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Influence of Irrigation Levels, In Presence of Potassium Silicate Sprays Treatments on Growth, Flowering and Chemical Constituents of Marigold (*tageteserecta*l.) Plant.

Mohamed, Safaa.M.[1], Abou El-Ghait,Eman M[1].,Audah, M.S.[2] and Amer, EmanE.A..[2]
[1.] *Horticulture Dept., Fac. of Agric., Benha University, Egypt*
[2.] *Floriculture Depart, Horticulture Research Institute, Agriculture Research Center, Egypt.*

Abstract

Field experiment was conducted at the nursery and Experimental farm of El-Qanater ElKhayria Horticultural Research Station, Qalubiya Governorate, Egypt, In cooperation with the Department of Horticulture, Faculty of Agriculture, Benha University, during the two growing successive seasons of 2017 and 2018.This work aimed to investigate the response of Marigold *Tageteserecta* L.seedlings grown under irrigation regime levels to foliar spray of different concentrations of potassium silica on vegetative growth, rooting, flowers yield and chemical constituents.Results illustrated that, the highest irrigation levelI_1(percentage of Available Soil Moisture Depletion "ASMD" was 25%), gave the maximum values of vegetative, flowering, roots parameters and chemical constituents in both seasons. Therefore, potassium silicate Si_4 (4.0mlL^{-1}) as foliar spray scored the highest values of parameters mentionedabove.Further more, the highest values of these parameters were observed when plants were sprayed with 4mlL^{-1}potassium silicate and grown under irrigation condition I_1 (25 % ASMD), while these values were minimum in Marigold at I_3 (75 % ASMD) and sprayed with potassium silicate treatment (0.0%) in 1[st] an 2[nd]seasons. Conclusively, it could be concluded that foliar application of potassium silicate (0.0,2.0 and 4.0 mlL^{-1}) may be an effective strategy in reducing drought stress treatments (25, 50 and 75 % ASMD) effects with superior for at 4 mlL^{-1} which enhanced all parameters were studied Marigold (*Tageteserecta* L.) plant. Therefore, application of K_2SiO_3 sprays is recommended for improving growth and chemical composition of Marigold under water-stress conditions, highest irrigation rate (25% ASMD.) has the lowest economic water productivity and potassium silicate sprays could alleviate water stress.

Key words: marigold (*Tageteserecta*L.), irrigation regime levels, potassium silicate, growth, flowering andchemical constituents.

Introduction

The genus Tagetes consist of approximately 50 species and belongs to family Asteraceae (**Lawrence,1985**). *Tageteserectra* L. is native to Mexico and other warm parts of America. Nowadays it is with yellow or orange flower-head, they are planted in mixed borders, the beds for mass display and post**(Szarka*et al.*, 2006)**. Marigold flowers are used in flower decorations and making garlands, during several religious and social functions and further the petals are used in dry flower making and the industry of pigment extraction. One of the major flower Marigold use is a herbaceous with aromatic cut flower and poultry feed (**Torkashvand and Zarchini 2012**).Marigold is grown commercially for the extraction of carotenoid pigments mainly xanthophyll's (**Sanghamitra*et al.*, 2015**). Previous studyfound that the antioxidant properties of marigold extract were in correlation with its polyphenol content (**Li *et al.*, 2007**). The isolation of polyphenols such as caffeic acid, gallic acid, acylated flavonoid – O-glycosides and methoxylated flavonoids from marigold was well literature by many authors i.e. (**Aquino *et al.*, 2002 andParejo*et al.*, 2005**). The flowers are used in drugs and pharmaceutical products, processed food, confectionery and in the poultry industry one of the most important effects of the plant is their use as very valuable intercrop for controlling plant parasitic nematodes and insecticidal activity (**Darwish, 1992**). Its essential oil is effective as antiparasitic, antispasmodic, antibiotic, antimicrobial and antiseptic (**Chowdhury, 2009**).

Water is becoming an increasingly scarce resource all over the world. Low rainfall, rapid evaporation and large demands of fresh water, as a result of the rapid increases in population and industrial growth, are among the major factor behind the water serious shortage (**Tadros and Al-Mefleh, 2011**). The effects of Renaissance Dam in Ethiopia (ElNahda Dam), would impose resources in Egypt. Also, if climate change results in intensification of drought, available water resources in the Mediterranean region may become increasingly unstable and vulnerable especially in Egypt which falls into aired and semi-aired regions, water stress is one of the main problems in aired and semi-aired areas. Lack of water influences most physiological processes, such as photo synthesis, development, coalescence and transmission of nutrients in plants (**Davis *et al.*, 2007**). It is predicted that climate change may cause more severe and frequent droughts in the near future (**Heffernan, 2013**). This situation imposes an immediate movement towards establishing a data base about the optimum requirements of water irrigation of different crops in order to rationalize the irrigation water consumption. Potassium silicate is a source of highly soluble potassium and silicon. It is used in agricultural production systems primarily as a silica amendment and has the added benefit of supplying small amounts of potassium.Silicon is one of the abundant elements in the lithosphere and it is the most abundant element in soil next to oxygen and comprises 28 per cent of its weight and 3-17 percent in soil solution **(Epstein, 1999**). Moreover, silicon plays an important role in increasing and enhancing with standing of fruit crops to biotic and a biotic stresses, photosynthesis, nutrient and water uptake, plant pigments and all cell division (**Ma, 2004).**

The present research aims to investigate the influence of three levels of drought stress (irrigation when 25, 50 and 75 % of available soil moisture was depleted) and potassium silicate (0.0,2.0 and 4.0 mlL^{-1}) foliar sprays on the growth, flowering and chemical composition of marigold (*Tageteserecta*L) plant.

Material and Methods

A field experiment was conducted at the Nursery and Experimental Farm of El-Qanater Elkhyria Horticultural Research Station, Qalubiya Governorate, Egypt. In cooperation with the Department of Horticulture, Faculty of Agriculture, Benha University, during the two growing successive seasons of 2017 and 2018.

