THE INFLUENCE OF SPRAYING WITH POTASSIUM SILICATE AND IRRIGATION WITH SALINE WATER IN SANDY SOIL ON Calendula officinalis L.

Attia, K. E. 1 and Naglaa F. S. Elbohy 2
1- Medicinal and Aromatic Plants Research Dept., Hortic. Research Institute, ARC., Egypt.
2- Ornamental Plants and Landscape Gardening Research Dept., Hortic. Research Institute, ARC., Egypt.

ABSTRACT

Two pots experiments were conducted at the Experimental Farm of El-Qassassin Horticultural Research Station, Agricultural Research Center, Ismailia Governorate, Egypt, during two successive seasons of 2016/2017 – 2017/2018, to investigate the effect of potassium silicate at (0, 4, 6, and 8 cm3/l) as a foliar spray under different levels of water salinity (tap water, 1000, 2000 and 3000 ppm) on Calendula officinalis L. plant. The experiment was performed in complete randomized block design as factorial experiment with 3 replicates. The obtained results cleared that using salinity levels decreased growth parameters (plant height, number of branches/plant, fresh and dry weights of herb/plant), flowering parameters (flower diameter, number of flowers/plant, fresh and dry weight of flowers (g/plant)) during eight cuts and fresh and dry weight of flowers (g/plant/season)) and chemical constituents (chlorophyll a, chlorophyll b, carbohydrate and carotenoid contents) compared to control. Moreover, the highest values in these parameters were registered by potassium silicate at 8 cm3/l concentration. Proline content increased in leaves with using saline water at 3000 ppm + potassium silicate at 8 cm3/l. Generally, it could be concluded that potassium silicate at 8 cm3/l, showed a uniform impact in alleviating inhibition of Calendula officinalis L. plant growth and productivity under moderate salinity stress condition.

Key words: Calendula officinalis L., potassium silicate, salinity and Proline.

INTRODUCTION

Calendula officinalis, commonly known as marigold is a member of Family Asteraceae, it is originated from Mediterranean countries, Eastern and Southern Europe and cultivated commonly in North America, Eastern Europe, Germany and India (Rigane et al., 2013). It is an erect, annual herbaceous aromatic plant, grows up to 60 cm in height with angular and glandular stems; flower-heads terminal, light yellow to deep orange; achenes 1.0-1.5 cm long, boat-shaped, faintly ribbed (Khan et al., 2011). The main constituents of marigold are carbohydrates, phenolic compounds, lipids, steroids, terpenoids, tocopherols, carotenoids, quinones and vitamin C (Shahrbabaki et al., 2013). Pot marigold was grown as an ornamental plant and for its importance as blood refiner, blood sugar reduce, anti-inflammatory, skin antifungal and antiviral properties (Mohammad and Kashani, 2012).

All over the world, abiotic stresses are considered as main causes of crop loss. Abiotic stresses such as salinity, drought or high temperature adversely affect plant growth and yield. Salinity is one of the serious abiotic stresses causing serious decline in the production of different plants (Sadak and Dawood, 2014).

Salinity affects all the major physiological and biochemical processes that regulate growth such as photosynthesis, protein synthesis, and lipid metabolism etc., salt induced reduction in growth is generally attributable to: (i) salt-induced osmotic...
stress (water deficit), (ii) specific ion effect, (iii) nutritional imbalance, (iv) hormonal imbalance, and salt-induced oxidative stress. Salinity reduces nutrients availability, it reduces its transport to the growing regions of the plant, thereby affecting the quality of both vegetative and reproductive organs. Several of the research results are reviewed in this trend (Munns and Tester, 2008).

Saline water as seawater was considered unsuitable for plant irrigation but recently, it could be used for irrigation under certain conditions (Zeid, 2011). Salinity stress causes many changes in the different metabolic and biochemical processes in plant cells, depending on the severity and the duration of this stress, thus finally results in decline of different crop production. Osmotic stress is the first effect that represses plant growth followed by ion toxicity (James et al., 2011).

Potassium is a major plant nutrient and plays an essential role in a variety of physiological processes, i.e. photosynthesis, protein synthesis and maintenance of water status in plant tissues (Marschner, 2012).

Silicon is reported that it reduces multiple stresses including biotic and abiotic stresses in plants by maintaining plant water potential, photosynthetic activity, stomatal conductance and leaf erectness under high transpiration rates (Crusciol et al., 2009; Saud et al., 2014; Shaaban and Abou El-Nour, 2014 and Das et al., 2017). Also, silicon (Si) is not considered an essential plant nutrient; however, several plant species demonstrate improved disease resistance, abiotic stress tolerance, and altered morphological traits when Si is present (Epstein, 1999). The beneficial effects of Si, direct or indirect, to plants under abiotic and/or biotic stress have been reported to occur in a wide variety of plants by increasing plant resistance to lodging, increasing the activity of some enzymes involved in the photosynthesis which promote greater photosynthetic activity in plants grown under different stresses, as well as reducing the availability of toxic elements such as Mn, Fe and Al to roots of plants and increases plants resistance to salt stress, therefore, Si recognized as a beneficial element required for plant unless it is not defined until now as either macro or micro nutrient essential element (Ma, 2004).

Potassium silicate is a source of highly soluble potassium and silicon, so it is used in agricultural production system primarily as a silicon amendment source and has utilized of supplying small amounts of potassium to help improve the quality of yield (Tarabih et al., 2014). Also, Bayat et al. (2013) studied the effect of foliage spraying of silicon (Si) on growth and ornamental characteristics of calendula grown under salt stress and greenhouse conditions. These results suggest that the negative effects of salinity on the growth and ornamental characteristics of calendula plants could be ameliorated by foliar application of Si treatments.

This investigation was carried out to evaluate the influence of different levels of foliar-applied potassium silicate on vegetative growth, flowering and chemical compositions of Calendula officinalis L. under irrigation with saline water.

MATERIALS AND METHODS

Two pots experiments were conducted in the Experimental Farm of El-Qassasin Horticultural Research Station, Agricultural Research Center, Ismailia Governorate, Egypt, during the two successive seasons (2016/2017 and 2017/2018) to study the response of Calendula officinalis L. to spraying with potassium silicate on plant tolerance of salinity.
The soil of the experimental site was sandy. The investigated soil characterized by 78.6 and 79.5% coarse sand, 9.3 and 8.4% fine sand, 6.5 and 7.6% silt, 5.6 and 4.5% clay, pH 7.4 and 7.3, EC 1.5 and 1.4 dSm⁻¹, K⁺ 0.4 and 0.6, Na⁺ 5.3 and 5.1, Ca²⁺ 3.6 and 3.9, Mg²⁺ 1.7 and 1.5, CO₃²⁻ 0 and 0, HCO₃⁻ 2.3 and 3.6, Cl⁻ 4.8 and 4.1, SO₄²⁻ 4.2 and 3.6 meqL⁻¹ and 0.07% and 0.09 organic matter in the 1st and 2nd seasons, respectively. The physical and chemical properties of the soil were determined according to Jackson (1973).

*Calendula officinalis* L. seeds were secured from Medicinal and Aromatic plants Research Department, Horticulture Research Institute, ARC., Egypt.

Seeds were sown in the land of the nursery on 15th Sept. in both seasons. After 45 days from planting (on Nov 1st in both seasons) when the seedlings had grown to approximately 10 cm in height and formed six leaves, they were transplanted into pots (one plant/30 cm diameter pot) filled with 12 kg of sandy soil.

Four salinity levels were prepared [control (irrigation with tap water), 1000, 2000 and 3000 ppm] by seawater obtained from Suez Canal in Ismailia region. One liter of water was added to each pot twice a week during the growing season (6 months). The chemical analysis of seawater obtained from Suez Canal is shown in Table (1).

