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RESPONSE OF *TAGETES PATULA* PLANTS TO FOLIAR APPLICATION OF POTASSIUM SILICATE AND SEAWEED EXTRACT UNDER VARIOUS IRRIGATION INTERVALS

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ABSTRACT: This study was carried out during the two successive seasons of 2018 and 2019 at Somosta, Beni-Suef Governorate, Egypt, to evaluate the effect of irrigation intervals, foliar application of potassium silicate and seaweed extract on vegetative and flowering growth parameters and essential oil percentage of *Tagetes patula* plants. Plant height (cm), number of branches, stem diameter (mm), leaf area (cm^2), plant fresh and dry weights (g), flowering date, number of inflorescences/plant, inflorescence diameter (cm), inflorescence fresh and dry weights/plant (g) and vase life/days were significantly decreased with rising intervals of irrigation. Irrigation regime of four days interval gave the earliest flowering. The results cleared that, foliar applications of seaweeds extract at 3 ml/l and 5 ml/l, potassium silicate at 3 ml/l and 5 ml/l significantly affected all studied parameters compared with control. The magnitude of increase is more pronounced by applying combination between potassium silicate and seaweed extract treatments at the high concentration. The most pronounced effect for the interaction was that found between potassium silicate at 5 ml/l plus seaweeds extract at 5 ml/l when plants irrigated every one or two days where the highest vegetative and flowering growth parameters and essential oil percentage were recorded in both seasons. So, it is advisable, to reduce the effect of drought stress, treating tagetes plants with high concentration of potassium silicate and/or seaweed extract each at 5 ml/l.

Key words: *Tagetes patula,* irrigation intervals, potassium silicate, seaweed extract.

INTRODUCTION

The tagetes genus consists of around 40-50 species and follows to the Asteraceae family (Lawrence, 1985). It has a pretty commercial flower that is gaining status because of its wide range of adaptation and increasing demand in wide area of the world (Asif, 2008). It is also one of the most important herbaceous ornamental with aromatic scent. It is highly ornamental in flowerbeds for mass display, pots, borders and may be used effectively in window and porch boxes (Nau, 1997). The flowers are used in medicines and pharmaceuticals, processed foods, confectionery and in the poultry industry. As an antiparasitic, antispasmodic, antibiotic, antimicrobial and antiseptic, its essential oil is successful (Chowdhury *et al.*, 2009).

Drought is considered to be one of the most significant factors restricting the development of plants in arid and semi-arid zones (Ehdaie, 1995), where a wide range of temperature variability and climate changes are encountered in certain areas. Under such conditions, lower yields and lower efficiency of water use occur, particularly in the context of water volume evaporation from year to year (Owies *et al.*, 2000).

Silicon (Si) is one of the most important sources of chemical elements in nature (Chen *et al.*, 2010) and plant growth micronutrients (Regina and Katarzyna, 2011). It is well known that Si is involved in plant tolerance to several stress factors, including soil silicon helping plants to remain alive under conditions of water scarcity and reducing transpiration in cells with high silicon concentration. Silicon alleviates the harmful effects on different abiotic stresses such as drought stress, salt stress, radiation damage, metal toxicity, high temperature, nutrient imbalance, freezing and chilling, etc. (Ma, 2004 and Liang *et al.*, 2007).

Seaweed extracts (SWE) are emerging as industrial biostimulants. Formulations for use as factors that foster plant growth and a tool for enhancing salinity, heat and drought tolerance. In order to improve resistance under stress, algal extracts target a variety of pathways. Red, green and brown macro algae are seaweeds that account for 10 percent of marine productivity (Battacharyya *et al.*, 2015). Seaweed offers an outstanding source of bioactive compounds such as carotenoids, protein, essential fatty acids, vitamins, amino acids, minerals and substances that promote growth (Bhaskar and Miyashita, 2005).

The aim of this study was to investigate the impact of irrigation intervals and the use of both potassium silicate, seaweed extract as foliar-spray application and their combination on vegetative, flowering and percentage of essential oil on marigold (*Tagetes patula,* L.) plant.

MATERIALS AND METHODS

The present investigation study was conducted at Somosta, Beni-Suef Governorate, Egypt, during the two successive seasons of 2018 and 2019.

The seeds of *Tagetes patula,* L. were obtained from Sids Agricultural Research Station, Medicinal and Aromatic Plants Dept. of Hort. Res. Inst., Agric. Res. Center, Egypt. Seeds were sown in the nursery on February 15th in both growing seasons. Uniform seedlings of 45 days old and 10 cm height were transplanted into plastic pots (30 cm) which filled with 10 kg of clayey soil and contained one seedling. The constituents and characteristics of the experimental soil are shown in Table (a) (Jackson, 1973).