This work aimed to investigate the response of *Tageteserecta* seedlings grown under irrigation regime levels to foliar spray of different concentrations of potassium silicate (26.6%K_2O and 10.4%SiO_3) on vegetative growth, rooting, flowering and chemical constituents. Seeds of *Tageteserecta* (100 seed weight 0.28g) was sown on 20th February and 25th February (during the first and second seasons respectively) in seedling trays at the Nursery of the Horticultural Research Station (Latitude: 30°. 08N Longitude: 31°.15 E Elevation: 16.9m).

Seeds were successfully germinated up to 8 days, when seedlings produced 3-4 true leaves and reached 8-10 cm long after two weeks from sowing, the plants were transplanted to the field. The experimental plot area was 15 m^2 , each plot were assigned to contain 5 rows with length 5m and width 0.6m and seedling were cultivated at 30 cm apart each row contain 16 plants and each plot contain 81 plants and each experimental unit had 3 experimental plots for Tagetes

Randomized soil sample representing the experimental area was taken at 0-30cm depth before beginning any treatments. The samples were examined for its physical and chemical characteristics at laboratory in the Soil, Water Environment Research Institute, Agriculture Research center, Giza, Egypt (as illustrated in Table 1 and 2).

Table 1. Physical and chemical properties of the soil**.**

Parameter		**Value**
Particle size distribution (%):		
Clay	%	31.5
Silt	%	33.5
Fine sand	%	34.0
Coarse sand	%	1.0
Texture class		Clay loam
$CaCO_3$	g / kg	38.1
Organic matter	g / kg	19.2
* Available K	mg / kg	190.5
* Available P	mg / kg	8.95
pH (1: 2.5 w/v soil : water suspension)		7.70
EC (dS / m, soil paste extract)		1.1
(Saturation percent)		68.2
Cations and anions in soil paste extract (mmolc/L):		
Na^+		4.20
K^+		0.31
Ca^{++}		2.97
Mg^{++}		2.73
$CO_3^=$		0.0
HCO_3^-		3.65
Cl^-		4.0
$SO_4^=$		2.56

Table 2. Field capacity, wilting point, available water and bulk density of the soil at various depths

Depth (cm)	**Field capacity (FC)**		**Wilting Point (WP)**		**Available water (AW)**		**Bulk density (BD) Mg/m^3**
	% by weight	**cm**	**% by weight**	**cm**	**% by weight**	**Cm**	
0-15	37.8	6.92	18.1	3.31	19.7	3.61	1.22
15-30	35.4	6.32	17.2	3.07	18.2	3.25	1.19
30-45	31.9	5.84	15.9	2.96	16.0	2.93	1.24
45-60	31.7	6.89	15.8	3.44	15.9	3.46	1.45
Total		**26.25**		**12.78**		**13.25**	

Soil physical analysis:

Particle size distribution was conducted using the pipette method and bulk density according to **Klute (1986)**. Soil moisture constant was determined using the pressure membrane apparatus, considering the saturation percent (SP) at KPa tension. Field capacity (FC) and wilting point (WP) at 0.33 and 15 bar, respectively. Available water is the difference between FC and WP **(Stackman, 1966).**

Soil chemical analysis:

1- Salinity of soil saturation extraction was measured in terms of electric conductivity (EC) in dS/m.

2- Cationic and anionic composition of the saturation extract of the soil were determined according to the standard methods described by **Richards (1954) and Jackson (1973):**

*- Soil pH was determined in the soil water suspension (1: 2.5 w/v soil: water) using aglass – electrode pH meter.

* Ca^{++} and Mg^{++} were measured by titration with versenate and Na^+ and K^+ were measured by flame photometer.

* CO_3^{--} and HCO_3^{-} were measured by titration with HCl.

* SO_4^{--} was calculated by subtraction.

Irrigation treatments were assigned in the main experimental plots and started 20 days after seedling transplanting. Irrigation water was practiced when the moisture content reached the desired soil moisture level in each treatment.

Soil moisture content was estimated gravimetrically at four depths of soil; 0-15, 15-30, 30-45 and 45-60 cmand computed periodically every two days. Soil moisture content was determined using a time domain reflectometry (TDR) sensor, which measures the volumetric soil moisture before and after each irrigation. The TDR is widely used to measure soil water content as described by **Dasberg and Dalton (1985).**

Table 3. Monthly and Seasonal applied irrigation water (m^3/fed.) to Marigold (*Tageteserecta*) in 2017 and 2018 seasons**.**

Months	**Applied irrigation water (m^3/fed.)**					
	2017			**2018**		
	I_1	**I_2**	**I_3**	**I_1**	**I_2**	**I_3**
April	302	201	201	292	195	195
May	586	391	293	617	411	308
June	827	591	473	816	583	466
July	1107	830	553	1056	792	528
August	883	631	378	861	615	369
Seasonal applied irrigation water (m^3/fed.)	**3704**	**2643**	**1898**	**3642**	**2596**	**1866**

There are three irrigation treatments as follows:

a:I_1 irrigation when 25% of available soil moisture was depleted (ASMD) wet

b:I_2 Irrigation when 50% of available soil moisture was depleted (ASMD) medium.

C:I_3 Irrigation when 75% of available soil moisture was depleted (ASMD) dry

Irrigation water applied (IWA):

Submerged flow orifice with fixed dimension was used to measure the amount of water applied, according to (Michael, 1978) as the following equation:

Q = CA

Where:

Q = discharge through orifice, (1/sec.).

C = coefficient of discharge, (0.61).

A= cross-sectional area of the orifice, cm^2.

g = acceleration due to gravity, cm^2/sec. (981 cm^2/sec.).

h = pressure head, causing discharge through the orifice, cm.

Crop water productivity (WP)

WP is defined as crop yield per unit applied irrigation water that is looking into the efficient use of applied irrigation water **(Zhang, 2003)** and is given as follow:

$$WP = \frac{\text{Biomass (kg/fed.)}}{\text{Seasonal AIW (m}^3\text{ water applied/fed.)}}$$

II. Potassium silicate (26.6%K_2O and 10.4 SO_3) was obtained from Fam. trade company, Egypt, and applied as foliar spray in three doses at 30 days interval after transplanting to the field, at the rates of 0.0, 2.0 and 4.0 mlL^{-1}. The leaf surfaces of the plants were totally wetted with potassium silicate solation till run off in afternoon just before sunset using a handheld sprayer. This treatment was assigned in a sub-plots. All plants received mineral fertilization NPK as ammonium sulphate (20.5%N) at the rate of 80Kg/feddan, triple superphosphate (15.8% P i.e. 37%P_2O_5) 75 kg/feddan and potassium sulphate (22kg K_2O) 50Kg K_2SO_4/feddan.