Table 1. Chemical properties of sea water used

| EC ppm | Anions ppm | Cations ppm |
|--------|------------|-------------|
| CO₃⁻   | HCO₃⁻      | Cl⁻         |
| 39347  | 7.62       | 365.63      |
| SO₄²⁻  | Ca²⁺       | Mg²⁺        |
| 86.02  | 59.2       | 36.8        |
| Na⁺    | K⁺         |             |
| 348.1  | 9.76       |             |

Seedlings were foliar sprayed till runoff with different concentrations of potassium silicate in equal doses (0, 4, 6 and 8 cm³/L). Three applications were made after 50, 70 and 90 days from transplanting; in this regard the first one was done on 20th December in both seasons. (potassium silicate contents: K₂O 10% and Si₂O₃ 25%)

The experiments were performed in complete randomized block design as factorial experiment with 3 replicates, each replicate contained 10 pots with one plant/pot. The experiment included 16 treatment combination of four salinity levels, and four concentrations of potassium silicate. Each pot was fertilized twice with 4.0 g nitrogen as ammonium nitrate (33.5 % N) and 6.5 g calcium super phosphate (15% P₂O₅) and 4.0 g potassium sulphate (48.5 K₂O) per pot. These fertilizers were applied after 30 and 60 days from transplanting.

**Data recorded:** the obtained data in this study were recorded as follows:

**Vegetative characters:**

Three plants were randomly taken from each treatment at 95 days from transplanting to evaluate the following vegetative growth characters:

1- Plant height (cm).
2- Number of branches/plant.
3- Fresh and dry weights of herb (g/plant).

**Floral characters:**

The flowers were weekly collected starting from the beginning of 1st March till 1st May in both seasons.

The flower heads were collected manually, when the petals were found in a horizontal position (*Vieira et al.*, 2006), and cut 8 times per season and the following data were recorded:

1- Inflorescence diameter (cm) in the first cut only.
2- Number of flowers/plant in the first cut only.
3- Fresh and dry weights of flowers (g/plant) were determined in each cut.
4- Fresh and dry yield of flowers (g/plant/season). (The sum of fresh and dry weights of flowers (g)/plant during 8 cuts in the season).

Chemical analysis:
1- Chlorophyll a and b contents (mg/g f.w.) in the leaves were determined at the middle of March in both seasons according to the procedure described by Mazumdar and Majumder (2003).

2- Total B carotene contents were determined in each dried flower head per plant (mg/g) according to Britton et al. (1995).

3- Total carbohydrates % (d.w.) was determined in dry leaves according to Herbert et al. (2005).

4- Proline content (μ mole g⁻¹ dry weight) was determined in dry leaves during three flowering using the method of Bates et al. (1973).

Statistical analysis:

The statistical analysis of the present data was carried out according to Steel and Torrie (1980) using L.S.D. at 5 and 1% levels for comparison between means of the different treatments.

RESULTS AND DISCUSSION

1. Vegetative characters:

Data presented in Table (2), show the effect of saline water on vegetative growth characters of Calendula officinalis L. plants expressed as, plant height, No. of branches per plant, fresh weight of herb (g)/plant and dry weight of herb (g)/plant. It is clear from data that, all growth characters were markedly reduced by increasing saline water level in irrigation water, such data reveal that using tap water significantly increased all the different vegetative growth parameters during both seasons of growth followed by irrigation with 1000 ppm. On the contrary, the lowest values in all measured growth traits were recorded in case of irrigation with saline water at a rate of 3000 ppm during both seasons of study. Reduction in vegetative parameters may ensue from the plants inability to adjust somatically, counteraction toxicities or related disruptive phenomena or from the excessive energy demand placed upon the metabolic machinery required by such homeostatic systems (Greenway and Munns 1980). These results are in agreement with those obtained by Nofal et al. (2015) on Calendula officinalis L. and Khorasaninejad et al. (2015) on Mentha piperita L.

Regarding foliar application of potassium silicate, it is clear from the same data in Table (2) that, spraying marigold plants with potassium silicate significantly increased plant height, no. of branches, fresh weight of herb (g)/plant and dry weight of herb (g)/plant as compared to control treatment. Foliar application of potassium silicate at 8cm³/l gave the significantly highest increases in vegetative parameters. while the lowest values were obtained at foliar application of potassium silicate at 0 cm³/l. Similar trend was found in other characters. Many researchers mentioned the role of silicon in plant resistance to both biotic and abiotic stresses including salinity (Adatia and Besford, 1986 and Crusciol et al., 2009). These results are in agreement with those obtained by Tarabih et al., (2014).

Concerning the combination between saline water levels and foliar application with potassium silicate, the data in Table 2 show that, there were significant differences among most of the interaction treatments on all studied vegetative characters. In general, the combination between irrigation with tap water and foliar application with potassium silicate at 8cm³/l gave the highest values of vegetative growth parameters during both seasons of growth. On the other side the lowest values in this respect were recorded by the combination between irrigation with saline water at3000 ppm and foliar application with
zero potassium silicate, these results are true in both seasons of study.

2- Floral characters:

2-1: Flower diameter (cm)/plant and number of flowers/plant:

As shown in Table (3), using salinity treatments significantly decreased flower diameter (cm)/plant and number of flowers/plant of *Calendula officinalis* L. compared to control in both seasons. In the same time, flower diameter (cm)/plant and number of flowers/plant were decreased with increasing of the levels of salinity to reach minimum by using that of 3000 ppm. These results are in agreement with those obtained by Roodbari et al. (2013) on *Mentha piperita* and Khaliq et al. (2014) on *Ocimum basilicum*.

Furthermore, in most cases, potassium silicate treatments significantly increased flower diameter (cm)/plant and number of flowers/plant of *Calendula officinalis* L. compared to untreated plants in the two seasons. Potassium silicate at 8 cm$^3$/l significantly increased flower diameter (cm)/plant and number of flowers/plant compared to control and the other ones under study. This result confirmed the findings reported earlier by Bayat et al (2013) on *Calendula officinalis* L.

In addition, the interaction between salinity and potassium silicate decreased flower diameter (cm)/plant and number of flowers/plant comparing to control. Also, using 8 cm$^3$/L potassium silicate increased flower diameter (cm)/plant and number of flowers/plant in comparison to the salinized plants under the same levels alone in the two seasons.

2-2: Fresh and dry weight of flowers (g)/plant during eight cuts:

Data illustrated in Tables (4-7) reveal that, salinity treatments generally decreased fresh and dry weight of flowers (g)/*Calendula officinalis* L. plant during eight cuts compared to control. This decrease was significant with the levels of 2000 and 3000 ppm. Also, the fresh and dry weight of flowers (g)/plant were decreased as the salinity levels increased up to 3000 ppm. These results may be due to salt-induced water stress reduction of chloroplast stoma volume and regeneration of reactive oxygen species in playing an important role in the inhibition of photosynthesis seen in salt stressed plants (Price and Hendry, 1991 and Allen, 1995). Similar results were obtained by Hashish et al. (2015) on *Calendula officinalis* L.

All potassium silicate rates increased fresh and dry weight of flowers (g)/plant of *Calendula officinalis* L. during eight cuts compared to control in both seasons. Such increase was significant by using the rates of 6 and 8 cm$^3$/l potassium silicate. These results are in line with those reported by Bayat et al (2013) on calendula plants.

Generally, fresh and dry weight of flowers (g)/plant of *Calendula officinalis* L. during eight cuts significantly increased by using 6 and 8 cm$^3$/l potassium silicate under salinity levels as compared to salinity treatments alone.

2-3: Fresh and dry yield of flowers (g)/plant.

Data presented in Table (8) suggest that, using salinity treatments significantly decreased fresh and dry yield of flowers (g) of *Calendula officinalis* L. compared to control in both seasons. Such decrease might be due to the disturbance in anabolic activities, affected by the decrease in water absorption and/or disturbance of minerals balance or absorption and utilization caused by salinity treatments (Hamad, 1996). These results confirmed the findings reported
earlier by Hashish et al. (2015) on *Calendula officinalis* L.