Experimental treatments and design:

A complete randomized block design following the split plot arrangement, in three replicates, was executed in this experiment with four irrigation intervals treatments (daily, every two days, every three and four days) in the main plots (A), after two weeks from transplanting, plants were irrigated with 300 ml/pot and six treatments (control, potassium silicate at 3 ml/l (PS1), potassium silicate at 5 ml/l (PS2), seaweed at 3 ml/l (SWE1), seaweed at 5 ml/l (SWE2), and potassium silicate at 5 ml/l plus seaweed at 5 ml/l (PS2 + SWE2) in the sub-plots (B). Seaweeds extract composition, (Algeser product from Shoura Chemicals Company), is shown in Table (b) according to (James, 1994) and potassium silicate (25% Si and 10% K_2O) were sprayed three times at two weeks interval after 7th April until runoff during each growing season. Triton B (0.05%) was applied to all the SWE and potassium silicate as a wetting agent.

Growth characteristics:

The vegetative growth parameters were included; plant height (cm), number of branches/plant, stem diameter (mm), leaf area (cm^2), plant fresh weight (g) and plant dry weight (g). While the flowering data included; flowering date (number of days from transplantation to the first apparent flowering bud), number of inflorescences/plant, inflorescence fresh weight (g), diameter of inflorescence (cm), inflorescence dry weight (g) and vase life (days).

Table a. Some physical and chemical characteristics of the experimental soil.

Organic matter %	$CaCO_3$ %	Sand %	Silt %	Clay %	Soil type	pH	ECe (dSm^{-1})
1.35	1.75	26	35	39	Clayey loam	7.4	3.2
Soluble ions (meq/l)					**Available elements**		
HCO^{3-} 2.5		Mg^{2+} 6.02			N 7.30 ppm		
Cl^- 9.3		Na^+ 4.55			P 4.40 ppm		
SO^{2-} 10.7		K^+ 0.32			K 0.83 ppm		
Ca^{2+} 10.9							

Table b. Analysis of seaweeds extract (according to James, 1994).

Character	Values	Character	Values
Moisture %	6.0	Mg %	0.5-0.9
Protein %	6-8	Ca %	0.2-1.5
Aliginic acid %	10-20	Zn ppm	10-100
Mannitol %	4-7	Mn ppm	5-12
Carbohydrate %	35-50	Fe ppm	50-200
Organic matter %	45-60	B ppm	20-100
Inorganic matter %	45-60	Cu ppm	1.0-6.0
Total N %	1.0-1.5	Mo ppm	1-5
P %	0.02-0.09	IAA%	0.03
S %	3-9	Cytokinins	0.02
K %	1.0-1.2	ABA%	0.01

Flowers were harvested at the optimal stage of growth (at least 3 rows of petals fully expanded) between 7:00 am and 10:00 am. The lower half of the stem was separated from its leaves and the stems were cut to a consistent length of 35 cm, within 5 minutes of being cut, flowers were then put into glass container vases. Vases were filled with tap water and the containers were held at room temperature. Vase life was terminated on the basis of 50 percent wilted or brown petals as defined by Dole *et al*. (2013).

Essential oil percentage:

According to Guenther (1961), essential oil percentage of tagetes was extracted for 2 hours by water distillation of 20 g of aerial parts of plant. The essential oil extracted was dehydrated with anhydrous sodium sulphate.

$$\text{Essential oil \%} = \frac{\text{volume oil in graduated tube} \times 100}{\text{sample weight (20 g)}}$$

Statistical analysis:

Statistical analysis of variance was used to analyze the experiment data using MSTAT-C (1986). The least significant difference (L.S.D.) test was used to compare the means of the gathered data at the level of 5%, as mentioned by Mead *et al.* (1993).

RESULTS AND DISCUSSION

Vegetative growth aspects:

Regarding the main impact on the plant growth parameters of irrigation intervals, data presented in Tables (1 and 2) declared that plant height, number of branches, stem diameter, plant fresh and dry weights and leaf area of tagetes plants were significantly decreased with increasing irrigation intervals in both seasons. The sharp reduction of plant growth parameters was found under irrigation interval at (4) days in both seasons. Under irrigation interval at 4-days the estimated reduction percentages in plant height, number of branches, stem diameter, leaf area and plant fresh and dry weights were 21.38 and 22.67, 30.72 and 34.59, 20.00 and 23.38, 34.79 and 32.75, 23.36 and 23.78, 30.37 and 29.92 compared to the control treatment for the two growing seasons, respectively. These results are in coincidence with those of Al-Ubaydi *et al.*

Table 1. Effect of irrigation intervals, potassium silicate and seaweed extract treatments on plant height (cm), number of branches and stem diameter (mm) of *Tagetes patula* plants during 2018 and 2019 seasons.