Nitrogen and potassium were given in three equal doses during growth while phosphorus was added to the soil during soil preparation. All other agricultural practices were performed when needed. Harvesting was carried out on 1st and 5th September in the first and the second seasons, respectively.

The layout of the experiments was split-plot design in random arrangement with two factors. The first factor (A) was irrigation levels were designed as in the main plots and the second factor (B) potassium silicate treatments were randomly arranged in the sub- plots, the experiments in included two plant species *Tageteserecta* 6 treatments of each with three replicates each replicate consist of 9 plants.

III. 3. Recorded Data:

III.3.1. Vegetative growth parameters:

1- Plant height (cm).
2- Number of branches. $plant^{-1}$.
3- Number of leaves. $Plant^{-1}$.
4- Biomass fresh weight. $Plant^{-1}$(g)(Sum of total vegetative parts including shoots and leaves $plant^{-1}$).
5- Biomass dry weight. $Plant^{-1}$(g)(Sum of total vegetative parts including shoots and leaves $plant^{-1}$).

III.3.2. Root growth parameters:

1- Root length (cm) the length of tallest root.
2- Root fresh weight. $plant^{-1}$(g).
3- Root dry weight. $plant^{-1}$(g).

III.3.3. Flowering parameters:

1- Length of flower pedicel (cm).
2- Number of flowers. $plant^{-1}$.
3- Flower diameter (cm).
4- Flower fresh weight. $plant^{-1}$.
5- Flower dry weight. $plant^{-1}$.

III.4. Chemical composition parameters:

III.4.1. Total carbohydrate content (mg.100g d.w.) was determined using colorimetric method of **Herbert *et al.*, (1971).**

III. 4.3 chlorophyll "a" content in the fresh leaves (mg.100g f.w.)

III. 4.3 chlorophyll "b" content in the fresh leaves (mg.100g f.w.)

III.4.4 Carotenoids content in the fresh leaves (mg.100g f.w.) were determined in fresh leaves using the described by **Wettsteine (1957).**

III.5. Statistical analysis:

The means of all obtained date from the studied factors were subjected to analysis of variance (ANOVA) as sub-plot experiments. The differences between the mean values of various treatments were compared by using the least significant difference (L.S.D) at 0.05% as given by **Snedecor and Cochran (1989)** using MSTAT-C statistical software package.

Results and Discussion

1- Effect of irrigation levels (drought stress) and potassium silicate (K_2SiO_3) sprays and their interaction treatmentsofMarigold on vegetative growth characters:

1.1. Plant height (cm):

Data presentedin Table (4) illustrated that,plant height of Marigold were significantly affected by irrigation levels (drought stress) of both seasons.It can be concluded that plant heights (cm) were significantly increased length of the plant with increasing soil moisture. The values were as follows: (141, 97.56 and 81.78 cm in the first season and 140.3, 117.2 and 87.68 cm in the second season) byirrigation levels when the percentages of available soil moisture were depleted to 25, 50 and 75%, respectively**.**On the other side, plant heights (cm) were significantly affected by of potassium silicate spray.All spray treatments were significantly better than control (spraying with distilled water) and the highest value for plant height was gained by spraying potassium silicate Si_4 (4mlL^{-1}). Furthermore, the combined treatments between irrigation levels and potassium silicate sprays showed that the maximum increment in plant height of Marigold was noticed when plants received the level of available moisture I_1 (25% ASMD) and sprayed with potassium silicate 4.0 mlL^{-1} (plant height 146.7 & 166.3 cm), while these values wereminimum in Marigold (69.67 & 45.67 cm) at I_3 and sprayed with distilled water(0.0 potassium silicate) in both season.

Table 4. Effect of irrigation levels (drought stress), potassium silicate and their interaction treatments on plant height (cm), number of branches plant-1 and number of leaves plant-1 of Marigold (*Tageteserecta*) in 2017 and 2018 seasons**.**

Character	Plant height (cm)				No. of branches plant-1				No. of leaves plant-1			
	Potassium silicate (B)			Mean	Potassium silicate (B)			Mean	Potassium silicate (B)			Mean
Irrigation(A)	0.0mlL-1	2.0 mlL-1	4.0 mlL-1		0.0ml L-1	2.0 mlL-1	4.0 mlL-1		0.0 mlL-1	2.0 mlL-1	4.0 mlL-1	
					First season; 2017							
I1 (25 % ASMD)	131.3	145.0	146.7	**141.0**	6.67	8.00	8.67	**7.78**	266.0	377.0	500.7	**381.2**
I2 (50 % ASMD)	86.00	102.0	104.7	**97.56**	4.33	5.33	5.33	**5.00**	255.0	260.7	370.7	**295.5**
I4(75 % ASMD)	69.67	84.67	91.00	**81.78**	3.00	4.00	5.33	**4.11**	165.0	201.3	307.3	**224.5**
Mean	**95.67**	**110.6**	**114.1**		**4.67**	**5.78**	**6.44**		**228.7**	**279.7**	**392.9**	
L.S.D. *p* ≤ 0.05	**A = 2.942; B = 2.942 & Ax B = 5.095**				**A = 0.978, B = 0.978, A x B =1.694**				**A= 3.822, B= 3.822, A x B = 6.620**			
					Second season; 2018							
I1 (25 % ASMD)	112.7	142.0	166.3	**140.3**	6.00	7.00	7.33	**6.78**	268.0	404.0	521.0	**397.7**
I2(50 % ASMD)	93.00	129.0	129.7	**117.2**	4.67	6.00	6.67	**5.78**	230	283.7	432.3	**315.3**
I3(75 % ASMD)	45.67	90.67	126.7	**87.67**	2.67	3.33	3.67	**3.22**	172.3	250.0	376.0	**266.1**
Mean	**83.78**	**120.6**	**140.9**		**4.44**	**5.44**	**5.89**		**223.4**	**312.6**	**443.1**	
L.S.D. *p* ≤ 0.05	**A = 3.077; B = 3.077 & A x B = 5.329**				**A = 0.919, B = 0.919, A x B = 1.591**				**A=3.887, B =3.887, A x B = 6.733**			

(% ASMD): Percentage of available soil moisture depletion.