However, 6 and 8 cm³/l potassium silicate significantly increased fresh and dry yield of flowers (g/plant) of *Calendula officinalis* L. compared to control in both seasons. The highest yields were obtained from the treatment of 8 cm³/l which yielded 196.8 and 33.09 g/plant/season in the first season, and 219.9 and 34.76 g/plant/season in the second one, from fresh and dry yield of flowers (g/plant/season, respectively. The advantages of increasing potassium silicate on enhancing plant growth have been previously reported by Tarabih et al., (2014).

Also, the best combination treatment was tap water followed by 1000 ppm of salinity and 8 cm³/l potassium silicate in comparison with the other combinations between salinity levels and potassium silicate rates under study in both seasons. The combined treatment of 8 cm³/l potassium silicate under 1000 ppm salinity raised fresh and dry yields of flowers (g/plant/season over 1000 ppm alone by 30.8 and 28.4% the first season, and by 26.6 and 25.2% the second one, respectively.

### 3-Chemical analysis:

#### 3-1: Chlorophyll a and b (mg/g fresh wt.):

Data listed in Table (9) suggest that, using salinity treatment at high level of 3000 ppm decreased chlorophyll a and b (mg/g) content in leaves as fresh weight compared to control in the two seasons. The injurious impacts of salinity on plant growth are due to the inhibition of photosynthesis, the induction of growth inhibitors, and reduction of leaf area, leaf protein, reduced ability to provide and utilize assimilates/photosynthates (Kashem et al., 2000).

Total chlorophyll content was increased by using potassium silicate as foliar spray compared to control in the two seasons. However, the highest values in this parameter were achieved with 8 cm³/l in both seasons compared with control and the other ones under study.

Moreover, chlorophyll a and b (mg/g) content in the leaves as fresh weight was increased as a result of the treatment of potassium silicate at 6 and 8 cm³/l combined to those of salinity at 1000 ppm in comparison to those of salinity alone (2000 and 3000 ppm) or those of the other ones of combination between potassium silicate and salinity in the first season.

#### 3-2: Total carbohydrates percentage and B carotene content (mg/plant).

Table (10) reveals that, total carbohydrates percentage and B carotene content significantly decreased by using salinity treatments, compared with control in both seasons. In the other words, using salinity treatments at higher levels (2000 and 3000 ppm) recorded the lowest values in this regard in the two seasons compared to control and the other levels under study. These results are in line with those reported by (James et al., 2011).

In addition, potassium silicate rates generally increased total carbohydrates percentage and B carotene content of *Calendula officinalis* L plants compared to control in both seasons, in most cases. This result is in agreement with those obtained by (Tarabih et al., 2014).

Also, total carbohydrates percentage and B carotene content in *Calendula officinalis* L plants was mostly decreased by using all potassium silicate rates under salinity treatments up to 3000 ppm level if compared with control in the two seasons. However, potassium silicate treatment at 6 and 8 cm³/l might succeed in increasing total carbohydrates percentage and B carotene under low and moderate salinity levels.
(1000 ppm) compared to those of control in both seasons.

3-3: Proline content (μ mole g⁻¹ dry weight).

Data illustrated in Table (10) reveal that, salinity treatments generally increased proline content in Calendula officinalis L plants compared to control. This increase was significant with the levels of 2000 and 3000 ppm. Accumulation of free amino acids, such as proline (Torello and Ricf, 1986 and Warren and Pulich, 1986) interpreted the significant role of proline in salinity stress alleviation to be related to enzymatic breakdown and may be rapidly converted to useful metabolic intermediates for growth and energy. They added that 26 mole/g fresh weight of endogenous proline is required to obtain better growth of any barley cultivar under salt stress conditions.

Also, the proline content in Calendula officinalis L plants was increased as the salinity levels increased up to 3000 ppm. All potassium silicate rates increased proline content in Calendula officinalis L plants compared to control in both seasons. Such increase was significant by using the rates of 6 and 8 cm³/l.

Generally, proline content in Calendula officinalis L plants significantly increased by using 6 and 8 cm³/l potassium silicate under salinity levels as compared to salinity treatments alone.

Conclusion

From above mentioned results, it is preferable to spray Calendula officinalis L plants with potassium silicate at 8 cm³/l three times a season under moderate salt stress (1000 ppm) to enhance the growth, yield components and total chlorophyll content as well as total carbohydrates percentage, B carotene content of marigold plant.

REFERENCES

Adatia, M. H. and R. T. Besford (1986). The effects of silicon on cucumber plants grown in recirculating nutrient solution. Ann. Bot. London, 58:343-51.

Allen, R.D. (1995). Dissection of oxidative stress tolerance using transgenic plants. Plant Physiol., 7:1049-1054.

Bates, L. S.; R. P. Waldren and I. D. Teare (1986). Rapid determination of free proline of water stress studies. Plant and Soil, 39: 205-207.

Bayat, H.; M. Alirezaie; H. Neamati and A. A. Saadabad (2013). Effect of Silicon on growth and ornamental traits of Salt-stressed Calendula (Calendula officinalis L.). Journal of Ornamental Plants, 3, (4): 207-214.

Britton, G.; G. Liaaen-Jensen and S. Pfander (1995). Carotenoids. Birkhauser Verlag, 1: 210–214.

Crusciol, C .A.; A. L. Pulz; L. B. Lemos, R. P. Soratto and G. P. Lima (2009). Effects of silicon and drought stress on tuber yield and leaf biochemical characteristics in potato. Crop Sci., 49: 949-954.

Das, K. K.; G. S. Swamy; D. Biswas and K. K. Chnaniya (2017). Response of soil application of diatomaceous earth as a source of silicon on leaf nutrient status of guava. Int. J. Curr. Microbiol. App. Sci., 6(4): 1394-1399.

Epstein, E. (1999). Silicon. Ann. Rev. Plant Physiol. Plant Mol. Biol. 50:641–646.

Greenway, H. and R. Munns,(1980). Mechanism sof salt tolerance in nonhalophytes. Ann. Rev. Plant physiol., 31: 149-190.

Hamad, E. H. A. (1996). Effect of salinity and some growth regulators on guar plants. M. Sc. Thesis, Fac. Agric., Zagazig Univ., Egypt.

Hashish, Kh.I.; A.M. A.Mazhar; G. N. Abdel Aziza and H. M. Mahgoub (2015). The influence of different levels of foliar-application SA on the flowering and some chemical compositions of Calendula officinalis L. under salinity irrigation. International Journal of ChemTech Research,.8(6): 890-897.
Herbert, D.; P. J. Philips and R. E. Strange (2005). Determination of total carbohydrates. Methods in Microbiology, 58: 209-344.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall, Englewood Cliffs, N. J.

James, R. A.; C. Blake; C. S. Byrt and R. Munns (2011). Major genes for Na⁺ exclusion, Nax1 and Nax2 (wheat HKT1:4 and HKT1:5), decrease Na⁺ accumulation in bread wheat leaves under saline and waterlogged conditions. J. of Experimental Botany, 62, 2939–2947.

Kashem, M. A.; N. Sultana; T. Ikeda; H. Hori; T. Loboda and T. Mitsui (2000). Alteration of starch-sucrose transition in germinating wheat seed under sodium chloride salinity. J. Plant Biol. 43: 121-127.

Khaliq, S.; Z. U. Zafar; H. R. Athar and R. Khaliq (2014). Physiological and biochemical basis of salt tolerance in Ocimum basilicum L. Journal of Medicinal Plants Studies, 2(1): 18-27.

Khan, M. U.; A. Rohilla; D. Bhatt; S. Afrin; S. Rohilla and S. H. Ansari (2011). Diverse belongings of Calendula officinalis L.: an overview. International J. of Pharmaceutical Sciences and Drug Research, 3(3): 173-177.

Khorasaninejad, S.; A. Mousavi, H. Soltanloo; K. Hemmati and A. Khalighi (2010). The Effect of Salinity Stress on Growth Parameters, Essential oil Yield and Constituent of Peppermint (Mentha piperita L.). World Applied Sciences Journal 11 (11): 1403-1407, 2010.

