr grown in the soil had the highest K concentration when irrigated with salinity level at EC of 8 dS.m-1, this reflected a 24% reduction when compared to the control treatment. A reduction of 25% and 22% for Bizet Sagr and Grand Slam Hygr, respectively, was recorded when plants are grown in zeolitic tuff. Increasing salinity level caused a significant reduction in P concentration in both varieties grown under both culturing media. Subjecting plants to the highest salinity level (8 dS.m-1) caused a 37% reduction in P concentration when compared to the control treatment. Results showed that subjecting both varieties to the highest salinity level caused a 45% and 47% reduction in N concentration in comparison to the control treatment for Bizet Sagr and Grand Slam Hygr, respectively, grown in soil, as well as 41% and 37% reduction, have grown in zeolitic tuff.

DISCUSSION

Salinity has a major effect on plant growth, development, and productivity. The responses to salinity vary not only among the different ornamental crops but also among the different plant varieties and organs. Depending on osmotic stress, some physiological changes may occur in stomatal resistance, transpiration, photosynthesis, root and leaf activity, and chlorophyll content (Kucukahmetler, 2000). Consequently, a reduction of flower quality and yield might be observed. These changes may permit their use as parameters in salt tolerance screening.

The current results indicated that the growth of D. caryophyllus decreased by increasing salinity, probably in response to limited cell expansion resulting from osmotic stress (Munns and Tester, 2008). A significant reduction in plant height in both varieties was reported as salinity levels in irrigation water increased. This finding is in agreement with Kotuby-Amacher et al. (2000) and Safi et al. (2006), in which they considered D. caryophyllus is a moderately tolerant plant that can tolerate up to 3 dS.m-1 in irrigation water. While Zapryanova and Atanassova (2009) found that D. caryophyllus can cope with salt levels up to 6 dS.m-1. Reductions in plant height were attributed to a reduction in the percentage of dividing cells with increasing salt concentration (Hossain et al., 2004). According to Ashraf et al. (2008), the reduction in plant growth may reflect the increase of metabolic energy needed to manage salt stress and reduce carbon gain due to the reduction in the rate of photosynthesis. Ghoulam et al. (2002) also reported that salt stress inhibits plant growth by causing water deficiency, reduction in metabolic activities, and nutrient deficiency due to salt ion toxicity.

The present results demonstrated that salt treatment significantly affected plant growth in terms of shoot FW and Wd. Increasing salinity level from zero to 8 dS.m-1 caused a significant reduction in FW of both tested varieties in both growing media. This reduction at the highest salinity level (8 dS.m-1) exceeded 58% for some tested plants as compared to the control treatment. According to Sharma and Hall (1992), the retardation of growth of plants is related to the impact of physiological activities and metabolism that results from water and nutrient stress occurring during salinity stress. In Petunia, shoot FW was reduced by 26% by using saline treatment (8 dS.m-1), and there was a reduction in both the number of leaves/plant and root size in comparison with the control plants (Safi et al., 2005). Moreover, Kafi et al. (2013) noticed a remarkable reduction in plant growth due to salinity stress. Additionally, root growth may also be inhibited due to higher external salt concentration by osmotic effects (Wild, 1988). Roots that absorb water and nutrients are always in direct contact with soil, thus, it is highly important to consider total root and shoot Wd to evaluate plant salt tolerance (Cassaniti et al., 2009; Rani et al., 2012).