1.2. Number of branchesPlant-1

Data presented in Table (4) showed thatthe number of branches plant-1increased with increasingpercentage of available soil moisturecontent at I_1 25 % followed by 50 % (I_2), whilethe number of branches decreased at 75% depletion of available soil moisture (I_3) butthere wasno significant difference between I_2 and I_3 in the first season. On the other hand, the number of branches plant-1 was progressively increased with increasing concentration of potassium silicate foliar sprays. However, the treatment of potassium silicate at 4.0-1 was superior than the treatment of potassium silicate at 2.0 mlL-1 in the first season but had no significant difference in the second one. Additionally number of branches were greatly increases by increases water quantity I_1 (25% ASMD) and potassium silicate treatment (4.0 mlL-1) as compared with I_3 (75% ASMD) and control (distilled water) in both season.

1.3. Number of leaves. Plant-1:

Data in Table (4) showed that the number of leaves. plant-1of Marigold was enhanced by increasingquantity of available soil moisture content I_1 25% ASMD followed by I_2 50% ASMD. Whereas, Marigold plants gave the greatest number of leaves when sprayed with potassium silicate 4.0 mlL-1 , while the lowest number of leaves was gained with control (sprayed with distilled water). On the other hand, the interaction between the highest irrigation water level (I_1 25%ASMD) and potassium silicate at 4.0 mlL-1 produced the greatest number of leaves as compared with I_3 (75% ASMD) and 0.0 potassium silicate (spray with distilled water) in both seasons.

1.4. Biomass of fresh weight (g).

Data presented in Table (5) demonstrated that, overall growthof plants was effected by the drought stress, where droughthad highly significant effect on shoot fresh weight, There was again adecreasing trend of shoot fresh weight with the increase in drought stress, maximum biomassfresh were at I_1 (25 % ASMD)irrigation when depleted 25% of available soil moisture in 1stand 2nd seasons. On the other hand,the fresh weight decreased with the treatment of control (without spraying) and the superiority of spraying with potassium silicate Si_4 (4mlL-1) over spraying with potassium silicate Si_2 (2mlL-1). There was an interaction where there was no significant difference between the treatment of (I_1) irrigation when depletion 25% of available soil moisture and (I_2) irrigation when depletion 50% of available soil moisture under

Table 5. Effect of irrigation levels (drought stress), potassium silicate and their interaction treatments on biomass fresh and dry weight plant^{-1} (gm) of Marigold (*Tageteserecta*) in 2017 and 2018 seasons.

Character	**Biomass fresh weight plant^{-1}(gm)**				**Biomass dry weight plant^{-1}(gm)**			
	Potassium silicate (B)			**Mean**	**Potassium silicate (B)**			**Mean**
Irrigation (A)	**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**		**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**	
				First season 2017				
I_1 (25 % ASMD)	103.3	110.0	364.0	**192.4**	35.33	40.17	53.60	**43.03**
I_2 (50 % ASMD)	77.63	105.3	206.0	**129.6**	29.23	32.33	57.97	**39.84**
I_3 (75 % ASMD)	69.67	94.77	79.80	**81.4**	19.33	21.70	22.80	**21.28**
Mean	**83.55**	**103.4**	**216.60**		**27.96**	**31.40**	**44.79**	
L.S.D. $p \leq 0.05$	**A=3.353, B=3.353, A x B=5.807**				**A=2.102, B=2.102, A x B=3.64**			
				Second season 2018				
I_1 (25 % ASMD)	128.0	132.50	227.4	**162.6**	25.30	26.67	36.33	**29.43**
I_2 (50 % ASMD)	91.50	107.7	138.13	**112.44**	23.60	29.13	33.63	**28.79**
I_3 (75 % ASMD)	21.70	78.17	85.23	**61.70**	13.10	24.1	33.63	**23.61**
Mean	**80.40**	**106.1**	**150.25**		**20.67**	**26.63**	**34.53**	
L.S.D. $p \leq 0.05$	**A=3.231, B=3.231, A x B=5.596**				**A=1.948, B=1.948, A x B=3.373**			

(% ASMD): percentage of available soil moisture depletion.

the spraying with potassium silicate Si_2 (2mlL^{-1}) in the first season. Moreover, there was interaction where there was no significant difference between spraying potassium silicate $SI_2$and Si_0 (control)under (I_1) irrigation when depletion 25% of available soil moisture in the second season.Furthermore, the interaction between the two factors(A & B) showed that potassium silicate sprays enhanced the biomass fresh weight and induced the highest values (364.0 & 227.4) in marigold especially plants were treated with potassium silicate treatment (4ml L^{-1}) as compared with control in both seasons, respectively.

1.5. Biomass dry weight (g)

Data presented in Table (5) showed that, dry weight increased with (I_1) irrigation when depleted 25% of available soil moisture follow (I_2) irrigation when depleted 50% depletion of available soil moisture but there was no significant difference between them in the second season anddry weight decreased with (I_3) irrigation when depleted 75% of available soil moisture. As for spraying, the dry weight decreased with the treatment of control (without spraying) and the superiority of spraying with potassium silicate Si_4 (4ml L-1) over spraying with potassium silicate Si_2 (2ml L-1)in the two seasons. In addition, there was an interaction where there was no significant difference between spraying with SI_4 (4ml L-1), Si_2 (2mlL^{-1}) and Si_0 (0ml L-1) potassium silicate under (I_3) irrigation when depleted (75%) of available soil moisture in the first season.Furthermore, marigold plants were sprayed with potassium silicate treatment (4ml L^{-1}) and irrigated at I_1 (75 % ASMD) induced high significant effect in biomass dry weight values (57.97 & 36.33) in marigold as compared with control in both seasons, respectively.