Potassium silicate and seaweed treatments (B)	Irrigation intervals (A)									
	A1	A2	A3	A4	Mean	A1	A2	A3	A4	Mean
	First season (2018)					Second season (2019)				
	Plant height (cm)									
Control (water)	52.7	50.5	45.7	41.3	47.6	53.7	50.2	48.6	39.4	48.0
PS1	55.3	51.1	47.1	43.2	49.2	54.6	52.8	49.2	42.4	49.8
PS2	57.1	52.7	49.6	44.5	51.0	56.5	55.7	50.5	44.7	51.9
SWE1	56.2	52.4	48.4	44.2	50.3	55.9	54.3	51.3	43.3	51.2
SWE2	57.7	53.2	49.5	46.7	51.8	58.3	56.4	55.2	45.6	53.9
PS2 + SWE2	60.4	56.7	52.3	47.3	54.2	62.4	61.3	59.7	48.3	57.9
Mean (A)	56.6	52.7	48.8	44.5		56.9	55.1	52.4	44.0	
L.S.D. at 5%	A: 3.2		B: 2.4	AB: 4.8		A: 1.9		B: 2.1	AB: 4.2	
	Number of branches									
Control (water)	14.3	13.7	10.5	8.7	11.8	13.7	12.2	11.3	7.5	11.2
PS1	14.7	13.3	11.7	9.6	12.3	15.3	12.5	11.7	8.2	11.9
PS2	15.7	13.6	13.7	10.7	13.4	16.5	14.3	13.3	11.5	13.9
SWE1	15.2	14.1	13.4	10.5	13.3	15.7	13.1	12.8	10.9	13.1
SWE2	15.5	14.7	14.1	11.3	13.9	16.3	15.4	13.7	11.7	14.3
PS2 + SWE2	16.2	16.7	14.3	13.0	15.1	17.7	15.7	15.3	12.5	15.3
Mean (A)	15.3	14.4	13.0	10.6		15.9	13.9	13.0	10.4	
L.S.D. at 5%	A: 1.1		B: 0.7	AB: 1.4		A: 1.5		B: 0.9	AB: 1.8	
	Stem diameter (mm)									
Control (water)	7.3	6.9	6.2	5.4	6.5	6.9	6.7	5.9	5.1	6.2
PS1	7.2	7.1	6.7	5.7	6.7	7.4	7.1	6.2	5.5	6.6
PS2	7.5	7.3	6.9	6.1	7.0	7.7	7.3	6.5	5.8	6.8
SWE1	7.4	7.6	6.5	5.9	6.9	7.5	7.8	6.3	6.1	6.9
SWE2	7.7	7.9	6.8	6.4	7.2	8.2	7.8	6.6	6.2	7.2
PS2 + SWE2	8.1	7.7	7.3	6.6	7.4	8.4	8.1	7.4	6.7	7.6
Mean (A)	7.5	7.4	6.7	6.0		7.7	7.5	6.5	5.9	
L.S.D. at 5%	A: 0.6		B: 0.4	AB: 0.8		A: 0.9		B: 0.3	AB: 0.6	

A1: daily irrigation, A2: irrigating every two days, A3: every three days and A4: every four days.
PS1: potassium silicate at 3 ml/l, PS2: potassium silicate at 5 ml/l, SWE1: seaweed at 3 ml/l, SWE2: seaweed at 5 ml/l, and PS2 + SWE2: potassium silicate at 5 ml/l + seaweed at 5 ml/l.

Table 2. Effect of irrigation intervals, potassium silicate and seaweed extract treatments on leaf area (cm^2) and plant fresh and dry weights (g) of *Tagetes patula* plants during 2018 and 2019 seasons.