Our results indicated that flower FW and DW were significantly reduced by increasing salinity level, which is in complete agreement with the findings of Garcia-Gomez et al. (2002) and Ahmad et al. (2013). 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). Flower stem length is a vital quality attribute of ornamental plants since it influences the economic value of the cut flower crops. Shoot elongation is the most sensitive growth process to water and salt stress (Wahome et al., 2000). Flower length and diameter were significantly reduced by increasing salinity level used up to 8 dS.m-1 compared to the control, which is agreed with Kucukahmetler (2000), who reported a reduction of flower size, stem thickness and length. Ahmad et al. (2013) explained the reasons for stem length and diameter reduction. According to their point of view, the presence of a high concentration of soluble salts in irrigation water blocks the vascular system and ultimately restricts water uptake. This results in water stress, which causes loss of cell turgidity and reduction in leaf expansion rates. This, in return, leads to a reduction in leaf area available for photosynthesis causing loss of stem length, stem diameter, and many losses in yield and quality. Also, it is pointed out that for carnations, high salt level up to 8 dS.m-1 reduced the number of blooms, but more frequently reduced the flower size and stem length. Plants are grown with 2.5 dS.m-1 substrates EC produced taller plants with higher flower yield plant (Ahmad et al., 2013). The results strongly indicate that not only flower production was affected by salinity, a delay of 28-38 days in flowering as a result of irrigation with highly saline water was also observed. These findings are in agreement with what was found by Fornes et al. (2007) as they noticed a strong reduction in growth and a delay in flowering in Calceolaria plants.

Keeping quality and length of vase life are important factors for the evaluation of cut flowers' quality for both domestic and export markets. Salinity decreased the vase life of cut flowers of D. caryophyllus used in this study. The plants had a slight reduction in the RFW on days 4, 7, and 10 in both growing media. Stomata resistance is used as a good non-destructive, rapid and easy physiological parameter to determine salt tolerance on plants subjected to different salinity levels. The impact of salinity stress on photosynthesis rate usually occurred through its effects on stomata function that depend on the type of salinity, duration of exposures, plant species, and stage of the plant growth (Flowers and Yeo, 1986). The current results indicated that stomata resistance was significantly increased with increasing salinity levels. These results are in agreement with Eisa et al. (2012), who showed that stomata resistance was dramatically increased with increasing salinity in irrigation water. It is considered as a physiological reaction that assists the plant to deal with salinity stress by closing its stomata to prevent the plant from facing instance physiological dehydration (Shahmersi et al., 2012).

Chlorophyll content of D. caryophyllus was significantly decreased with increasing salinity levels. Several studies indicated a reduction in chlorophyll content under salt stress (Fornes et al., 2007; Turan et al., 2009; Nawaz et al., 2010). Salinity stress reduces chlorophyll content through inhibition of chlorophyll synthesis and acceleration of chlorophyll degradation by chlorophyllase enzyme (Qasim et al., 2003). In general, a plant that possesses the highest RWC at salinity conditions can tolerate the toxic effects of salts during growth and developmental stages (Lee and Senadhira, 1998). Our results showed a significant reduction in RWC in response to the increased salinity level. In this regard, Cicek and Cakirlar (2002) studied the physiological response of maize to salinity level, and they found that RWC decreased after salt stress. Also, the current results indicated that chlorophyll fluorescence yield of D. caryophyllus decreased with increasing salinity levels. Chlorophyll fluorescence and chlorophyll degradation under salt-stressed conditions are important parameters to determine the pigment stability and photosynthesis activity in the leaf tissues (Chaum and Kirdmanee, 2009). The reduction in chlorophyll fluorescence with increased salt concentration may be attributed to the effect of the salt on the reaction centers of photosystem II or acceleration in leaf senescence (Lazar, 2006). Moreover, Redondo-Gomez et al. (2007) concluded that the decrease in chlorophyll fluorescence is due to impaired photosystem II and photochemical activity, which lead to damage in the functionality of the photosynthetic apparatus.

In our findings, zeolitic tuff was better than soil in the experiments. So, it is recommended to grow D. caryophyllus in zeolitic tuff rather than in soil medium when saline water is used for irrigation, which is in agreement with the findings of Safi et al. 2005. Ramesh et al. (2011) found that using zeolites is better due to their unique physical and chemical properties including ion exchange, dehydration-rehydration, and adsorption properties made them useful in agricultural applications and environmental engineering as zeolites were found to increase crop yield and to promote nutrient use efficiency. Furthermore, Abdi et al. (2006) reported that zeolite increased the rate of photosynthesis due to the availability of different elements and water for the plants.