Production of dry mass is directly related to the amount of water transpired as there is reduction in growth of plants by alerting either the efficiency withwhich photosynthesis aid to new growth or the rate atwhich they are used in maintaining the existing dry matter**Dubey, 1997**). Similar results were also reported by **Ibrahim *et al.*,(2015)** onFahl Egyptian Clove,and **Dhanasekaran*et al.*,(2019)**on zinnia and petunia.

2. Flowers characters:

2.1 Number of flowers.plant^{-1} .

Data presented in Table (6) declared that, there was an increase in the number of flowers / plants with the treatment of (I_2) irrigation when depletion 50% of available soil moisture Follow (I_1) 25% and the number of flowers / plants decreased (I_3) irrigation when depletion 75% of available soil moisture. As for the potassium silicate spray treatments, the number of flowers / plants decreased with the control treatment (without spraying) and the Si_4 (4ml L-1) potassium silicate spray was superior to the Si_2 (2ml L-1). On the other hand, there was an interaction where there was no significant difference between spraying potassium silicate SI_0, Si_2 under (I_1) irrigation when depletion 25%, of available soil moisture in the first and second season. The interaction of both factors (A & B) significantly raised the values of No. of flowers/plant (68.0 &72.0) of two species in all seasons.

Similar results also reported by **Javid, (2005**) that highest number of flowers plant^{-1}was obtained when the plots received 20 gKm^{-2}. Potassium plays a significant role in the transport of water and nutrients in plant xylem. The result also in line with **Pal and Ghosh (2010)** who find out that yield of flowers in African marigold (*Tageteserecta* L.)

2.2. Flower diameter (cm)

Data in Table (6) stated that, the effect of irrigation treatments, there was an increase in the diameter of the flower (cm) with the treatment of (I_1) irrigation when depletion 25%, of available soil moisture and (I_2) irrigation when depletion 50%, of available soil moisture but there was no significant difference between them in the first and second season.As for the potassium silicate spray treatments, the flower diameter (cm) decreased with the control treatment (without spraying) and the Si_4 potassium silicate spray (4ml L-1) outperformed the Si_2 potassium silicate spray (2ml L-1), but there was no significant difference between them in the second season. There was a interaction where the treatment of irrigation with (I_2) irrigation when depletion 50% of available soil moisture go one better than (I_1) irrigation when depletion25%, of available soil moisture under the treatment of control treatment (without spraying) in the second season. On the other hand, there was an interaction where there was no significant difference between spraying with SI_4, Si_2 potassium silicate under (I_2) irrigation when depletion 50%, of available soil moisture in the first season. Maximum flower diameter (7.67 & 6.67 cm) was noticed in plots were irrigated at I_1 (25 % ASMD)., and treated potassium silicate treatment (4ml L^{-1}) for marigold in both seasons, while flower diameter was reduced by increasing drought stress.

Table 6. Effect of irrigation levels(drought stress), potassium silicate and their interaction treatments on number of flowers $plant^{-1}$. Flower diameter (cm) and flower pedicel length(cm) of Marigold (*Tageteserecta*) in 2017 and 2018 seasons**.**

Character	**No. of flowers $plant^{-1}$**				**Flower diameter (cm)**				**Flower pedicel length (cm)**			
	Potassium silicate (B)			**Mean**	**Potassium silicate (B)**			**Mean**	**Potassium silicate (B)**			**Mean**
Irrigation(A)	**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**		**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**		**0.0 ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**	
First season; 2017												
I_1 (25 % ASMD)	20.00	29.33	68.00	**39.11**	5.83	6.33	7.67	**6.61**	26.67	26.00	27.33	**26.67**
I_2(50 % ASMD)	16.67	25.00	50.67	**30.78**	5.67	6.67	7.00	**6.45**	7.67	11.00	11.00	**9.89**
I_3(75 % ASMD)	10.33	16.33	27.00	**17.89**	2.70	3.03	3.23	**2.99**	3.08	9.34	14.33	**8.92**
Mean	**15.67**	**23.56**	**48.56**		**4.56**	**5.34**	**5.97**		**12.47**	**15.45**	**17.55**	
L.S.D. $p \le 0.05$	**A=2.637, B=2.637, A x B=4.568**				**A=0.2188, B=2.188, A x B=0.379**				**A = 1.254; B = 1.254 & A x B = 2.171**			
Second season; 2018												
I_1 (25 % ASMD)	21.00	36.00	72.00	**43.00**	5.40	6.57	6.67	**6.21**	16.33	20.00	21.67	**19.33**
I_2(50 % ASMD)	12.67	26.33	33.00	**24.00**	6.00	6.07	6.23	**6.10**	10.34	12.00	17.00	**13.11**
I_3(75 % ASMD)	14.00	19.67	23.00	**18.89**	2.77	3.47	3.23	**3.16**	9.33	9.67	12.33	**10.44**
Mean	**15.89**	**27.33**	**42.67**		**4.72**	**5.37**	**5.38**		**12.00**	**13.89**	**17.00**	
L.S.D. $p \le 0.05$	**A=2.709, B=2.709, A x B=4.692**				**A=0.289, B=0.289, A x B=0.501**				**A = 1.170; B; 1.170 & A x B = 2.027**			

(% ASMD) : percentages of available soil moisture depletion

2.3. Flower pedicel length (cm)

Data in Table (6) showed that, flower pedicel length irrigation gave I_1 (ASMD 25%) the best significantly length in the flower pedicel and then followed I_2 and I_3, which there was no significant difference between them in the first season. The main effect of potassium silicate spray all spray treatments were significantly better than control (without spraying) and the best length was with the flower pedicel by spraying potassium silicate Si_4 (4 ml L-1). However,the highest values of flower pedicel length values i.e., (27.33 & 21.67 cm) were observed in both seasons when were sprayed with 4ml L-1 potassium silicate and grown under control condition I_1 (25 % ASMD) , while these values were minimum in marigold (3.08 & 9.33 cm) at I_3 (75 % ASMD) and sprayed with potassium silicate treatment (0.0 %) in both seasons.