Potassium silicate and seaweed treatments (B)	Irrigation intervals (A)									
	A1	A2	A3	A4	Mean	A1	A2	A3	A4	Mean
	First season (2018)					Second season (2019)				
Leaf area (cm^2)										
Control (water)	4.82	4.45	3.64	3.11	4.01	5.26	4.72	3.85	3.25	4.27
PS1	5.14	4.57	3.69	3.42	4.21	5.36	4.93	4.09	3.54	4.48
PS2	5.58	4.95	4.15	3.65	4.58	5.72	5.45	4.38	4.05	4.90
SWE1	5.43	4.72	3.98	3.50	4.41	5.65	5.15	4.32	3.77	4.72
SWE2	5.75	5.35	4.62	3.77	4.87	6.08	5.76	4.81	4.15	5.20
PS2 + SWE2	6.22	6.10	5.13	4.05	5.38	6.35	6.17	5.23	4.42	5.54
Mean (A)	5.49	5.02	4.20	3.58		5.74	5.36	4.45	3.86	
L.S.D. at 5%	A: 0.35		B: 0.43		AB: 0.86	A: 0.27		B: 0.61		AB: 1.22
Plant fresh weight (g)										
Control (water)	68.5	66.8	62.3	52.3	62.5	65.4	64.2	60.5	47.2	59.3
PS1	72.1	67.4	65.7	55.6	65.2	67.7	66.7	62.3	49.7	61.6
PS2	77.8	73.6	66.4	57.4	68.8	69.5	68.4	65.5	53.2	64.2
SWE1	75.3	70.7	64.8	56.2	66.8	70.2	67.5	64.7	52.4	63.7
SWE2	78.7	74.5	69.3	62.4	71.2	76.3	74.7	68.6	58.6	69.6
PS2 + SWE2	84.6	80.7	76.4	66.7	77.1	79.8	78.3	72.4	65.7	74.1
Mean (A)	76.2	72.3	67.5	58.4		71.5	70.0	65.7	54.5	
L.S.D. at 5%	A: 3.3		B: 2.6		AB: 5.2	A: 2.1		B: 1.8		AB: 3.6
Plant dry weight (g)										
Control (water)	11.7	11.3	10.6	8.4	10.5	10.8	10.5	9.7	7.8	9.7
PS1	12.5	11.5	10.9	8.7	10.9	11.4	11.0	10.4	8.3	10.3
PS2	13.7	12.7	11.8	9.3	11.9	13.2	12.7	11.3	9.7	11.7
SWE1	13.1	12.4	11.3	9.1	11.5	12.7	11.5	10.7	8.7	10.9
SWE2	14.4	13.6	12.4	10.2	12.7	13.7	12.4	11.6	9.4	11.8
PS2 + SWE2	15.7	14.0	13.4	10.5	13.4	14.2	13.2	12.5	9.7	12.4
Mean (A)	13.5	12.6	11.7	9.4		12.7	11.9	11.0	8.9	
L.S.D. at 5%	A: 0.7		B: 1.1		AB: 2.2	A: 0.4		B: 0.8		AB: 1.6

A1: daily irrigation, A2: irrigating every two days, A3: every three days and A4: every four days.
PS1: potassium silicate at 3 ml/l, PS2: potassium silicate at 5 ml/l, SWE1: seaweed at 3 ml/l, SWE2: seaweed at 5 ml/l, and PS2 + SWE2: potassium silicate at 5 ml/l + seaweed at 5 ml/l.

(2017) and Hussein *et al.* (2011). Water stress normally negatively affects plant growth and development, it can decrease plant height by decreasing the enlargement and division of cells (Manivannan *et al.*, 2007 and Yazdani *et al.*, 2007). By decreasing the available water content, drought stress will decrease plant dry weight, thereby decreasing leaf area and number as well as plant height (Ahmadi Azar *et al.*, 2015).

Data presented in Tables (1 and 2) show the effect of foliar application of potassium silicate, SWE and their combinations in the highest concentrations on the growth parameters namely plant height, number of branches, stem diameter, leaf area and plant fresh and dry weights in both seasons. The obtained data proved that all vegetative growth characters were significantly enhanced due to these abovementioned treatments compared to untreated plants in the two seasons. The highest values concerning these characters were resulted from the treatment of combination between seaweed extract and potassium silicate at high concentration. In agreement with these results concerning foliar application of silicon were those of Moustafa *et al.* (2018) on *Moringa oleifera*. The role of silicon in enhancing plant growth is through the promotion of beneficial plant physiological processes (Korndörfer and Lepsch, 2001). It gives plants resistance to multiple stresses and is effective on controlling various pests and diseases caused by both fungi and bacteria (Ma, 2004). It plays a major role in plant stimulation of antioxidant enzymes (Liang *et al.*, 2007) and in improving the status of plant water (Romero *et al.*, 2006). In addition, Jugal and Ramani (2017) reported that Si plays a crucial role in improving the efficiency of nitrogen usage and distribution of ions.

Seaweed extract has resulted in a pronounced growth increase. This increase may be due to the existence of certain biochemical compounds such as growth regulators, organic components, macro components and micro components in seaweed extract that may be needed for the induction of antioxidant enzymes responsible for reducing the levels of reactive oxygen species (ROS). The promoting effect of the application of seaweed extract in tagetes plants were found to be similar with those obtained by (Abdou *et al.*, 2018) on gladiolus plants, they found that vegetative growth parameters increased by seaweed extract treatments as compared to control. These findings may be due to the beneficial effect of the availability of naturally occurring nutrients in seaweed extracts, plant growth hormones (auxins, cytokinines and gibberellins) as well as other plant bio-stimulants, such as amino acids, vitamins that could sustain photosynthetic rates, increase plant resistance, delay plant senescence and regulate cell division (Strick *et al.*, 1997 and Hemida *et al.*, 2015).