Increasing salinity level caused a significant change in the mineral concentrations in both D. caryophyllus varieties and media. In this regard, Abdi et al. (2006) reported that the application of zeolite improved N efficiency in soil up to 16-22%. Also, zeolite had the potential to adsorb K from chemical fertilizers and reduce leaching, and be used as a slow-release K fertilizer. Chloride was shown to be related to the inhibition of photosynthesis under saline conditions (Garcia-Legaz et al., 1993). In our findings, D. caryophyllus accumulated less chloride in their leaves, which indicates a more tolerance to salinity. Our findings indicated that N concentration in plants decreased by 45-47% grown in soil. N and Mg are constituent elements of the chlorophyll molecule. Chlorophyll content was significantly correlated with the foliar N content in several studies, including some with ornamental plants (Wang et al., 2004). K has many important roles in plant tissues; it is important in osmotic stress, remediation of salt toxicity, and essential as enzymes activation in the cytosol (Ashraf et al., 2008). K content in tested plants was decreased. Bhatt et al. (2008) reported a decline in K concentration by increasing Na concentration in the growing media. Moreover, the presence of a significant concentration of NaCl in the growing medium accounts for a reduction in the uptake of K given the competition with Na for its transporters (Niu et al., 1995). P availability is reduced in saline soils because of the ionic strength effects and because P concentration is tightly controlled by sorption processes and by the low solubility of Ca-P minerals. Therefore, it is clear that P concentration in field-grown crops decreased as salinity increased (Sharpley et al., 1993). The accumulation of ions in the plant depends on the uptake of ions through selectivity of the cell membrane and subsequent through the loading of these ions in the xylem (El-Hendawy, 2004). Our data indicated that P content decreased by 64% relative to control treatment has grown in soil and 37% for plants grown in zeolitic tuff. Total P and total sulfur concentration most likely decreased because of the interaction of phosphates and sulfates with the increasing external concentration of Ca^{2+}, producing insoluble forms of phosphorus and sulfur (Grattan and Grieve, 1999).

In conclusion, increasing salinity inhibited D. caryophyllus growth and caused a decrease in plant height, fresh and dry yield, and relative water content as well as a change in the number of minerals in the plant tissues. An appropriate irrigation regime must be used as a key to success in ornamentals' growth control. Furthermore, using the correct varieties and culturing media which can adapt to salinity levels presented in the available water resources can be successfully produced economically feasible ornamental crops. Finally, it is preferred to use zeolitic tuff instead of soil as it may act as a slow-release K-fertilizer.

REFERENCES

Abacus Concepts. (1991). *supernova 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.

Al-Jayyousi, O.R. (2003). Scenarios for public-private partnerships in water management: A case study from Jordan. *Int. J. Water Resour. Dev., 19:* 185–201.

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. Pl. Res., 16:* 383–401.

Cabanero, F.J., Marti, V. and Carvajal, M. (2004). Does calcium determine water uptake under saline conditions in pepper plants or is it water flux that determines calcium uptake? *Pl. Sci., 166:* 443–450.

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

Chaum, S. and Kirdmanee, C. (2009). Effect of salt stress on proline accumulation, photosynthetic ability, and growth characters of two maize cultivars. *Pak. J. Bot., 41:* 87–98.

Cicek, N. and Cakirlar, H. (2002). The effect of salinity on some physiological parameters in two maize cultivars. *Bulg. J. Pl. Physiol., 28:* 66–74.

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.

El-Hendawy, S. (2004). *Salinity tolerance in Egyptian spring wheat genotypes.* Ph.D. Thesis, Dept. Pflwiss., Tech. Univ., München, Germany, pp 118.

Flowers, T.J. and Yeo, A.R. (1986). In relations to the plant under drought and salinity. Aust. *J. Pl. Physiol., 13:* 75–91.