Siapplication could have contributed to increased turgor pressure within the flower, resulting in cell swelling and thus larger flower diameters.**)**additionally, potassium ions stimulate petal cell expansion **Wong *et al* .,(1989)**. Similar results were found in a study on Impatiens and Pelargonium (**Noor *et al.*, (2014)**on *Zinnia elegans*,**Seyyedeh*et al.*,(2016)** on Zinnia plant.

2.4. Flower fresh weight (g) plant^{-1}

Data in Table (7) showed that, weight of fresh flowers g/plant increased with the treatment of irrigation (I_1) irrigation when depleted 25% of available soil moisture, followed (I_2) irrigation when depleted 50% . Meanwhile, the fresh weight of flowers decreased with the treatment of control (without spraying) and the superiority of spraying with potassium silicate Si_4 (4ml L-1) over spraying with potassium silicate Si_2 (2ml L-1).The heaviest flower fresh weight (65.30 & 46.33) were achieved when marigold plots were irrigated at I_1 (25 % ASMD) and sprayed with potassium silicate Si_4 (4ml L-1) in both seasons, respectively.

2.5. Flower dry weight (g) plant^{-1}

Data presented in Table (7) illustrated that, dry weight of flowers increased with (I_1) irrigation when depleted 25% of available soil moisture follow (I_2) irrigation when depleted 50% depletion. As for spraying, the dry weight **of** flowers decreased with the treatment of control (without spraying) and the superiority of spraying with potassium silicate Si_4 (4ml L-1) over spraying with potassium silicate Si_2 (2ml L-1).Also,maximumflower dry weight (gm) plant^{-1} values were (18.47 & 16.73) for marigold in both seasons.

These observations go in line with those obtainedby, **Noor *et al.*, (2014)** on zinnia and, **Seyyedeh*et al.*, (2016)** on zinnia plant.

Table 7. Effect of irrigation levels(drought stress), potassium silicate and their interaction treatments on flowers fresh weight plant^{-1} (g) and flowers dry weight plant^{-1} (g) of Marigold (*Tageteserecta*) in 2017 and 2018 seasons.

Character	Flowers fresh weight plant^{-1} (gm)				Flowers dry weight plant^{-1} (gm)			
	Potassium silicate (B)			Mean	Potassium silicate (B)			Mean
Irrigation(A)	0.0ml L^{-1}	2.0 ml L^{-1}	4.0 ml L^{-1}		0.0ml L^{-1}	2.0 ml L^{-1}	4.0 ml L^{-1}	
	First season; 2017							
I_1 (25 % ASMD)	30.57	55.67	65.30	**50.51**	7.07	13.9	18.47	**13.15**
I_2 (50 % ASMD)	26.67	38.40	48.00	**37.69**	4.67	7.67	15.6	**9.31**
I_3 (75 % ASMD)	12.90	23.83	35.67	**24.13**	3.33	5.73	11.43	**6.83**
Mean	**23.38**	**39.30**	**49.66**		**5.02**	**9.10**	**15.17**	
L.S.D. $p \leq 0.05$	**A=2.471 , B=2.471, A X B=4.281**				**A=1.209 ,B=1.209,A XB=2.094**			
	Second season; 2018							
I_1 (25 % ASMD)	18.43	37.00	46.33	**33.92**	6.1	12.57	16.73	**11.80**
I_2 (50 % ASMD)	11.27	30.17	42.67	**28.04**	5.87	7.53	14.67	**9.36**
I_3 (75 % ASMD)	10.63	23.73	37.07	**23.81**	3.23	4.33	6.07	**4.54**
Mean	**13.44**	**30.30**	**42.02**		**5.07**	**8.14**	**12.49**	
L.S.D. $p \leq 0.05$	**A=2.259, B=2.259, A x B=3.913**				**A=1.104, B=1.104, A x B=1.913**			

(% ASMD): percentage of available soil moisture depletion.

3.1 Root parameters:

3.1. Root length (cm)

Data presented in Table (8) illustrated that, The main effect of irrigation treatments shows that increased length of the root with increasing soil moisture but no significant difference between irrigation when depletion (I_1) 25 and (I_2) 50 % of available soil moisture . spray potassium silicate succeeded in significantly increasing better than control (without spraying) and the highest value for plant length was by spraying potassium silicate Si_4 (4m / L-1) then followed Si_2 (2m / L-1) and the lowest value by the control (0.0 m / L-1). Interaction between irrigation and sprinkling there was no significant difference between irrigation when depleted I_1 (25%), I_2 (50%) and I_3 (75%) of available soil moisture under the spray with potassium silicate Si_2 (2 ml L-1) and Si_0 (0.0 ml L-1) in the first season. On the other hand, there was no significant difference between spraying with potassium silicate SI_2 (2 ml L-1) and Si_4 (4 ml L-1) under I_1 irrigation when depleted 25% of available soil moisture in the second season.

3.2. Root fresh weight (g)

Data presented in Table (8) demonstrated that, fresh weight of root (g)increased with irrigation treatment (I_1) irrigation when depleted 25% of available soil moisture, follow (I_2) irrigation when depleted 50% of available soil moisture in the first season but there was no difference between irrigation when depleted 25% and 50% of available soil moisturein the second seasons. As for the spraying treatments, the fresh weight decreased with the treatment of control (without spraying) and the spraying with potassium silicate Si_4 (4ml L-1) was superior to spraying with potassium silicate Si_2 (2ml L-1)in both seasons. There was a interaction where superiority the treatment of (I_2) irrigation when depleted 50% of available soil moisture on (I_1) irrigation when depleted 25% depletion of available soil moisture under spraying with Si_2 potassium silicate (2ml L-1) in the second season. On the other hand, there was a interaction where there was no difference between spraying potassium silicate and Si_2 (2ml L-1) and Si $_0$ (0.0ml L-1) under irrigation when depleted (I_3) 75% of available soil moisture in the first season.