Ma, J. F.; N. Mitani; S. Nagao; S. Konishi; K. Tamai; T. Iwashita and M. Yano. (2004). Characterization of the silicon uptake system and molecular mapping of the silicon transporter gene in rice. Plant Physiology, 136: 3284–3289.

Marschner, P. (2012). Marschner’s Mineral Nutrition of Higher Plants, 3rd ed.; Academic Press: London, UK.: 178-189.

Mazumdar, B. C. and Majumder, K. (2003). Methods of Physiochemical Analysis of Fruits. Daya Publishing House Delhi, India.

Mohammad, S. M. and H. H. Kashani (2012). Pot marigold (Calendula officinalis) medicinal usage and cultivation. Scientific Research and Essays, 7(14): 1468-1472.

Munns, R. and M. Tester (2008). Mechanisms of salinity tolerance. Ann. Rev. Plant Biol., 59: 651-681.

Nofal, F. H.; U. M.El-Segai and A. E.Seleem (2015). Response of Calendula officinalis L. plants to growth stimulants under salinity stress. American-Eurasian J. Agric. & Environ. Sci., 15 (9): 1767-1778.

Price, A. H. and G. A. F. Hendry (1991). Iron catalysed oxygen radical formation and its possible contribution to drought damage in nine native grasses and three cereals. Plant Cell Environ., 14:477-484.

Rigane, G.; S. Ben Younes; H. Ghazghazi and R. Ben Salem (2013). Investigation into the biological activities and chemical composition of Calendula officinalis L. growing in Tunisia. International Food Research Journal, 20(6): 3001-3007.

Roodbari, N.; S. Roodbari; A. Ganjali; F. S. Nejad and M. Ansarifar (2013). The effect of salinity stress on growth parameters and essential oil percentage of peppermint (Mentha piperita L.). International Journal of Advanced Biological and Biomedical Research, 1 (9): 1009-1015.

Sadak, Mervat, Sh. and Dawood, Mona G. (2014). Role of ascorbic acid and α-tocopherol in alleviating salinity stress on flax plant (Linum usitatissimum L.). J. of Stress Physiology & Biochemistry, 10 (1): 93-111.

Saud, S.; X. Li; Y. Chen; L. Zhang; S. Fahad; S. Hussain; A. Sadiq and Y. Chen (2014). Silicon application increases drought tolerance of kentucky bluegrass by improving plant water relations and morphophysiological functions. The Scientific World Journal, 2014; 2014: 368694.

Shaaban, M. M. and E. A. Abou El-Nour (2014). Macro and micro-nutrients concentrations and uptake by maize seedlings irrigated with fresh or saline water as affected by K-silicate foliar fertilization. American Journal of Plant Physiology, 9: 95-102.
Shahrbabaki S. M.; S. Zoalhasani and M. Kodory (2013). Effects of sowing date and nitrogen fertilizer on seed and flower yield of pot marigold (Calendula officinalis L.) in the Kerman. Advances in Environmental Biology, 7(13), 3925-3929.

Steel, R. G. D. and S. H. Torrie (1980). Principles and Procedure of Statistics. Second Edition, Mc-Grow Hill Inc. Advances in Environmental Biology 7(13), 3925-3929.

Tarabih, M. E.; E. E. El-Eryan and M. A. El-Metwally (2014). Physiological and pathological impacts of potassium silicate on storability of Anna apple fruits. American Journal of Plant Physiology, 9(2): 52-67.

Torello, W. A. and L. A. Ricf (1986). Effects of NaCl stress on proline and cations accumulation in salt sensitive and tolerant turf grasses. Plant and Soil, 93 : 241 – 247.

Vieira, M. C.; H. E. Gomes; A. Sangalli; Z. N. A. Heredia; I. R. Teixeira and M. B. M. Ramos (2006). Crescimento e produção de biomassa de calêndula (Calendula officinalis L.) proveniente de dois tipos de diásporos e duas colorações de capitulos florais. Rev. Bras. Pl. Med., 8: 193 – 197.

Warren, M. and J. R. Pulich (1986). Variations in leaf soluble amino acids and ammonium content in subtropical sea grasses related to salinity stress. Plant Physiol., 80: 283 – 286.

Zeid, I. M. (2011). Alleviation of seawater stress during germination and early growth of barley. Int J. Agric Res Rev., 2, 59-67.
Table 2. Effect of salinity levels, potassium silicate concentrations and their interaction on plant height, number of branches, fresh and dry weights of herb (g/plant) of *Calendula officinalis* L. in two seasons (2016/2017 and 2017/2018)

| Treatments | Plant height (cm)  | No. of branches  | Fresh weight of herb (g)/plant | Dry weight of herb (g)/plant |
|------------|-------------------|------------------|--------------------------------|----------------------------|
|            | 1st season        | 2nd season       | 1st season                     | 2nd season                 | 1st season                | 2nd season                |
| **Effect of salinity** |                   |                  |                                |                            |                          |                            |
| Tap water  | 46.92             | 50.33            | 10.83                          | 11.58                      | 460.67                    | 475.42                     | 100.62                      | 104.20                     |
| 1000 ppm   | 39.42             | 42.00            | 9.67                           | 10.42                      | 376.33                    | 394.83                     | 82.55                       | 86.13                       |
| 2000 ppm   | 30.25             | 35.50            | 7.33                           | 8.75                       | 311.25                    | 320.67                     | 68.23                       | 70.17                       |
| 3000 ppm   | 26.08             | 26.92            | 5.83                           | 7.08                       | 273.42                    | 288.25                     | 60.03                       | 63.01                       |
| LSD. at 5% | 2.77              | 1.19             | 0.75                           | 0.94                       | 3.97                      | 6.93                       | 1.23                        | 0.92                        |
| LSD. at 1% | 4.20              | 1.80             | 1.09                           | 1.43                       | 6.02                      | 10.49                      | 1.86                        | 1.40                        |
| **Effect of potassium silicate (cm³/l)** |                   |                  |                                |                            |                          |                            |
| 0          | 32.92             | 34.00            | 6.50                           | 7.80                       | 332.25                    | 343.83                     | 72.53                       | 74.87                       |
| 4          | 34.92             | 37.75            | 8.00                           | 9.25                       | 345.75                    | 362.75                     | 75.93                       | 79.61                       |
| 6          | 37.50             | 41.00            | 9.08                           | 9.92                       | 364.08                    | 378.25                     | 79.84                       | 82.78                       |
| 8          | 37.33             | 41.58            | 10.08                          | 11.08                      | 379.58                    | 394.33                     | 83.13                       | 86.25                       |
| LSD. at 5% | 1.43              | 1.16             | 0.87                           | 0.77                       | 6.26                      | 5.96                       | 1.32                        | 1.32                        |
| LSD. at 1% | 1.94              | 1.57             | 1.18                           | 1.04                       | 8.48                      | 8.08                       | 1.79                        | 1.79                        |
| **Effect of interaction between salinity and potassium silicate (cm³/l)** |                   |                  |                                |                            |                          |                            |
| Tap water  | 44.33             | 46.33            | 8.33                           | 9.33                       | 434.33                    | 442.33                     | 93.60                       | 96.37                       |
| 4          | 40.00             | 43.33            | 10.33                          | 11.00                      | 445.33                    | 464.33                     | 98.03                       | 102.57                      |
| 6          | 47.67             | 53.00            | 13.00                          | 13.67                      | 492.33                    | 509.33                     | 107.27                      | 111.10                      |
| 8          | 36.33             | 37.75            | 7.67                           | 8.67                       | 351.00                    | 367.33                     | 77.70                       | 79.77                       |
| 1000 ppm   | 38.33             | 41.33            | 9.00                           | 10.67                      | 368.67                    | 389.33                     | 80.53                       | 85.20                       |
| 6          | 40.33             | 43.33            | 10.67                          | 10.33                      | 386.67                    | 406.67                     | 84.10                       | 88.80                       |
| 8          | 42.67             | 45.67            | 11.33                          | 12.00                      | 409.00                    | 416.00                     | 87.87                       | 90.77                       |
| LSD. at 5% | 1.79              | 1.18             | 1.04                           | 1.04                       | 8.48                      | 8.08                       | 1.79                        | 1.79                        |
| LSD. at 1% | 2.36              | 1.57             | 1.18                           | 1.04                       | 9.87                      | 9.47                       | 2.36                        | 2.36                        |
Table 3. Effect of salinity levels, potassium silicate concentrations and their interaction on flower diameter (cm)/plant and number of flowers/plant of *Calendula officinalis* L. in two seasons (2016/2017 and 2017/2018)