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.

Garcia-Gomez, A., Bernal, M.P. and Roig, A. (2002). Growth of ornamental plants in two composts prepared from agro-industrial wastes. *Bioresour.Technol., 83:* 81–87.

Garcia-Legaz, M.F., Ortiz, J.M., Garcilidon, A. and Cerda, A. (1993). Effect of salinity on growth, ion content, and CO2 assimilation rate in lemon varieties on different rootstocks. *Physiol. Plantarum, 89:* 427–432.

Ghoulam, C., Foursy, A. and Fores, K. (2002). Effect of salt stress on growth, inorganic ions, and proline accumulation in relation to osmotic adjustment in five sugar beet cultivars*. Environ. Exp. Bot., 47*: 39–50.

Grattan, S.R. and Grieve, C.M. (1999). Mineral nutrient acquisition and response by plants grown in saline environments*. Handb. Pl. Crop Stress, 2:*203–229.

Hossain, Z., Mandal, A.K.A., Shukla, R. and Datta, S.K. (2004). NaCl stress: Its chromotoxic effects and antioxidant behavior in roots of Chrysanthemum morifolium Ramat. *Pl. Sci., 166*:215–220.

Jordan Statistical Yearbook. (2016). Department of Statistics, Amman Agricultural Surveys, Jordan, No. 67, pp 282.

Kafi, M., Jafari, M.H. and Moayedi, A. (2013). The sensitivity of grain sorghum Sorghum bicolor L. developmental stages to salinity stress: An integrated approach. J*. Agric. Sci. Technol., 15:* 723–736.

Kotuby-Amacher, J., Koenig, R. and Kitchen, B. (2000). Salinity and plant tolerance. Utah State Univ.Extension, USA, Publication No. 43, pp 8.

Kucukahmetler, O. (2000). The effects of salinity on yield and quality of ornamental plants and cut flowers. Proc. Int. Symp. *Techniques to control salination for horticulture productivity, 573*: 407–414.

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

Lee, S.Y. and Senadhira, D. (1998). Salinity tolerance of progenies between Korean cultivars and IRR's new plant type lines in rice*. Kor. J. Crop Sci., 43:* 234–238.

Martinez, P.M., C.A. Cortes and Avila, G.E. (2004). Evaluation of three pigment levels of marigold petals *Tagetes erecta* on skin pigmentation of broiler chicken. Technol. Pecu. Mex., 42: 105–111.

McCammon, T.A., Marquart-Pyatt, S.T. and Kopp, K.L. (2009). Water-conserving landscapes: An evaluation of homeowner preference. *J. Extension, 47:* 1–10.

Mohsen, S. (2007).Water strategies and potential of desalination in Jordan. *Desalination, 203:* 27–46.

Munns, R. and Tester, M. (2008). Mechanisms of salinity tolerance*. Annu. Rev. Pl. 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.

Navarro, J.M., Garrido, C., Martinez, V. and Carvajal, M. (2003).Water relations and xylem transport of nutrients in pepper plants grown under two different salts stress regimes. *Pl. Grow. Regul., 41:* 237–245.

Nawaz, K., Talat, A., Hussain, K. and Majeed, A. (2010). Induction of salt tolerance in two cultivars of sorghum Sorghum bicolor L. by exogenous application of proline at the seedling stage. *World Appl. Sci. J., 10:* 93–99.

Niu, X., Bressan, R.A., Hasegawa, P.M. and Pardo, J.M. (1995). Ion homeostasis in NaCl stress environments. *Pl. Physiol., 109:* 735–742.

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

Niu, G. and Rodriguez, D. (2010). Response of bedding plants to saline water irrigation. *Hort. Sci.,45:* 628–636.

Owais, S.J., Abdel-Ghani, A.H., Ghrair, A.M., Al-Dalain, S.A. and AlMajali, N. (2013). Effect of natural Jordanian volcanic tuff on growth, irrigation water saving, and leaves mineral content of Salvia officinalis. *Jor. J. Agric. Sci., 9:* 439–456.