The interaction between interval irrigation in combination with potassium silicate and seaweed treatments or both of them in the high level was not significant, in the two seasons, for each of plant height, stem diameter and branch number and plant fresh weight except for the 4 days interval irrigation as shown in Table (1 and 2). The best overall results, for the six vegetative growth traits were obtained due to supplying plants with dual dose of seaweed at 5 ml/l plus potassium silicate 5 ml/l, in combination with interval irrigation treatments except for plant height and fresh weight of plant in the 4 days interval irrigation.

Flowering aspects:

All flowering aspects of tagetes plants were affected by irrigation intervals. Data presented in Tables (3 and 4) illustrated that increasing the irrigation intervals decreased flowering date, number of inflorescences/plant, inflorescence diameter (cm), inflorescence fresh and dry weight (g) and vase life by 15.06 and 17.44 %, 37.86 and 30.07 %, 29.73 and 25.71 %, 31.28 and 24.23 %, 26.67 and 27.50 % and 30.97 and 25.89 % for irrigation every 4-days

Table 3. Effect of irrigation intervals, potassium silicate and seaweed extract treatments on flowering date (days), number of inflorescences/plant and inflorescence diameter (cm) of *Tagetes patula* plants during 2018 and 2019 seasons.

Potassium silicate and seaweed treatments (B)	Irrigation intervals (A)									
	A1	A2	A3	A4	Mean (B)	A1	A2	A3	A4	Mean (B)
	First season (2018)					Second season (2019)				
	Flowering date/days (first apparent flowering bud)									
Control (water)	74.5	70.4	67.5	62.3	68.7	75.7	74.2	69.2	64.4	70.9
PS1	73.6	68.0	66.3	64.1	68.0	75.1	74.7	64.8	65.7	70.1
PS2	71.5	73.5	69.4	65.2	69.9	73.4	71.6	63.7	60.3	67.3
SWE1	72.7	69.7	67.3	59.2	67.2	74.5	70.3	62.3	58.4	66.4
SWE2	69.3	65.3	62.5	58.4	63.9	72.3	68.2	61.5	57.7	64.9
PS2 + SWE2	68.4	63.3	58.5	55.9	61.5	69.1	62.7	60.6	57.2	62.4
Mean (A)	71.7	68.4	65.3	60.9		73.4	70.3	63.7	60.6	
L.S.D. at 5%	A: 2.9		B: 4.2		AB: 8.4	A: 3.1		B: 3.7		AB: 7.4
	Number of inflorescences/plant									
Control (water)	12.3	10.4	8.7	7.2	9.7	12.8	10.8	9.3	8.4	10.3
PS1	12.7	10.5	9.1	7.4	9.9	13.3	13.0	10.4	9.1	11.5
PS2	14.5	11.3	9.7	9.3	11.2	13.5	13.5	10.8	10.3	12.0
SWE1	13.8	11.2	10.2	8.5	10.9	12.4	12.8	10.6	9.5	11.3
SWE2	14.7	13.4	11.4	9.3	12.2	15.1	14.1	12.5	9.7	12.9
PS2 + SWE2	15.7	14.5	13.1	10.7	13.5	16.3	14.9	13.2	11.3	13.9
Mean (A)	14.0	11.9	10.4	8.7		13.9	13.2	11.13	9.72	
L.S.D. at 5%	A: 0.9		B: 1.2		AB: 2.4	A: 1.1		B: 0.9		AB: 1.8
	Inflorescences diameter (cm)									
Control (water)	3.3	3.1	2.7	2.1	2.8	2.9	3.0	2.4	1.9	2.6
PS1	3.5	3.2	2.9	2.3	3.0	3.1	3.2	2.7	2.2	2.8
PS2	3.7	3.5	3.4	2.8	3.4	3.4	3.5	3.2	2.7	3.2
SWE1	3.5	3.0	3.1	2.5	3.0	3.4	3.3	2.9	2.5	3.0
SWE2	3.8	3.7	3.5	2.7	3.4	3.6	3.5	3.3	2.9	3.3
PS2 + SWE2	4.1	4.1	3.8	3.1	3.9	4.3	3.7	3.7	3.2	3.7
Mean (A)	3.7	3.4	3.2	2.6		3.5	3.4	3.0	2.6	
L.S.D. at 5%	A: 0.2		B: 0.2		AB: 0.4	A: 0.1		B: 0.2		AB: 0.4

A1: daily irrigation, A2: irrigating every two days, A3: every three days and A4: every four days.
PS1: potassium silicate at 3 ml/l, PS2: potassium silicate at 5 ml/l, SWE1: seaweed at 3 ml/l, SWE2: seaweed at 5 ml/l, and PS2 + SWE2: potassium silicate at 5 ml/l + seaweed at 5 ml/l.