3.3. Root dry weight (g)

Data presented in Table (8) showed that dry weight of root (g) increased with (I_1) irrigation when depleted 25% of available soil moisture follow (I_2) irrigation when depleted 50% depletion of available soil moisture but there was no significant difference between them in the first season only. As for spraying, the dry weight decreased with the treatment of control

Table 8. Effect ofirrigation levels(drought stress), potassium silicate and their interaction treatmentsroot length plant^{-1}(cm), fresh weight of root plant^{-1}(gm) and dry weight of root plant^{-1} (gm) of Marigold (*Tageteserecta*) in 2017 and 2018 seasons.

Character	Root length plant^{-1} (cm)				Fresh weight of root plant^{-1} (gm)				Dry weight of root plant^{-1} (gm)			
	Potassium silicate (B)			Mean	Potassium silicate (B)			Mean	Potassium silicate (B)			Mean
Irrigation(A)	0.0ml L^{-1}	2.0 ml L^{-1}	4.0 ml L^{-1}		0.0ml L^{-1}	2.0 ml L^{-1}	4.0 ml L^{-1}		0.0 ml L^{-1}	2.0 ml L^{-1}	4.0 ml L^{-1}	
	First season; 2017											
I_1 (25 % ASMD)	17.10	18.30	20.53	**18.64**	18.10	31.33	36.60	**28.68**	7.57	15.13	18.13	**13.61**
I_2(50 % ASMD)	15.20	18.57	20.67	**18.15**	17.90	21.80	28.77	**22.82**	8.77	12.33	17.3	**12.80**
I_3(75 % ASMD)	15.10	17.00	18.17	**16.76**	9.53	11.77	23.70	**15.00**	4.47	5.1	6.47	**5.35**
Mean	**15.80**	**17.96**	**19.79**		**15.18**	**21.63**	**29.69**		**6.94**	**10.85**	**13.97**	
L.S.D. $p \le 0.05$	**A=1.1630, B=1.1630, A x B=2.015**				**A=1.438, B=1.438, A x B=2.490**				**A=1.706, B=1.706, A x B=2.955**			
	Second season; 2018											
I_1 (25 % ASMD)	16.00	23.00	24.00	**21.00**	25.40	31.17	37.63	**31.40**	10.44	13.77	23.67	**15.86**
I_2(50 % ASMD)	20.67	21.33	24.33	**22.11**	20.47	34.93	37.73	**31.04**	8.65	15.83	16.10	**13.53**
I_3(75 % ASMD)	15.33	16.33	20.00	**17.22**	9.23	20.00	24.07	**17.77**	5.70	7.40	8.30	**7.13**
Mean	**17.33**	**20.22**	**22.78**		**18.37**	**28.70**	**33.14**		**8.26**	**12.33**	**16.02**	
L.S.D. $p \le 0.05$	**A= 1.211, B= 1.211, A x B = 2.098**				**A=1.497, B=1.497, A x B=2.594**				**A=1.984, B=1.984, A x B=3.436**			

(% ASMD) : precentag of available soil moisture was depletion.

(without spraying) and the superiority of spraying with potassium silicate Si_4 (4ml L-1) over spraying with potassium silicate Si_2 (2ml L-1). There was an interaction where there was no significant difference between the treatment of (I_2) irrigation when depletion 50% of available soil moisture and (I_3) irrigation when depletion 75% of available soil moisture under the spraying with potassium silicate Si_0 (0.0ml L-1) in the second season.On the other side, there was an interaction where there was no significant difference between spraying with SI_4 (4ml L-1) and Si_2 (2ml L-1) potassium silicate under irrigation when depleted 50% and 75% of available soil moisture in the second season. The reason for better performance of marigold could be that its root system might have developed certain mechanism to cope with drought stress. Potassium silicate significantly enhanced the reduction of root length, fresh and dry weight.Potassium is a key nutrient in the development of new root growth **(McAfee, 2008). Passioura (1982)** also reported that the reduction in the growth of the roots due to low water supply includes the root characteristics especially root length,root density and root thickness. Root system that enhances the ability of a plant to capture water is a fundamental adaptation mechanism to drought.

4.Chemical composition:

4.1. Carbohydrates content %

Data presented in Table (9) showed that,carbohydrates content %increased with(I_1) irrigation when depleted 25% of available soil moisture follow (I_2) irrigation when depleted 50%

of available soil moisture.As for the potassium silicate spray treatments, the carbohydrates content % was decreased with the control treatment (without spraying) and the Si_4 potassium

Table 9. Effect of irrigation levels, potassium silicate and their interaction treatments on carbohydrates content of marigold (*Tageteserecta*) in (2017 and 2018) seasons.

Character	**Carbohydrates content**			
	Potassium silicate (B)			
Irrigation(A)	**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**	**Mean**
	First season; 2017			
I_1 (25 % ASMD)	22.92	24.35	25.92	**24.40**
I_2(50 % ASMD)	21.86	24.42	24.22	**23.50**
I_3(75 % ASMD)	20.42	21.92	22.95	**21.77**
Mean	**21.74**	**23.57**	**24.37**	
L.S.D. $p \leq 0.05$ for the interaction A x B	**A=0.1187, B=0.1187, A x B=0.206**			
	Second season; 2018			
I_1 (25 % ASMD)	23.69	25.12	26.69	**25.17**
I_2(50 % ASMD)	22.63	25.19	24.99	**24.27**
I_3(75 % ASMD)	21.19	22.69	23.72	**22.53**
Mean	**22.50**	**24.33**	**25.13**	
L.S.D. $p \leq 0.05$ for the interaction A x B	**A=0.147, B=0.147, A x B=0.255**			

(% ASMD) : percentage of available soil moisture was depletion.

silicate spray (4 ml L-1) was superior to the Si_2 potassium silicate spray (2m / L-1) in the first and the second seasons.The high value of carbohydrate (25.92 and 26.69 %) as affectedby irrigation with I_1 (25 % ASMD) and 4 ml L^{-1} potassiumsilicate spray for in both seasons for marigold.In this respect, potassium increases carbon exchange and enhances carbohydrate movement (**Collins and Duke, 1981).Noor et al (2014)** on zinnia and **Hoda I.M. Ibrahim *et al.*, (2015)** on Fahl Egyptian Clover.