Qasim, M.M., Ashraf, M.A., Jamil, M.Y., Ashraf, S.U. and Rha, E.S. (2003). Water relation and leaf gas exchange prosperities in some elite canola lines under salt stress. *Ann. Appl. Biol., 142:* 307–316.

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

Rani, C.R., Reema, C., Alka, S. and Singh, P.K. (2012).Salt tolerance of Sorghum bicolor cultivars during germination and seedling growth. Res. *J. Recent Sci., 1:* 1–10.

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.

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.

Safi, M.I., Fardous, A., Muddaber, M., El-Zuraiqi, S., Al-Hadidi, L., and Bashabsheh, I. (2006). Chemical effect of reclaimed water on soil and carnation tissue planted in soil and tuff media. Bulg. *J. Agric. Sci., 12:* 559–569.

Shahmersi, A.F., Ebadi, A., Kandi, M.A. and Sanayei, S. (2012). The mineral nitrogen fertilizer affects the photosynthetic index of alfalfa Medicago sativa under salinity stress conditions. Int. Res. *J. Appl. Basic Sci., 3:* 1641–1645.

Sharma, P.K. and Hall, D.O. (1992). Changes in carotenoid composition and photosynthesis in sorghum under high light and salt stresses. *J. Pl. Physiol., 140:* 661–666.

Sharpley, A.N., Daniel, T.C. and Edwards, D.R. (1993). Phosphorus movement in the landscape. *J. Prod. Agric., 6:* 492–500.

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.* (2nd Edn.), Dordrecht Kluwer Acad. Publ., pp 180.

Turan, M., Elkarim, A., Taban, N. and Taban, S. (2009). Effect of salt stress on growth, stomata resistance, proline, and chlorophyll concentrations on maize plant.Afr. *J. Agric. Res., 4:* 893–897.

Wahome, P.K., Jesch, H.H. and Grittner, I. (2000). Effect of NaCl on the vegetative growth and flower quality of roses. *Angew. Bot., 74:* 38–41.

Wang, Q., Chen, J., Stamps, R. and Li, Y. (2004). Correlation of visual quality grading and SPAD reading of green-leaved foliage plants. *J. Pl. Nutr., 28:* 1215–1225.

Wild, A. (1988). *Russell's soil conditions and plant growth*. (11th Edn.), Longman, Harlow, pp 991.

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

Zar, J.H. (1999). *Bio-statistical analysis*. (4th Edn.) Prentice-Hall, Upper Saddle River, NJ. pp 663.

.

Appendices

Table 1. Plant height (cm) and plant fresh and dry weights (g/plant) for two Dianthus caryophyllusvarieties grown at different salinity levels in soil and zeolitic tuff.

	EC	Plant height		Fresh weight		Dry weight	
	dS.m-1	Soil	Z. tuff	Soil	Z. tuff	Soil	Z. tuff
Bizet Sagr	0	69.2a	81.9a	52.7a	51.5a	14.5a	10.6a
	2	65.2b	72.0b	47.7b	46.8b	11.7ab	8.70b
	4	59.5c	66.5bc	43.5c	43.1c	9.6bc	7.40c
	6	55.7d	61.3c	37.4d	38.1d	8.3bc	6.50d
	8	50.7e	52.4d	30.4e	28.1e	6.9c	5.00e
	Mean	60.1	66.8	42.0	41.5	10.1	7.60
Grand Slam Hygr	0	74.1a	85.7a	54.1a	53.3a	11.5a	10.8a
	2	71.4a	80.6a	46.7b	48.1b	9.7ab	8.70b
	4	65.0b	69.9b	39.9c	43.5c	8.0bc	7.70c
	6	58.0c	62.4c	31.6d	35.8d	7.8bc	6.40d
	8	50.3d	57.5c	23.5e	25.4e	6.2c	5.10e
	Mean	63.8	71.2	38.8	41.2	8.6	7.70

Means within the same column and variety followed by the same letter are not significantly different at p≤0.5.