| Treatments | Flower diameter (cm) | No. of flowers/plant |
|------------|----------------------|----------------------|
|            | 1st season | 2nd season | 1st season | 2nd season |
| **Effect of salinity** | | | | |
| Tap water  | 6.833 | 6.963 | 10.08 | 9.17 |
| 1000 ppm   | 6.302 | 6.525 | 8.83 | 7.58 |
| 2000 ppm   | 6.072 | 6.223 | 6.83 | 7.08 |
| 3000 ppm   | 5.773 | 5.876 | 6.08 | 6.00 |
| LSD. at 5% | 0.036 | 0.039 | 0.69 | 1.08 |
| LSD. at 1% | 0.055 | 0.059 | 1.05 | 1.63 |
| **Effect of potassium silicate (cm³/l)** | | | | |
| Tap water  | 5.948 | 6.058 | 5.92 | 5.67 |
| 4          | 6.122 | 6.273 | 7.42 | 6.42 |
| 6          | 6.359 | 6.556 | 8.50 | 7.83 |
| 8          | 6.551 | 6.701 | 10.00 | 9.92 |
| LSD. at 5% | 0.047 | 0.057 | 0.75 | 0.68 |
| LSD. at 1% | 0.064 | 0.077 | 1.02 | 0.92 |
| **Effect of interaction between salinity and potassium silicate (cm³/l)** | | | | |
| Tap water  | 6.287 | 6.337 | 7.67 | 6.67 |
| 4          | 6.587 | 6.683 | 9.33 | 7.67 |
| 6          | 7.170 | 7.317 | 10.67 | 10.00 |
| 8          | 7.290 | 7.517 | 12.67 | 12.33 |
| LSD. at 5% | 0.074 | 0.089 | 1.51 | 1.36 |
| LSD. at 1% | 0.128 | 0.155 | 2.04 | 1.85 |
Table 4. Effect of salinity levels and potassium silicate concentrations on fresh weight of flowers (g)/plant of *Calendula officinalis* L. during eight cuts in two seasons (2016/2017 and 2017/2018)

|                | 1<sup>st</sup> cut | 2<sup>nd</sup> cut | 3<sup>rd</sup> cut | 4<sup>th</sup> cut | 5<sup>th</sup> cut | 6<sup>th</sup> cut | 7<sup>th</sup> Pcut | 8<sup>th</sup> cut |
|----------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
|                | Tap water           |                     |                     |                     |                     |                     |                     |                     |
| Salinity       | 1000 ppm            | 17.76               | 21.00               | 28.20               | 36.38               | 30.89               | 27.93               | 22.54               | 20.13               |
|                | 2000 ppm            | 16.30               | 18.40               | 24.61               | 31.37               | 28.46               | 25.58               | 20.33               | 18.52               |
|                | 3000 ppm            | 14.48               | 16.59               | 18.71               | 25.76               | 26.72               | 21.61               | 18.86               | 17.18               |
|                |                     | 12.53               | 15.18               | 16.11               | 21.97               | 23.93               | 18.48               | 17.44               | 15.80               |
| LSD. at 5%     |                     | 0.76                | 0.69                | 0.97                | 0.73                | 0.38                | 0.45                | 0.34                | 0.75                |
| LSD. at 1%     |                     | 1.15                | 1.04                | 1.48                | 1.11                | 0.57                | 0.68                | 0.51                | 1.14                |
| Potassium silicate (cm<sup>3</sup>/l) | 0          | 13.29               | 15.17               | 18.98               | 25.23               | 24.69               | 20.60               | 17.18               | 14.75               |
|                | 2                   | 14.26               | 16.88               | 20.65               | 27.84               | 26.21               | 22.42               | 18.84               | 16.53               |
|                | 4                   | 15.80               | 18.40               | 22.94               | 30.25               | 28.28               | 24.28               | 20.55               | 18.88               |
|                | 8                   | 17.74               | 20.71               | 25.05               | 32.14               | 30.83               | 26.30               | 22.59               | 21.46               |
| LSD. at 5%     |                     | 0.72                | 0.79                | 0.75                | 0.82                | 0.74                | 0.58                | 0.65                | 0.89                |
| LSD. at 1%     |                     | 0.98                | 1.07                | 1.01                | 1.12                | 1.01                | 0.79                | 0.88                | 1.21                |
|                | Tap water           | 19.58               | 21.55               | 29.31               | 38.34               | 33.03               | 29.27               | 24.50               | 22.36               |
| Salinity       | 1000 ppm            | 17.49               | 19.57               | 26.53               | 35.29               | 30.06               | 27.02               | 22.27               | 19.84               |
|                | 2000 ppm            | 15.42               | 17.46               | 23.87               | 27.78               | 27.92               | 23.62               | 20.33               | 18.37               |
|                | 3000 ppm            | 13.62               | 15.34               | 20.72               | 24.06               | 24.40               | 21.25               | 18.63               | 16.95               |
| LSD. at 5%     |                     | 0.65                | 0.47                | 0.93                | 0.46                | 0.73                | 0.48                | 0.56                | 0.77                |
| LSD. at 1%     |                     | 0.99                | 0.71                | 1.41                | 0.70                | 1.11                | 0.73                | 0.85                | 1.17                |
| Potassium silicate (cm<sup>3</sup>/l) | 0          | 14.55               | 16.12               | 22.47               | 28.24               | 25.89               | 22.45               | 18.89               | 16.10               |
|                | 2                   | 15.72               | 17.35               | 24.08               | 30.50               | 27.41               | 24.12               | 20.52               | 17.75               |
|                | 4                   | 17.13               | 19.10               | 25.81               | 32.59               | 29.90               | 26.33               | 22.19               | 20.10               |
|                | 8                   | 18.71               | 21.35               | 28.07               | 34.14               | 32.22               | 28.26               | 24.14               | 23.57               |
| LSD. at 5%     |                     | 0.63                | 0.66                | 0.81                | 0.86                | 0.72                | 0.63                | 0.75                | 0.80                |
| LSD. at 1%     |                     | 0.85                | 0.89                | 1.09                | 1.17                | 0.98                | 0.85                | 1.02                | 1.08                |
Table 5. Effect of the interaction between salinity levels and potassium silicate concentrations on fresh weight of flowers (g/plant of *Calendula officinalis* L. during eight cuts in two seasons (2016/2017 and 2017/2018)