Table 4. Effect of irrigation intervals, potassium silicate and seaweed extract treatments on inflorescence fresh and dry weights (g) and vase life (days) of *Tagetes patula* plants during 2018 and 2019 seasons.

Potassium silicate and seaweed treatments (B)	Irrigation intervals (A)									
	A1	A2	A3	A4	Mean (B)	A1	A2	A3	A4	Mean (B)
	First season (2018)					Second season (2019)				
Inflorescence fresh weight (g)										
Control (water)	3.48	3.35	3.07	2.45	3.09	3.65	3.46	3.12	2.73	3.24
PS1	4.05	3.73	3.31	2.67	3.44	3.84	3.67	3.32	2.94	3.44
PS2	4.18	3.86	3.62	2.83	3.62	4.11	3.92	3.45	3.13	3.65
SWE1	3.55	3.42	3.16	2.44	3.14	3.78	3.55	3.15	2.81	3.32
SWE2	3.85	3.60	3.28	2.71	3.36	3.87	3.74	3.28	3.05	3.49
PS2 + SWE2	4.31	3.95	3.82	2.95	3.76	4.25	4.14	3.75	3.18	3.83
Mean (A)	3.90	3.65	3.37	2.68		3.92	3.75	3.35	2.97	
L.S.D. at 5%	A: 0.09		B: 0.08		AB: 0.16	A: 0.06		B: 0.11		AB: 0.22
Inflorescence dry weight (g)										
Control (water)	0.38	0.39	0.33	0.30	0.35	0.36	0.34	0.31	0.26	0.32
PS1	0.44	0.42	0.35	0.32	0.38	0.38	0.37	0.34	0.27	0.34
PS2	0.47	0.45	0.38	0.35	0.41	0.42	0.39	0.37	0.32	0.38
SWE1	0.41	0.39	0.34	0.32	0.37	0.37	0.35	0.33	0.26	0.33
SWE2	0.45	0.42	0.36	0.34	0.39	0.39	0.37	0.36	0.31	0.36
PS2 + SWE2	0.52	0.48	0.39	0.35	0.44	0.49	0.46	0.41	0.32	0.42
Mean (A)	0.45	0.43	0.36	0.33		0.40	0.38	0.35	0.29	
L.S.D. at 5%	A: 0.03		B: 0.01		AB: 0.02	A: 0.02		B: 0.02		AB: 0.04
Vase life (days)										
Control (water)	10.2	9.8	8.6	6.4	8.8	9.8	9.4	9.2	7.4	9.0
PS1	11.4	10.6	9.4	7.4	9.7	10.6	10.2	10.0	8.2	9.8
PS2	11.8	11.2	10.2	8.2	10.4	11.6	10.8	10.6	8.8	10.5
SWE1	10.6	10.4	9.2	7.8	9.5	10.8	10.2	9.8	7.8	9.7
SWE2	11.6	10.8	9.6	8.4	10.1	11.4	11.0	10.4	8.4	10.3
PS2 + SWE2	12.4	11.6	10.2	8.8	10.8	12.8	12.2	10.6	9.2	11.2
Mean (A)	11.3	10.7	9.5	7.8		11.2	10.6	10.1	8.3	
L.S.D. at 5%	A: 1.1		B: 0.7		AB: 1.4	A: 0.8		B: 0.6		AB: 1.2

A1: daily irrigation, A2: irrigating every two days, A3: every three days and A4: every four days.
PS1: potassium silicate at 3 ml/l, PS2: potassium silicate at 5 ml/l, SWE1: seaweed at 3 ml/l, SWE2: seaweed at 5 ml/l, and PS2 + SWE2: potassium silicate at 5 ml/l + seaweed at 5 ml/l.

compared with daily irrigation in the first and second season, respectively. The earliest first apparent flowering bud has been obtained from the longest irrigation interval (60.9 and 60.6 days), while irrigation interval every day delayed the flowering date (71.7 and 73.4 days) in the 1st and 2nd seasons, respectively. Maximum number of inflorescences/plant (14.00 and 13.90) were resulted with daily irrigation followed by (11.90 and 13.20) at two days of irrigation interval, then, three days of irrigation interval (10.40 and 11.13), while four days interval produced minimum (8.70 and 9.72) number of inflorescences/plant in the 1st and 2nd seasons, respectively. These findings are in harmony with those of Abdel-Said *et al.* (2019) on *Lilium longiflorum* and Akhtar *et al.* (2019) on *Calendula officinalis* and *Dianthus barbatus.* It was notcied that various conditions of drought stress can have different effects on flowering, while drought sometimes results in barrenness during flowering (Farooq *et al.*, 2009 and Wu *et al.*, 2017). Jaimez *et al.* (2000) and Bissuel-Belaygue *et al.* (2002) found that in some ornamental plants, drought stress significantly affected flower aspects (number of aborted flowers, length of bulb inflorescence, and number of floral buds). The preliminary plant response to water stress which results in the decrease in photosynthesis rate is the closure of stomata to prevent transpirational water loss (Mahajan and Tuteja, 2005 and Mansfield and Atkinson, 1990). Subsequently, the decrease in the rate of photosynthesis would minimize flower formation and number (Salehi and Bahadoran, 2015). It seems that due to the reduction of photosynthesis and consequently the decrease of leaf area and the transfer of assimilated compounds to flowers, water stress will shorten the flowering perio (Jafarzadeh *et al.*, 2013).