Table 2. Days to flowering and flower fresh and dry weight (g/plant) for two Dianthus caryophyllusvarieties grown at different salinity levels in soil and zeolitic tuff.

	EC	Days to flowering		Fresh weight		Dry weight	
	dS.m-1	Soil	Z. tuff	Soil	Z. tuff	Soil	Z. tuff
Bizet Sagr	0	160.40e	166.80d	31.61a	31.21a	8.11a	7.99a
	2	170.20d	172.40c	25.87b	24.91b	6.91b	6.14b
	4	181.20c	182.00b	22.60c	21.05c	5.41c	5.52bc
	6	192.00b	192.80a	19.24d	17.84d	4.68c	4.87c
	8	197.40a	196.80a	15.74e	15.41e	3.63d	3.80d
	Mean	180.24	182.16	22.56	22.08	5.62	5.66
Grand Slam Hygr	0	156.80a	166.00e	29.95a	28.53a	7.82a	8.63a
	2	133.20a	170.40d	25.09b	25.86b	6.47b	6.03b
	4	172.80a	177.20c	21.44c	22.40c	5.65b	4.96c
	6	181.40a	183.60b	19.09d	19.28d	5.67b	4.88c
	8	195.80a	191.40a	14.64e	14.82e	4.03c	3.61d
	Mean	168.00	177.72	21.93	22.18	5.92	5.62

Means within the same column and variety followed by the same letter are not significantly different at p≤0.5

Table 3. Flower length and diameter (mm) for two Dianthus caryophyllusvarieties grown at different salinity levels in soil and zeolitic tuff.

	EC	Flower length		Flower diameter	
	dS.m-1	Soil	Z. tuff	Soil	Z. tuff
Bizet Sagr	0	53.93a	53.81a	51.11a	52.24a
	2	43.57b	45.68b	44.96b	46.65b
	4	38.55c	38.28c	36.87c	43.21c
	6	31.88d	32.33d	34.05d	36.22d
	8	23.77e	24.41e	30.38e	31.79e
	Mean	38.34	38.90	39.47	42.02
Grand Slam Hygr	0	52.90a	55.92a	51.81a	51.90a
	2	44.57b	47.88b	46.41b	47.43b
	4	37.86c	42.43c	38.03c	35.02c
	6	33.74d	37.86d	31.17d	24.84d
	8	27.42e	31.39e	27.11e	23.02d
	Mean	39.08	43.10	38.59	36.44

Means within the same column and variety followed by the same letter are not significantly different at $p \leq 0.5$.

Table 4. Relative fresh weight (g/plant) for two Dianthus caryophyllusvarieties plants grown at different salinity levels in soil and zeolitic tuff.

			EC dS.m-1					
Bizet Sagr			0	2	4	6	8	Mean
	Soil	RFW1	100a	100a	100a	100a	100a	100
		RFW4	126a	119ab	114bc	108bc	103c	114
		RFW7	113a	107ab	98ab	91b	85b	99
		RFW10	101a	93ab	77ab	77b	74b	84
		RFW14	82a	72a	68a	63a	56a	68
	Z. tuff	RFW1	100a	100a	100a	100a	100a	100
		RFW4	125a	117a	115a	111a	128a	119
		RFW7	124a	118a	108a	98a	91a	108
		RFW10	118a	107a	97a	92a	86a	100
		RFW14	82a	71a	66a	59a	51a	68
Grand Slam Hygr			0	71a 2	4	6	8	mean
	Soil	RFW1	100a	100a	100a	100a	100a	100
		RFW4	123a	117a	113a	113a	103a	114
		RFW7	116a	110b	104b	96c	91c	104

		RFW10	101a	84b	85b	82bc	74c	85
		RFW14	73a	68ab	62ab	60ab	54b	64
	Z. tuff	RFW1	100a	100a	100a	100a	100a	100
		RFW4	147a	122b	120b	116b	112b	123
		RFW7	138a	130b	121b	118b	108b	123
		RFW10	126a	113a	102a	93a	87a	104
		RFW14	93a	80b	73b	66b	54b	74

Means within the same row and variety followed by the same letter are not significantly different at p≤0.5.