| Salinity | Potassium silicate(cm³/l) | 1st cut | 2nd cut | 3rd cut | 4th cut | 5th cut | 6th cut | 7th cut | 8th cut |
|----------|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Tap water | 0                        | 15.09  | 17.88  | 23.89  | 32.93  | 27.65  | 24.86  | 19.78  | 16.74  |
|          | 2                        | 16.65  | 19.95  | 26.36  | 34.76  | 29.15  | 26.72  | 21.58  | 18.47  |
|          | 4                        | 18.11  | 21.26  | 30.19  | 37.91  | 32.29  | 28.95  | 23.29  | 20.95  |
|          | 8                        | 21.18  | 24.89  | 32.35  | 39.92  | 34.47  | 31.20  | 25.48  | 24.37  |
| 1000 ppm | 0                        | 13.93  | 15.83  | 22.01  | 26.72  | 26.29  | 22.22  | 17.75  | 15.49  |
|          | 2                        | 14.86  | 17.46  | 23.35  | 30.22  | 27.22  | 24.64  | 19.21  | 17.38  |
|          | 4                        | 16.74  | 18.79  | 25.31  | 33.48  | 28.66  | 26.48  | 20.85  | 19.80  |
|          | 8                        | 19.68  | 21.51  | 27.75  | 35.05  | 31.67  | 28.97  | 23.52  | 21.41  |
| 2000 ppm | 0                        | 12.69  | 14.20  | 16.11  | 22.33  | 23.79  | 18.91  | 16.41  | 13.92  |
|          | 2                        | 13.17  | 15.34  | 17.82  | 25.04  | 25.69  | 20.52  | 17.90  | 16.14  |
|          | 4                        | 15.34  | 17.57  | 19.80  | 27.06  | 27.14  | 22.42  | 19.81  | 18.26  |
|          | 8                        | 16.74  | 19.25  | 21.11  | 28.60  | 30.25  | 24.60  | 21.33  | 20.39  |
| 3000 ppm | 0                        | 11.44  | 12.78  | 13.91  | 18.96  | 21.01  | 16.41  | 14.79  | 12.86  |
|          | 2                        | 12.35  | 14.77  | 15.08  | 21.36  | 22.79  | 17.80  | 16.69  | 14.14  |
|          | 4                        | 13.01  | 15.97  | 16.47  | 22.56  | 25.01  | 19.29  | 18.24  | 16.51  |
|          | 8                        | 13.34  | 17.19  | 18.99  | 24.99  | 26.92  | 20.43  | 20.03  | 19.68  |
| LSD. at 5%|                          | 1.45   | 1.57   | 1.50   | 1.65   | 1.48   | 1.16   | 1.30   | 1.79   |
| LSD. at 1%|                          | 1.96   | 2.13   | 2.03   | 2.23   | 2.01   | 1.58   | 1.77   | 2.42   |

First season

| Salinity | Potassium silicate(cm³/l) | 1st cut | 2nd cut | 3rd cut | 4th cut | 5th cut | 6th cut | 7th cut | 8th cut |
|----------|--------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Tap water | 0                        | 16.75  | 18.68  | 26.24  | 35.09  | 29.87  | 26.23  | 21.80  | 19.04  |
|          | 2                        | 18.54  | 20.31  | 27.83  | 38.27  | 31.65  | 28.65  | 23.47  | 20.71  |
|          | 4                        | 19.90  | 21.55  | 30.15  | 38.91  | 34.60  | 30.21  | 25.38  | 23.15  |
|          | 8                        | 23.15  | 25.65  | 33.01  | 41.09  | 36.01  | 31.98  | 27.36  | 26.55  |
| 1000 ppm | 0                        | 15.21  | 17.10  | 24.18  | 32.16  | 27.02  | 23.87  | 19.63  | 16.22  |
|          | 2                        | 16.00  | 18.37  | 25.19  | 34.86  | 28.43  | 25.78  | 21.58  | 18.57  |
|          | 4                        | 18.67  | 19.96  | 27.61  | 36.45  | 30.92  | 28.04  | 23.24  | 21.15  |
|          | 8                        | 20.06  | 22.85  | 29.14  | 37.70  | 33.89  | 30.40  | 24.62  | 23.40  |
| 2000 ppm | 0                        | 13.73  | 15.19  | 21.31  | 24.40  | 25.04  | 20.73  | 17.87  | 15.27  |
|          | 2                        | 14.85  | 16.34  | 23.38  | 26.36  | 26.58  | 21.98  | 19.40  | 16.74  |
|          | 4                        | 15.69  | 18.34  | 24.15  | 29.42  | 28.55  | 24.90  | 20.76  | 18.64  |
|          | 8                        | 17.39  | 19.98  | 26.63  | 30.93  | 31.49  | 26.88  | 23.29  | 22.82  |
| 3000 ppm | 0                        | 12.49  | 13.50  | 18.15  | 21.28  | 21.64  | 18.95  | 16.24  | 13.86  |
|          | 2                        | 13.49  | 14.38  | 19.91  | 22.52  | 22.95  | 20.08  | 17.64  | 15.00  |
|          | 4                        | 14.25  | 16.57  | 21.33  | 25.60  | 25.53  | 22.17  | 19.38  | 17.46  |
|          | 8                        | 14.26  | 16.91  | 23.50  | 26.86  | 27.49  | 23.80  | 21.28  | 21.49  |
| LSD. at 5%|                          | 1.26   | 1.32   | 1.61   | 1.73   | 1.44   | 1.25   | 1.51   | 1.60   |
| LSD. at 1%|                          | 1.71   | 1.79   | 2.18   | 2.34   | 1.95   | 1.70   | 2.04   | 2.16   |
Table 6. Effect of salinity levels and potassium silicate concentrations on dry weight of flowers (g/plant of *Calendula officinalis* L.) during eight cuts in two seasons (2016/2017 and 2017/2018)

| Salinity Level | Potassium Silicate (cm³/l) | 1st Cut | 2nd Cut | 3rd Cut | 4th Cut | 5th Cut | 6th Cut | 7th Cut | 8th Cut |
|---------------|-----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| Tap water     |                             | 3.43   | 4.08   | 4.68   | 6.87   | 4.94   | 4.45   | 3.86   | 3.33   |
| 1000 ppm      |                             | 2.86   | 3.70   | 3.96   | 5.29   | 4.54   | 3.88   | 3.48   | 2.90   |
| 2000 ppm      |                             | 2.42   | 3.23   | 3.38   | 3.99   | 4.12   | 3.35   | 3.02   | 2.54   |
| 3000 ppm      |                             | 2.07   | 2.90   | 3.05   | 3.49   | 3.55   | 2.95   | 2.76   | 2.08   |
| LSD. at 5%    |                             | 0.29   | 0.25   | 0.06   | 0.32   | 0.31   | 0.10   | 0.09   | 0.05   |
| LSD. at 1%    |                             | 0.44   | 0.37   | 0.09   | 0.48   | 0.47   | 0.15   | 0.14   | 0.07   |
| 0             |                             | 2.11   | 2.92   | 3.46   | 3.89   | 3.68   | 3.28   | 2.99   | 2.47   |
| 2             |                             | 2.43   | 3.23   | 3.64   | 4.72   | 3.98   | 3.48   | 3.13   | 2.60   |
| 4             |                             | 2.95   | 3.64   | 3.82   | 5.24   | 4.48   | 3.78   | 3.36   | 2.76   |
| 8             |                             | 3.28   | 4.13   | 4.14   | 5.79   | 5.01   | 4.08   | 3.64   | 3.01   |
| LSD. at 5%    |                             | 0.21   | 0.22   | 0.07   | 0.21   | 0.18   | 0.09   | 0.08   | 0.05   |
| LSD. at 1%    |                             | 0.29   | 0.30   | 0.09   | 0.28   | 0.25   | 0.12   | 0.11   | 0.07   |
| 0             |                             | 2.40   | 2.89   | 3.58   | 4.16   | 4.06   | 3.51   | 3.18   | 2.84   |
| 2             |                             | 2.73   | 3.36   | 3.73   | 4.64   | 4.33   | 3.68   | 3.34   | 2.99   |
| 4             |                             | 3.22   | 3.78   | 3.92   | 5.22   | 4.73   | 3.91   | 3.50   | 3.15   |
| 8             |                             | 3.62   | 4.24   | 4.29   | 5.91   | 5.23   | 4.36   | 3.75   | 3.36   |
| LSD. at 5%    |                             | 0.20   | 0.22   | 0.06   | 0.23   | 0.15   | 0.12   | 0.07   | 0.07   |
| LSD. at 1%    |                             | 0.28   | 0.30   | 0.08   | 0.32   | 0.21   | 0.16   | 0.09   | 0.10   |
Table 7. Effect of the interaction between salinity levels and potassium silicate concentrations on dry weight of flowers (g/plant) of *Calendula officinalis* L. during eight cuts in two seasons (2016/2017 and 2017/2018)