4.2. Chlorophyll a&b and carotenoids content %.

Data presented in Table (10) showed that, chl.a&b content %.content % increased with(I_1) irrigation when depleted 25% of available soil moisture follow (I_2) irrigation when depleted 50% of available soil moisture. Chlorophyll A&B content % decreased (I_3) irrigation when depleted 75% of available soil moisture. **t**he chlorophyll A&B content % was decreased with the control treatment (without spraying) and the Si_4 potassium silicate spray (4 ml L-1) was superior to the Si_2 potassium silicate spray (2m / L-1).On the other hand, there was a interaction where both potassium silicate spray treatments SI_4(4ml L-1) and Si_2 (2ml L-1) were similar under dry irrigation (I_3) 75% depletion of available soil moisture.

These results are inagreement with some earlier studies by **Sivanesan*et al.*, (2013)** mentioned that,, the chlorophyll content in the leaves of chrysanthemum cultivars increased along with the increase of Si concentration in the nutrient solution supplemented to plants and**Dębicz*et al.*, (2016)** on*Gazaniarigens*

4.3. Carotenoids content%

Data presented in Table (10) stated that, ,carotenoids content % significantly was decreased by increasing drought stress. High values of carotenoids content wereby (I_1) irrigation when depleted 25%.carotenoids content % was decreased with the control treatment (without spraying) and the Si_4 potassium silicate spray (4 ml L-1) was superior to the Si_2 potassium silicate spray (2m / L-1) On the other hand, there was a interaction where both potassium silicate spray treatments SI_0(0.0ml L-1) and Si_2 (2ml L-1) were similar under irrigation 25 and 50% depletion of available soil moisture.

Conclusively it could be concluded that foliar application potassium silicate (0.0,2,4 ml L-1) may be an effective strategy in reducing drought stress treatments (25, 50 and 75 % ASMD) effects with superior for at 4 ml L-1 which enhanced all parameters were studied. marigold (*Tageteserecta* L.) plant. Therefore, application of K_2SiO_3 sprays is recommended for improving growth, physical and chemical composition of marigold under water-stress conditions, highest irrigation rate (25% ASMD.) has the lowest economic water productivity and potassium silicate sprays could alleviate water stress.

Table 10. Effect of irrigation levels, potassium silicate and their interaction treatments on Chlorophyll a , b and Carotenoids content fresh leaves of marigold (*Tageteserecta*) in 2018 season.

Character	**Chlorophyll a (Mg/100g f.w.)**				**Chlorophyll b (Mg/100g f.w.)**				**Carotenoids (Mg/100g f.w.)**			
	Potassium silicate (B)			**Mean**	**Potassium silicate (B)**			**Mean**	**Potassium silicate (B)**			**Mean**
Irrigation (A)	**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**		**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**		**0.0ml L^{-1}**	**2.0 ml L^{-1}**	**4.0 ml L^{-1}**	
I_1 (25 % ASMD)	16.00	14.17	16.67	**15.61**	13.33	11.33	14.33	**13.00**	3.17	3.00	3.32	**3.16**
I_2(50 % ASMD)	9.83	15.33	15.57	**13.58**	7.83	12.67	12.12	**10.87**	2.08	2.36	3.08	
I_3(75 % ASMD)	8.33	9.25	15.33	**10.97**	7.33	8.50	13.00	**9.61**	1.67	2.33	1.67	**1.89**
Mean	**11.39**	**12.92**	**15.86**		**9.50**	**10.83**	**13.15**		**2.31**	**2.56**	**2.70**	
L.S.D. $p \leq 0.05$ for the interaction	**A=0.766, B=0.766, A x B=1.327**				**A=0.451, B=0.451, A x B=0.782**				**A=0.140, B=0.140, A x B=0.243**			

(% ASMD) : precentag of available soil moisture was depletion.

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تأثير مستويات الري في ظل وجود معاملات الرش بسيليكات البوتاسيوم على النمو والتزهير والمكونات الكيميائية لنبات القطيفة *Tageteserecta* L

صفاء مصطفى محمد[1] ، ايمان مختار ابو الغيط[1] ، مصطفى سيد عودة[2]، ايمان السيد عبد الحميد عامر[2]

[1]قسم البساتين – كليه الزراعه – جامعه بنها –مصر

[2]قسم الزينة – معهد بحوث البساتين–مركز البحوث الزراعية– مصر

أجريت التجربة الحقلية في المشتل والمزرعة التجريبية بمحطة بحوث القناطر الخيريةمحافظة القليوبية ،مصر ، بالتعاون مع قسم البساتين بكلية الزراعة جامعة بنها خلال موسمي النمو المتتاليين 2017 و 2018. يهدف هذا العمل إلى دراسة مدى إستجابة نباتات القطيفة إلى تقنين كميات مياه الرى إلى ثلاث معدلات عند إستنفاد مستويات مختلفة من الماء الميسر وهى إستنفاد 25% من الماء الميسر وإستنفاد 50% من الماء الميسر وإستنفاد 75% من الماء الميسر بمفردها أو بالتاخل مع معاملات الرش بسليكات البوتاسيوم عند معدلات صفر، 2، 4 مل/لتر على الصفات الخضرية والجذرية والزهرية والكربوهيدرات الكلية والكلورفيل أ ، ب والكاروتينيدات لنباتات القطيفة ولقد تأثرت القياسات الخضرية وهى إرتفاع النبات وعدد الأفرع وعدد الأوراق والوزن الطازج والجاف وأدت المعاملة عند إستنفاذ 25% من الماء الميسر مع الرش بسيليكات البوتاسيوم إلى أعلى القيم وأيضاً فى طول الجذر ووزن الجذور الطازج والجاف كما أدت هذه المعاملة إلى زيادة فى طول عنق الأزهار وزيادة عدد الأزهار وقطر الزهرة كما أدت إلى زيادة فى محتوى النباتات من الكربوهيدرات الكلية وكلورفيل أ، ب والكاروتينات ويوصى بإستخدام سليكات البوتاسيوم لتحسين ظروف الإجهاد المائى لنباتات القطيفة.