Table 5. Leaf greenness (SPAD), stomata resistance (s.cm-1), chlorophyll fluorescence **and relative water content (RWC) for two Dianthus caryophyllus varieties grown at different salinity levels in soil and zeolitic tuff.**

	EC	**SPAD**		**Stomatal resistance**		**Chlorophyll fluorescence**		**RWC**	
	dS.m-1	Soil	Z. tuff	Soil	Z. tuff	Soil	Z. tuff	Soil	Z. tuff
Bizet Sagr	0	45.7a	73.9a	1.76d	1.47d	0.74a	0.76a	88.00a	86.97a
	2	41.4b	64.2b	3.31c	2.80c	0.67b	0.67b	80.52b	77.40b
	4	32.9c	56.4c	4.08bc	3.51bc	0.62c	0.63bc	72.41c	68.39c
	6	24.5d	51.2d	4.50b	4.09b	0.61c	0.61c	64.71d	61.81d
	8	16.4e	46.4e	5.92a	5.25a	0.54d	0.54d	53.20e	52.90e
	Mean	32.2	58.4	3.91	3.43	0.64	0.64	71.77	69.49
Grand Slam Hygr	0	48.4a	77.7a	1.97c	1.57c	0.73a	0.76a	88.57a	85.11a
	2	43.0b	70.4b	3.74b	3.04b	0.68b	0.66b	78.30b	79.72b
	4	36.2c	64.1c	4.01b	3.60b	0.62c	0.63bc	70.76c	71.85c
	6	26.9d	58.0d	5.23a	3.94b	0.61c	0.61c	63.63d	64.36d
	8	15.5e	45.7e	6.17a	5.00a	0.53d	0.54d	54.45e	49.83e
	Mean	34.0	63.2	4.22	3.43	0.63	0.64	71.14	70.17

Means within the same column and variety followed by the same letter are not significantly different at p≤0.5.

Table 6. Mineral concentration (%) in two Dianthus caryophyllus varieties grown at different salinity levels in a greenhouse.

	EC	**Na**		**Cl**		**K**		**P**		**N**	
	$dS.m^{-1}$	Soil	Z. tuff	Soil	Z. tuff	Soil	Z. tuff	Soil	Z. tuff	Soil	Z. tuff
Bizet Sagr	0	1.75e	1.40e	0.98e	0.79e	1.73a	1.47a	0.58a	0.54a	2.53a	1.88a
	2	1.93d	1.75d	1.08d	0.98d	1.63b	1.34b	0.54b	0.50a	1.81ab	1.55b
	4	2.29c	2.26c	1.28c	1.22c	1.50c	1.22c	0.44c	0.45b	1.88b	1.42c

	6	2.80b	3.00b	1.57b	1.68b	1.42d	1.18c	0.34d	0.40b	1.58b	1.31d
	8	3.37a	3.31a	1.89a	1.85a	1.32e	1.10d	0.21e	0.34c	1.40b	1.11e
	Mean	2.43	2.34	1.36	1.3	1.52	1.26	0.42	0.45	1.84	1.45
Grand Slam Hygr	0	1.69e	2.43e	0.94e	1.36e	1.44a	1.39a	0.78a	0.69a	1.52a	1.62a
	2	2.16d	2.96d	1.21d	1.65d	1.31b	1.33b	0.67b	0.64ab	1.22b	1.43b
	4	2.69c	3.36c	1.50c	1.88c	1.23c	1.26c	0.60bc	0.59bc	1.08c	1.31c
	6	3.50b	3.66b	1.96b	2.05b	1.17d	1.19d	0.53cd	0.54c	0.97d	1.11d
	8	3.72a	3.86a	2.08a	2.16a	1.10e	1.09e	0.49d	0.46d	0.80e	1.01e
	Mean	2.75	3.25	1.54	1.82	1.25	1.25	0.61	0.51	1.12	1.29

Means within the same column and variety followed by the same letter are not significantly different at $p \leq 0.5$.