| Salinity | Potassium silicate(cm³/l) | 1st cut | 2nd cut | 3rd cut | 4th cut | 5th cut | 6th cut | 7th cut | 8th cut |
|----------|---------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Tap water | 0                          | 2.53    | 3.33    | 4.29    | 5.23    | 4.22    | 3.92    | 3.53    | 3.09    |
|          | 2                          | 3.13    | 3.70    | 4.51    | 6.80    | 4.44    | 4.13    | 3.70    | 3.22    |
|          | 4                          | 3.80    | 4.37    | 4.74    | 7.48    | 5.24    | 4.61    | 3.93    | 3.39    |
|          | 8                          | 4.23    | 4.90    | 5.17    | 7.97    | 5.85    | 5.12    | 4.29    | 3.63    |
| 1000 ppm | 0                          | 2.33    | 3.13    | 3.65    | 4.34    | 4.12    | 3.59    | 3.17    | 2.68    |
|          | 2                          | 2.53    | 3.53    | 3.88    | 5.13    | 4.23    | 3.73    | 3.32    | 2.82    |
|          | 4                          | 3.03    | 3.80    | 4.09    | 5.53    | 4.67    | 3.95    | 3.55    | 2.94    |
|          | 8                          | 3.53    | 4.33    | 4.23    | 6.17    | 5.14    | 4.24    | 3.89    | 3.15    |
| 2000 ppm | 0                          | 1.90    | 2.83    | 3.07    | 3.20    | 3.63    | 2.98    | 2.78    | 2.21    |
|          | 2                          | 2.17    | 3.07    | 3.22    | 3.71    | 3.91    | 3.24    | 2.91    | 2.38    |
|          | 4                          | 2.67    | 3.33    | 3.34    | 4.27    | 4.24    | 3.47    | 3.11    | 2.58    |
|          | 8                          | 2.93    | 3.70    | 3.87    | 4.79    | 4.71    | 3.68    | 3.29    | 2.98    |
| 3000 ppm | 0                          | 1.67    | 2.37    | 2.83    | 2.77    | 2.74    | 2.63    | 2.47    | 1.89    |
|          | 2                          | 1.90    | 2.60    | 2.94    | 3.22    | 3.33    | 2.81    | 2.60    | 1.99    |
|          | 4                          | 2.30    | 3.07    | 3.12    | 3.71    | 3.79    | 3.06    | 2.86    | 2.14    |
|          | 8                          | 2.40    | 3.57    | 3.30    | 4.25    | 4.34    | 3.29    | 3.09    | 2.29    |
| LSD. at 5% |                         | 0.43    | 0.44    | 0.13    | 0.42    | 0.37    | 0.18    | 0.17    | 0.11    |
| LSD. at 1% |                         | 0.58    | 0.59    | 0.18    | 0.57    | 0.50    | 0.24    | 0.23    | 0.15    |

Second season

| Salinity | Potassium silicate(cm³/l) | 1st cut | 2nd cut | 3rd cut | 4th cut | 5th cut | 6th cut | 7th cut | 8th cut |
|----------|---------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| Tap water | 0                          | 2.73    | 3.70    | 4.38    | 5.39    | 4.78    | 4.10    | 3.68    | 3.36    |
|          | 2                          | 3.43    | 4.10    | 4.60    | 6.53    | 5.24    | 4.25    | 3.83    | 3.57    |
|          | 4                          | 3.97    | 4.57    | 4.87    | 7.12    | 5.83    | 4.57    | 4.03    | 3.68    |
|          | 8                          | 4.40    | 5.20    | 5.32    | 8.30    | 6.44    | 5.33    | 4.20    | 3.89    |
| 1000 ppm | 0                          | 2.53    | 3.20    | 3.74    | 4.43    | 4.19    | 3.82    | 3.49    | 3.10    |
|          | 2                          | 2.83    | 3.73    | 3.86    | 4.64    | 4.35    | 3.96    | 3.69    | 3.21    |
|          | 4                          | 3.40    | 4.03    | 4.01    | 5.08    | 4.64    | 4.17    | 3.82    | 3.38    |
|          | 8                          | 3.80    | 4.57    | 4.32    | 5.45    | 5.28    | 4.59    | 4.07    | 3.61    |
| 2000 ppm | 0                          | 2.33    | 2.53    | 3.19    | 3.55    | 3.75    | 3.27    | 2.94    | 2.79    |
|          | 2                          | 2.47    | 2.97    | 3.33    | 3.91    | 4.00    | 4.00    | 3.43    | 3.09    | 2.90    |
|          | 4                          | 2.90    | 3.47    | 3.48    | 4.67    | 4.50    | 3.63    | 3.21    | 3.04    |
|          | 8                          | 3.37    | 3.77    | 4.03    | 5.04    | 4.93    | 3.95    | 3.43    | 3.21    |
| 3000 ppm | 0                          | 2.00    | 2.13    | 3.03    | 3.26    | 3.51    | 2.84    | 2.61    | 2.10    |
|          | 2                          | 2.20    | 2.63    | 3.13    | 3.49    | 3.72    | 3.09    | 2.74    | 2.27    |
|          | 4                          | 2.60    | 3.03    | 3.33    | 4.02    | 3.96    | 3.28    | 2.96    | 2.49    |
|          | 8                          | 2.90    | 3.43    | 3.48    | 4.84    | 4.29    | 3.59    | 3.29    | 2.73    |
| LSD. at 5% |                         | 0.41    | 0.45    | 0.12    | 0.46    | 0.31    | 0.23    | 0.13    | 0.14    |
| LSD. at 1% |                         | 0.55    | 0.60    | 0.17    | 0.63    | 0.41    | 0.31    | 0.18    | 0.20    |
Table 8. Effect of salinity levels, potassium silicate concentrations and their interaction on fresh and dry yield of flowers (g/plant of *Calendula officinalis* L. in two seasons (2016/2017 and 2017/2018)

|                       | Fresh yield of flowers (g)/plant | Dry yield of flowers (g)/plant |
|-----------------------|----------------------------------|--------------------------------|
|                       | 1<sup>st</sup> season            | 2<sup>nd</sup> season         |
| Tap water             |                                  |                                |
| 1000 ppm              |                                  |                                |
| 2000 ppm              |                                  |                                |
| 3000 ppm              |                                  |                                |
| LSD. at 5%            | 4.4                              | 1.31                           |
| LSD. at 1%            | 6.6                              | 1.98                           |

| Effect of potassium silicate (cm³/l) | 1<sup>st</sup> season | 2<sup>nd</sup> season |
|-------------------------------------|-----------------------|-----------------------|
| 0                                   | 149.9                 | 164.7                 |
| 4                                   | 163.6                 | 177.5                 |
| 6                                   | 179.4                 | 193.2                 |
| 8                                   | 196.8                 | 219.9                 |
| LSD. at 5%                          | 5.5                   | 15.8                  |
| LSD. at 1%                          | 7.4                   | 21.4                  |

| Effect of interaction between salinity and potassium silicate (cm³/l) | 1<sup>st</sup> season | 2<sup>nd</sup> season |
|---------------------------------------------------------------------|-----------------------|-----------------------|
| Tap water                                                           |                       |                       |
| 1000 ppm                                                           |                       |                       |
| 2000 ppm                                                           |                       |                       |
| 3000 ppm                                                           |                       |                       |
| LSD. at 5%                                                         | 10.9                  | 31.5                  |
| LSD. at 1%                                                         | 14.8                  | 42.7                  |
Table 9. Effect of salinity levels, potassium silicate concentrations and their interaction on chlorophyll a and b (mg/g fresh wt) contents of Calendula officinalis L. in two seasons (2016/2017 and 2017/2018)

