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

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ABSTRACT

Two pots experiments were conducted at the Experimental Farm of El-Qassasin 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 cm^3/l concentration. Proline content increased in leaves with using saline water at 3000 ppm + potassium silicate at 8 cm^3/l. Generally, it could be concluded that potassium silicate at 8 cm^3/l, showed a uniform impact in alleviating inhibition of *Calendula officinallis* 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

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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.

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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, Ca^{++} 3.6 and 3.9, Mg^{++} 1.7 and 1.5, CO_3^{--} 0 and 0, HCO_3^- 2.3 and 3.6 , Cl^- 4.8 and 4.1, SO_4^{--} 4.2 and 3.6 meqL- 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			
	CO_3^-	HCO_3^-	CL^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
39347	--	7.62	365.63	86.02	59.2	36.8	348.1	9.76

Seedlings were foliar sprayed till runoff with different concentrations of potassium silicate in equal doses (0, 4, 6 and 8 cm^3/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 : K_2O 10% and $Si_2O_3$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% P_2O_5) and 4.0 g potassium sulphate (48.5 K_2O) 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 at95 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.

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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 $8cm^3/l$ gave the significantly highest increases in vegetative parameters. while the lowest values were obtained at foliar application of potassium silicate at 0 cm^3/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 $8cm^3/l$ 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

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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

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earlier by **Hashish *et al.* (2015)** on *Calendula officinalis* L.

However, 6 and 8 cm^3/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 cm^3/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 cm^3/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 cm^3/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 cm^3/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 cm^3/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 cm^3/l might succeed in increasing total carbohydrates percentage and B carotene under low and moderate salinity levels

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(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 cm^3/l.

Generally, proline content in *Calendula officinalis* L plants significantly increased by using 6 and 8 cm^3/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 cm^3/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.

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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		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	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 (cm^3/l)									
0		32.92	34.42	6.50	7.58	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 (cm^3/l)									
Tap water	0	44.33	46.33	8.33	9.33	434.33	442.33	93.60	96.37
	4	46.67	49.33	10.33	11.00	445.33	464.33	98.03	102.57
	6	49.00	52.67	11.67	12.33	470.67	485.67	103.57	106.77
	8	47.67	53.00	13.00	13.67	492.33	509.33	107.27	111.10
1000 ppm	0	36.33	37.67	7.67	8.67	351.00	367.33	77.70	79.77
	4	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	399.00	416.00	87.87	90.77
2000 ppm	0	27.67	31.67	5.67	7.00	294.00	301.33	64.40	66.23
	4	29.67	34.67	7.33	8.33	307.00	314.00	67.37	68.67
	6	32.33	37.33	7.67	9.33	317.00	327.00	69.70	71.00
	8	31.33	38.33	8.67	10.33	327.00	340.33	71.47	74.77
3000 ppm	0	23.33	22.00	4.33	5.33	249.67	264.33	54.40	57.10
	4	25.00	25.67	5.33	7.00	262.00	283.33	57.80	62.00
	6	28.33	30.67	6.33	7.67	282.00	293.67	62.00	64.57
	8	27.67	29.33	7.33	8.33	300.00	311.67	65.93	68.37
LSD. at 5%		2.86	2.32	1.74	1.54	12.52	11.92	2.64	2.64
LSD. at 1%		3.88	3.15	2.36	2.08	16.97	16.16	3.57	3.57

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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 (cm^3/l)					
0		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 (cm^3/l)					
Tap water	**0**	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
1000 ppm	**0**	6.070	6.223	6.33	6.00
	4	6.183	6.420	7.67	6.33
	6	6.277	6.673	9.67	7.67
	8	6.680	6.783	11.67	10.33
2000 ppm	**0**	5.907	6.030	5.00	5.67
	4	5.983	6.173	6.67	6.33
	6	6.130	6.273	7.33	7.00
	8	6.267	6.417	8.33	9.33
3000 ppm	**0**	5.530	5.640	4.67	4.33
	4	5.733	5.817	6.00	5.33
	6	5.860	5.960	6.33	6.67
	8	5.967	6.087	7.33	7.67
LSD. at 5%		0.094	0.114	1.51	1.36
LSD. at 1%		0.128	0.155	2.04	1.85

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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)

		1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut	7th Pcut	8th cut
		First season							
Salinity	Tap water	17.76	21.00	28.20	36.38	30.89	27.93	22.54	20.13
	1000 ppm	16.30	18.40	24.61	31.37	28.46	25.58	20.33	18.52
	2000 ppm	14.48	16.59	18.71	25.76	26.72	21.61	18.86	17.18
	3000 ppm	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^3/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
		Second season							
Salinity	Tap water	19.58	21.55	29.31	38.34	33.03	29.27	24.50	22.36
	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^3/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