دراسة تأثير ملوحة مياه الري و أوساط زراعية على النمو والعمليات الفسيولوجية وتركيز العناصر الغذائية لنبات القرنفل الوردي Dianthus caryophyllus

رشا عمارين[1]*، عمر كفاوين[2]، جمال عياد[3]، فراس الزيود[4]، ألاء غيظان[5]

[1] دكتوراة في البستنة، المركز الوطني للبحوث الزراعية, الأردن.

[2] أستاذ علم النبات، قسم البستنة والمحاصيل، كلية الزراعة، الجامعة الأردنية، عمان، الأردن.

[3] أستاذ فسيولوجيا النبات، قسم البستنة والمحاصيل، كلية الزراعة، الجامعة الأردنية، عمان، الأردن.

[4] أستاذ علم المكافحة الحيوية والمتكاملة للآفات، كلية الزراعة، جامعة مؤتة، الكرك، الأردن.

[5] دكتوراه في وقاية النبات، عمان، الأردن.

تاريخ استلام البحث 2020/6/5 وتاريخ قبوله 2020/12/27.

ملخص

تُعدُّ ملوحة التربة احدى العوامل البيئية الرئيسية التي تحد من نمو النبات وتطوره، وتعتبر مشكلة في المناطق الجافة وشبه الجافة، حيث هطول الامطار غير كاف لترشيح الاملاح، ويعتبر القرنفل الوردي *Dianthus caryophyllus L.* من المنتجات الرئيسية في الأردن ولديه احتياجات ري مختلفة وقدرة على التأقلم مع نقص المياه، وبالتالي، وعليه يهدف البحث الحالي إلى دراسة تأثير الري بمستويات مختلفة من الملوحة على النمو و بعض العمليات الفسيولوجية والعناصر المعدنية لنوعين من القرنفل (*Bizet Sagr* و *Grand Slam Hygr*). أجريت التجارب تحت ظروف البيوت الزجاجية في الجامعة الأردنية خلال موسم النمو 2016/2015. وتمت زراعة النباتات اما في التربة او الطوف الايزوليتي بخمسة مستويات ملوحة مختلفة. وأشارت النتائج إلى أنَّ النمو لكلا النوعين من القرنقل الوردي يختلف اختلافًا معنويا باختلاف مستويات الملوحة المختلفة في كلا الوسطين، وأدت زيادة الملوحة إلى انخفاض معنوي في طول النبات، والوزن الرطب والجاف، وقطر الزهرة، وتأخر وقت الإزهار. وأدى ارتفاع مستوى الملوحة أيضًا إلى انخفاض معنوي في اخضرار الورقة ولمعانها، ونسبة المحتوى المائي، وزيادة مقاومة الثغور لكلا الصنفين من النبات في كل من وسطي النمو. وأدى ارتفاع مستوى الملوحة إلى زيادة معنوية في تركيز الصوديوم والكلوريد وانخفاض في تراكيز البوتاسيوم والفوسفور والنيتروجين في النباتات في كلا الصنفين والوسطين، وفي الخلاصة، فان الملوحة أحدثت تأثيراً معنوياً على النمو، وجميع المعالم الفسيولوجية والمعدنية التي تم قياسها في التجربة لنبات القرنفل الوردي. ولذا يجب استخدام نظام ري مناسب كمفتاح للنجاح في تنظيم نمو نباتات الزينة.

الكلمات الدالة: القرنفل الوردي، الملوحة، وسط النمو، التوف الصخري، النمو.