| Salinity | Chlorophyll a (mg/g fresh wt) | Chlorophyll b (mg/g fresh wt) |
|----------|-------------------------------|-------------------------------|
|          | 1st season                    | 2nd season                    | 1st season | 2nd season |
| Tape water|                               |                               |            |            |
| 1000 ppm | 0.389                         | 0.422                         | 0.215      | 0.227      |
| 2000 ppm | 0.372                         | 0.387                         | 0.193      | 0.207      |
| 3000 ppm | 0.338                         | 0.373                         | 0.153      | 0.162      |
| LSD. at 5%| 0.004                         | 0.006                         | 0.014      | 0.015      |
| LSD. at 1%| 0.006                         | 0.009                         | 0.021      | 0.022      |

| Potassium silicate(cm³/l) | Chlorophyll a (mg/g fresh wt) | Chlorophyll b (mg/g fresh wt) |
|---------------------------|-------------------------------|-------------------------------|
|                          | 1st season                    | 2nd season                    | 1st season | 2nd season |
| 0                         | 0.351                         | 0.373                         | 0.167      | 0.176      |
| 4                         | 0.375                         | 0.393                         | 0.185      | 0.199      |
| 6                         | 0.398                         | 0.427                         | 0.210      | 0.220      |
| 8                         | 0.417                         | 0.452                         | 0.231      | 0.241      |
| LSD. at 5%                | 0.011                         | 0.013                         | 0.011      | 0.010      |
| LSD. at 1%                | 0.015                         | 0.018                         | 0.015      | 0.013      |

| Salinity | Potassium silicate(cm³/l) | Chlorophyll a (mg/g fresh wt) | Chlorophyll b (mg/g fresh wt) |
|----------|---------------------------|-------------------------------|-------------------------------|
|          | 1st season | 2nd season | 1st season | 2nd season |
| Tape water| 0          | 0.387      | 0.423      | 0.203      | 0.210      |
|           | 4          | 0.427      | 0.437      | 0.230      | 0.233      |
|           | 6          | 0.470      | 0.477      | 0.237      | 0.250      |
|           | 8          | 0.480      | 0.507      | 0.257      | 0.270      |
| 1000 ppm | 0          | 0.357      | 0.377      | 0.183      | 0.193      |
|           | 4          | 0.380      | 0.407      | 0.203      | 0.220      |
|           | 6          | 0.393      | 0.443      | 0.230      | 0.240      |
|           | 8          | 0.427      | 0.463      | 0.243      | 0.253      |
| 2000 ppm | 0          | 0.343      | 0.357      | 0.167      | 0.177      |
|           | 4          | 0.360      | 0.370      | 0.173      | 0.193      |
|           | 6          | 0.380      | 0.397      | 0.207      | 0.220      |
|           | 8          | 0.403      | 0.427      | 0.227      | 0.237      |
| 3000 ppm | 0          | 0.317      | 0.337      | 0.117      | 0.123      |
|           | 4          | 0.333      | 0.357      | 0.133      | 0.150      |
|           | 6          | 0.347      | 0.390      | 0.167      | 0.170      |
|           | 8          | 0.357      | 0.410      | 0.197      | 0.203      |
| LSD. at 5%| 0.022      | 0.027      | 0.022      | 0.019      |
| LSD. at 1%| 0.030      | 0.036      | 0.030      | 0.026      |
Table 10. Effect of salinity levels, potassium silicate concentrations and their interaction on total carbohydrates percentage, carotenoids content and proline content of *Calendula officinalis* L. at the two seasons of (2016/2017 and 2017/2018)

|                     | Total carbohydrates % | B carotenes in flowers(mg/plant) | Proline content (μ mole g⁻¹ dry weight) |
|---------------------|------------------------|----------------------------------|-----------------------------------------|
|                     | 1st season             | 2nd season                       | 1st season                              | 2nd season |
| **Effect of salinity** |                        |                                  |                                         |            |
| Tape water          | 35.40                  | 36.41                            | 264.1                                   | 265.2      | 3.567       | 3.958       |
| 1000 ppm            | 31.44                  | 34.44                            | 259.2                                   | 263.2      | 5.508       | 6.000       |
| 2000 ppm            | 30.11                  | 30.75                            | 255.4                                   | 258.0      | 6.633       | 7.567       |
| 3000 ppm            | 28.65                  | 28.95                            | 252.8                                   | 255.6      | 8.025       | 8.765       |
| **LSD. at 5%**      | 0.67                   | 0.79                             | 1.1                                     | 0.9        | 0.170       | 0.223       |
| **LSD. at 1%**      | 1.02                   | 1.19                             | 1.7                                     | 1.4        | 0.258       | 0.338       |
| **Effect of potassium silicate (cm³/l)** |         |                                  |                                         |            |
| 0                   | 27.02                  | 28.24                            | 254.2                                   | 256.2      | 4.625       | 5.408       |
| 4                   | 29.77                  | 31.40                            | 256.8                                   | 258.8      | 5.633       | 6.242       |
| 6                   | 33.02                  | 33.93                            | 259.2                                   | 262.0      | 6.425       | 6.992       |
| 8                   | 35.79                  | 36.98                            | 261.3                                   | 264.9      | 7.050       | 7.648       |
| **LSD. at 5%**      | 0.74                   | 0.81                             | 0.8                                     | 1.2        | 0.229       | 0.281       |
| **LSD. at 1%**      | 1.00                   | 1.10                             | 1.1                                     | 1.7        | 0.311       | 0.380       |
| **Effect of interaction between salinity and potassium silicate (cm³/l)** |   |                                  |                                         |            |
| Tape water 0        | 28.89                  | 30.29                            | 257.7                                   | 259.3      | 2.267       | 2.867       |
| 0                   | 27.58                  | 28.85                            | 255.3                                   | 257.7      | 4.300       | 4.767       |
| 4                   | 34.24                  | 35.35                            | 262.7                                   | 261.3      | 3.433       | 3.433       |
| 6                   | 37.51                  | 38.29                            | 266.3                                   | 267.7      | 4.133       | 4.567       |
| 8                   | 40.96                  | 41.72                            | 269.7                                   | 272.3      | 4.433       | 4.967       |
| 1000 ppm 0         | 26.74                  | 27.82                            | 253.3                                   | 255.3      | 5.400       | 6.533       |
| 0                   | 26.74                  | 27.82                            | 253.3                                   | 255.3      | 5.400       | 6.533       |
| 4                   | 32.82                  | 36.53                            | 260.7                                   | 265.0      | 5.933       | 6.333       |
| 6                   | 35.69                  | 37.99                            | 263.0                                   | 267.3      | 6.433       | 7.100       |
| 8                   | 39.93                  | 38.73                            | 269.7                                   | 272.3      | 4.433       | 4.967       |
| 2000 ppm 0         | 28.20                  | 28.98                            | 254.7                                   | 257.0      | 6.200       | 7.333       |
| 0                   | 26.74                  | 27.82                            | 253.3                                   | 255.3      | 5.400       | 6.533       |
| 4                   | 31.55                  | 31.48                            | 256.0                                   | 259.0      | 7.100       | 7.933       |
| 6                   | 33.93                  | 34.73                            | 257.7                                   | 260.7      | 7.833       | 8.467       |
| 8                   | 38.20                  | 37.98                            | 263.0                                   | 267.3      | 6.433       | 7.100       |
| 3000 ppm 0         | 24.87                  | 26.00                            | 250.3                                   | 252.3      | 6.533       | 7.467       |
| 0                   | 26.74                  | 27.82                            | 253.3                                   | 255.3      | 5.400       | 6.533       |
| 4                   | 30.21                  | 29.43                            | 257.7                                   | 256.3      | 8.533       | 9.133       |
| 6                   | 32.58                  | 33.47                            | 255.0                                   | 259.3      | 9.500       | 10.060      |
| 8                   | 1.48                   | 1.62                             | 1.7                                     | 2.5        | 0.458       | 0.561       |
| **LSD. at 5%**      | 2.01                   | 2.19                             | 2.3                                     | 3.4        | 0.621       | 0.761       |