In relation to the other factor, the five tested stimulants, namely, potassium silicate or/and seaweed extract caused an increase in number inflorescences/plant, inflorescence diameter, inflorescence fresh and dry weights and vase life over those given by control treatment in both seasons as shown in Tables (3 and 4). These treatments hastened the first apparent flowering bud of tagetes plants. Using the two materials together was significantly preferable than using each substance alone in this respect. Tagetes produced maximum number of inflorescences/plant (13.50 and 13.90), maximum inflorescences diameter (3.90 and 3.70 cm), maximum inflorescence fresh and dry weight (3.76 and 3.83 for fresh and 0.44 and 0.42 g for dry weight) and maximum vase life (10.80 and 11.20 days) at potassium silicate 5ml/l + seaweed extract 5ml/l in both seasons, respectively. However, the untreated plants produced the minimum values. Also, the earliest flowering was obtained from combination with two substances at high level (61.50 and 62.40 days).

Silicon's prevalent positive action on growth characteristics may be due to its essential roles in protecting plants from drought, cold, disease and fungal attack, relieving abiotic stress (salinity and toxicity of heavy metals), and enhancing root growth, water and nutrient uptake and plant pigments (Ma *et al.*, 2001; Datnoff *et. al.*, 2007 and Qin and Tian, 2009). These results are consistent with those obtained by Bayat (2013) on the impact of silicon on stimulating growth characteristics.

Seaweed extracts have stimulating effects on growth characteristics which may be due to its important action on improving cell division since it contains higher amounts of nutrients, namely N, Mg, S, P, Cu, K, Mn, Ca, Mo, Fe, and B, natural hormones such as cytokinins, IAA and GA_3, amino acids, vitamins and antioxidants (James, 1994 and Soliman *et al.*, 2000). These components play an important role in protecting plant cells from damage and all plant stresses and improving the division of cells and organic food biosynthesis (Kulk, 1995 and Strick *et al.*, 1997). These findings are in accordance with those obtained with regard to the impact of seaweed extracts on growth characteristics

(Ragab, 2016 and Abdou *et al.*, 2018). The progressive impact of silicon and seaweed extract on flowering time could be due to their vital role in in balancing the ratio between carbohydrates and nitrogen in favour of flowering (Soliman *et al.*, 2000 and Neumann and Zur-Nieden, 2001).

Tables (3 and 4) show that the interaction between factor A (interval irrigation) and factor B (potassium silicate and/or seaweed) for flowering date, number of inflorescences per plant, inflorescences diameter and fresh and dry weights of inflorescence were significant in both seasons except for the irrigation interval every two days in comparison with plants irrigated daily. The highest overall values of flowering characters, were obtained from plants treated by dual dose of potassium silicate and seaweed in combination with the interval irrigation. However, no effect of this treatment was found on the flowering date.

Essential oil percentage:

In relation to irrigation intervals treatments, obtained results presented in Table (5) stated that no significant differences were detected among four ones for essential oil percentage in the two seasons. The highest values were given from plants irrigated daily (0.067 and 0.070 %) in both the first and second seasons, respectively, while the minimum values were resulted from irrigation intervals at four days (0.062 and 0.064 %) in the first season and in the second, respectively. The reduction in essential oil may be attributed to disturbance in carbohydrate and photosynthesis production under stress and suppression of the growth of plants (Flexas and Medrano, 2002). Similar results were observed for *Cympobogon flexuosus* under drought (Sangwan *et al.*, 2002).

Supplying tagetes plants with combination of potassium silicate and SWE at high concentration, caused a significant

Table 5. Effect of irrigation intervals, potassium silicate and seaweed extract treatments on essential oil percentage of *Tagetes patula* plants during 2018 and 2019 seasons.