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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(cm^3/l)	1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut	7th cut	8th cut
					First season				
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
					Second season				
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

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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)

		1st Cut	2nd Cut	3rd Cut	4th Cut	5th Cut	6th cut	7th cut	8th cut
					First season				
Salinity	**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
Potassium silicate (cm^3/l)	**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
					Second season				
Salinity	**Tap water**	3.63	4.39	4.79	6.84	5.57	4.56	3.94	3.63
	1000 ppm	3.14	3.88	3.98	4.90	4.61	4.13	3.77	3.32
	2000 ppm	2.77	3.18	3.51	4.29	4.29	3.57	3.17	2.99
	3000 ppm	2.43	2.81	3.24	3.90	3.87	3.20	2.90	2.40
LSD. at 5%		0.21	0.28	0.06	0.33	0.16	0.12	0.06	0.06
LSD. at 1%		0.32	0.43	0.09	0.51	0.25	0.19	0.10	0.09
Potassium silicate(cm^3/l)	**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

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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(cm^3/l)	1st cut	2nd cut	3rd cut	4th cut	5th cut	6th cut	7th cut	8th cut
					First season				
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				
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	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

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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	
		1st season	2nd season	1st season	2nd season
Effect of salinity					
Tap water		204.8	217.9	35.63	37.35
1000 ppm		183.6	198.1	30.61	31.74
2000 ppm		159.9	174.8	26.05	27.77
3000 ppm		141.4	164.4	22.83	24.74
LSD. at 5%		4.4	17.7	1.31	1.17
LSD. at 1%		6.6	26.8	1.98	1.77
Effect of potassium silicate (cm^3/l)					
0		149.9	164.7	24.78	26.61
4		163.6	177.5	27.20	28.80
6		179.4	193.2	30.04	31.44
8		196.8	219.9	33.09	34.76
	LSD. at 5%	5.5	15.8	0.96	1.00
	LSD. at 1%	7.4	21.4	1.30	1.35
Effect of interaction between salinity and potassium silicate (cm^3/l)					
Tap water	0	178.8	193.7	30.15	32.12
	4	193.6	209.4	33.63	35.55
	6	213.0	223.8	37.56	38.65
	8	233.9	244.8	41.16	43.09
1000 ppm	0	160.2	175.4	27.01	28.49
	4	174.3	188.8	29.18	30.27
	6	190.1	206.0	31.56	32.53
	8	209.6	222.0	34.69	35.67
2000 ppm	0	138.4	153.5	22.60	24.36
	4	151.6	165.6	24.61	26.10
	6	167.4	180.5	27.01	28.89
	8	182.3	199.4	29.96	31.72
3000 ppm	0	122.1	136.1	19.36	21.48
	4	135.0	146.0	21.38	23.27
	6	147.1	162.3	24.03	25.68
	8	161.6	213.4	26.53	28.55
LSD. at 5%		10.9	31.5	1.92	2.00
LSD. at 1%		14.8	42.7	2.61	2.71

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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)

		Chlorophyll a (mg/g fresh wt)		Chlorophyll b (mg/g fresh wt)	
		1st season	2nd season	1st season	2nd season
Salinity					
Tape water		0.441	0.461	0.232	0.241
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(cm^3/l)					
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(cm^3/l)**				
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

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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	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 (cm^3/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 (cm^3/l)							
Tape water	**0**	28.89	30.29	257.7	259.3	2.267	2.867
	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**	27.58	28.85	255.3	257.7	4.300	4.767
	4	29.68	34.37	257.7	262.7	5.367	5.800
	6	32.82	36.53	260.7	265.0	5.933	6.333
	8	35.69	37.99	263.0	267.3	6.433	7.100
2000 ppm	**0**	26.74	27.82	253.3	255.3	5.400	6.533
	4	28.20	28.98	254.7	257.0	6.200	7.333
	6	31.55	31.48	256.0	259.0	7.100	7.933
	8	33.93	34.73	257.7	260.7	7.833	8.467
3000 ppm	**0**	24.87	26.00	250.3	252.3	6.533	7.467
	4	26.96	26.91	252.3	254.3	7.533	8.400
	6	30.21	29.43	253.7	256.3	8.533	9.133
	8	32.58	33.47	255.0	259.3	9.500	10.060
LSD. at 5%		1.48	1.62	1.7	2.5	0.458	0.561
LSD. at 1%		2.01	2.19	2.3	3.4	0.621	0.761

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