Potassium silicate and seaweed treatments (B)	Irrigation intervals (A)									
	A1	A2	A3	A4	Mean (B)	A1	A2	A3	A4	Mean (B)
	First season (2018)					Second season (2019)				
	Essential oil %									
Control (water)	0.057	0.056	0.054	0.055	0.056	0.062	0.061	0.059	0.058	0.060
PS1	0.062	0.059	0.057	0.056	0.059	0.067	0.065	0.066	0.059	0.064
PS2	0.068	0.065	0.063	0.064	0.065	0.071	0.068	0.067	0.062	0.067
SWE1	0.065	0.062	0.062	0.060	0.062	0.069	0.070	0.065	0.065	0.067
SWE2	0.072	0.068	0.067	0.066	0.068	0.074	0.072	0.069	0.068	0.071
PS2 + SWE2	0.079	0.075	0.073	0.072	0.074	0.075	0.073	0.070	0.069	0.072
Mean (A)	0.067	0.064	0.063	0.062		0.070	0.068	0.066	0.064	
L.S.D. at 5%	A: N.S		B: 0.015		AB: N.S	A: N.S		B: 0.011		AB: N.S

A1: daily irrigation, A2: irrigating every two days, A3: every three days and A4: every four days.
PS1: potassium silicate at 3 ml/l, PS2: potassium silicate at 5 ml/l, SWE1: seaweed at 3 ml/l, SWE2: seaweed at 5 ml/l, and PS2 + SWE2: potassium silicate at 5 ml/l + seaweed at 5 ml/l.

increase in the percentage of essential oil compared with control treatment in the two experimental seasons as shown in Table (5). The increase in the essential oil percentage when tagetes plants may be due to the higher energy in synthesis of biochemical metabolites as a result to applied seaweed extract. These findings are in harmony with those mentioned by El-Leithy *et al.* (2019) who found that using the seaweed extract significantly increased all the studied characters of essential oil and chemical constituents of *Plectuanthus amboinicus* (Lour). The capability of Si in promoting essential oil percentage was stated by Waly *et al.* (2019) on *Rosmarinus officinalis* L.

The interaction between the two factors (A×B) treatments was no significant for essential oil% as compared with the control treatment in both seasons. The high percentages were obtained due to potassium silicate + seaweed extract at high concentration for plants irrigated daily as recorded 0.079 % in the first season and 0.075 % in the second season, respectively.

It could be recommended that to reduce the effect of drought stress, suppling *Tagetes patula* plants with 5 ml/l of seaweed extract and/or potassium silicate to obtain the best growth characteristics, oil percentage and vase life.

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إستجابة نباتات القطيفة للرش الورقي بسيليكات البوتاسيوم ومستخلص الأعشاب البحرية تحت فترات الري المختلفة

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تم اجراء هذه الدراسة في مدينة سمسطا بمحافظة بني سويف، جمهورية مصر العربية، خلال الموسمين المتعاقبين ٢٠١٨ و٢٠١٩ لتقييم تأثير فترات الري وكذلك الرش الورقي بمركب سيليكات البوتاسيوم ومستخلص الأعشاب البحرية على صفات النمو الخضري والزهري والنسبة المئوية للزيت الطيار لنباتات القطيفة (*Tagetes patula*). وجد أن صفات ارتفاع النبات، عدد الأفرع، قطر الساق، الوزن الجاف والطازج للنبات، مساحة الورقة، عدد النورات للنبات، قطر النورات، موعد بداية التزهير، الوزن الطازج والجاف لمحصول الأزهار للنبات وكذلك مدة بقاء الأزهار بعد القطف، قد تناقصت نتائجها معنويا مع تباعد فترات الري في كلا الموسمين. كما وجد أن الري كل أربعة أيام أسرع في بداية التزهير عن باقي فترات الري الأخرى. وأوضحت نتائج الرش الورقي لمستخلصات الأعشاب البحرية بمعدلات ٣ و٥ مل/لتر وكذلك الرش بسيليكات البوتاسيوم بمعدلات ٣ و٥ مل/لتر تأثيراً معنويا على جميع الصفات محل الدراسة مقارنة بمعاملة الكنترول (الرش بالماء). وُجد أن أفضل النتائج في جميع صفات النمو عند معاملة نباتات القطيفة بالتركيز الأعلى من سيليكات البوتاسيوم ومستخلص الأعشاب البحرية. وكان التأثير الأكثر وضوحاً لمعاملات التفاعل عند الرش بسيليكات البوتاسيوم ومستخلص الأعشاب البحرية بمعدل ٥ مل/لتر مع ري النباتات كل يوم أو يومين وتم تسجيل أعلى نتائج من حيث صفات النمو الخضري والزهري والنسبة المئوية للزيت الطيار لتلك المعاملات. لذا يفضل معاملة نباتات القطيفة بالتركيز الأعلى من مستخلص الأعشاب البحرية وسيليكات البوتاسيوم أو إحداهما، للتقليل من تأثير إجهاد الجفاف أو تباعد فترات الري.