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EFFECT OF IRRIGATION LEVELS AND FOLIAR SPRAYING WITH SEAWEED EXTRACT, POTASSIUM SILICATE AND ABSCISIC ACID ON GROWTH, CORM YIELD AND QUALITY OF TARO

[165]

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ABSTRACT

The field experiment was established at the experimental farm of the Horticultural Research Station of Barrage, Qalyubia Governorate during 2014 and 2015 growing seasons to evaluate the impact of irrigation levels i.e.,120, 100, 80 and 60% of the evapotranspiration (ETc) and stress alleviation substances (seaweed extract, potassium silicate and abscisic acid against control treatment) on growth, corm yield and quality of taro (*Colocasia esculenta* cv. Balady), with a particular attempt to establish irrigation water strategy for taro cultivation. The results indicated a reduction in plant growth and corm yield as well as quality due to minimizing irrigation level from 120 to 60% ETc. But the highest water use efficiency (WUE) was obtained with 80% irrigation level. Seaweed extract showed a superior enhancement in all measured vegetative, yield and quality parameters followed by potassium silicate compared to abscisic acid or control. Seaweed extract heightened the WUE compared to other substances. Results concluded that using 80% irrigation level accompanied by spraying plants with seaweed extract led to a mild reduction in the plant growth, yield and quality but conferred the higher WUE compared to other interactive treatments.

Keywords: Taro, vegetative growth, Deficit irrigation, Stress alleviation substances, Seaweed extract, Potassium silicate, Abscisic, Corm yield, Water use efficiency.

INTRODUCTION

Taro [*Colocasia esculenta* (L.) Schott] is grown throughout the humid tropics and subtropics areas **(Matthews et al 2017).** Moreover,taro is considers a valuable source of essential mineral nutrients **(Mergedus et al 2015)** and is high in fiber, vitamins A, C, E and B6 **(Wills et al 1983; Lebot and Lawac, 2017).** According to the FAO definition (FAO, 1994), taro is the 5th crop between the main six crops that accumulate starch in roots, tubers, rhizomes, corms and stems which commonly consumed as human and animal food, and as manufactured food products. Meanwhile, it needs high water requirements thus shows least water use efficiency **(Uyeda et al 2011; Ganança et al 2018).**

Shortage the freshwater quantity devoted to the agriculture in Egypt made the researchers looking for policies and/or practices to maximize the water use efficiency or water productivity. Meanwhile, the insistence on taro cultivation, semi-aquatic plant, consumes a plenty of water so it becomes imperative to adopt agricultural policies use less water for continuing taro cultivation without reducing its area. **Howell (2001)** reported that the main pathway for enhancing the water use efficiency in irrigation agriculture concentrate on engineering and agronomic management aspects. These approaches for using less water were reported by **Evans and Sadler (2008**) as deficit irrigation, efficient irrigation systems such as sprinkler and drip irrigation systems, covering soil surface (mulching) as well as agronomic practices as conservation tillage, defoliation and spraying anti-stress and anti-transpiration substances **(El-Zohiri and Abd Elal, 2014; Abu El-Azm and Youssef, 2015).**

Due to the shortage of the available information on a success of applying irrigation systems other than the furrow irrigation as a popular irrigation system for taro irrigation in the areas of Nile valley and delta, applying drip irrigation system in taro cultivation, as a higher efficient irrigation method, in loamy and clay soils could be accompanied by certain stresses on the plant especially under deficit irrigation. Therefore, this work was designed to investigate utilizing deficit irrigation for water conservation and avoiding the potential deleterious effect on taro plants using spraying stimulation substances.

MATERIALS AND METHODS

Experimental site and plant materials: The field experiment was conducted during 2014 and 2015 growing seasons at the Experimental Farm of the Horticultural Research Station of Barrage, Qalyubia Governorate, Egypt. According to soil analysis results **Table (1)** soil texture of the experimental site was a clay. The taro cultivar used for this study was a local cultivar (Balady) which is the common cultivar in Egypt. The planting dates were on 10 and 15th of March, in the first and second seasons, respectively.

Table 1. The physical and chemical properties of the experimental soil.

Physical properties									
Sand		**Silt %**			**Clay %**		**Texture**		
30.67		22.74			46.59		Clay		
Chemical properties									
Soluble ions in saturated extract, (meq/l)									
EC dS/m	pH	HCO_3^-	Cl^-	So_4^-	Ca^{++}	Mg^{++}	Na^+	K^+	
0.19	8.30	0.89	0.5	0.51	0.26	0.34	0.70	0.6	

Experimental treatments and design: The experiment involved four irrigation levels (60, 80, 100 and 120% of the crop evapotranspiration ETc) applied through drip irrigation system. The irrigation levels were calculated using FAO-CROPWAT software version 8 to calculate the crop irrigation water requirements based on the reference crop evapotranspiration as described by Penman-Monteith which has now become the standard for estim ating reference crop evapotranspiration **(Smith and Steduto, 2012).** Evapotranspiration was calculated according to the water balance approach as described by **James (1995).** The irrigation treatments were applied after 60 days from planting then continued until harvesting. The second factor was plant stimulant substances which were seaweed extract (1.5 g/l) in a powder form, potassium silicate (2 g/l) in a powder form and abscisic acid (30 ppm) in a trading form (proton) involved 10 abscisic acid as well as spraying distilled water as a control treatment. The plant stimulant substances were sprayed after two months from planting date and repeated every two weeks.

The experimental design was a split-plot with four replications. The irrigation levels were distributed randomly in the main plots. Meanwhile, the four plant stimulant substances were randomly distributed in the subplots. Each subplot composed of five rows with row width of 80 cm and row length of 5m.

Cormels with the same weights of about 100 g were used as planting materials and were planted at 25 cm spacing in one line along the row. Cultivation and all cultural practices other than irrigation (fertilization, weeding, and pest control) were performed according to the recommendations of the Egyptian Ministry of Agriculture, were kept normal and uniform for all the treatments.

Data recorded:

A random sample of five plants from the three inner rows of each experimental plot were taken at the harvest (270 days after the planting date) and the vegetative growth data were recorded. Plant height was measured from the ground level to the top point of plant. Also, the standing leaves on each individual plant were counted, and average leaf area was estimated. In the mid growing season, total chlorophyll content of five leaves was determined by using Minolta SPAD-502 Chlorophyll Meter (MINOLTA CO., LTD. Japan). The same leaves were dried at 70C^o to constant weight then leaf dry matter was estimated according to the following formula:

Leaf dry matter percent = (dry weight of leaves / fresh weight of leaves) x 100. Also the dried leaves from each sample was subjected to measuring the nutrients. Nitrogen percent was measured determined according to **Kock and Mc Meckin (1924)**. Phosphorus percent was measured calorimetrically at the wave length 680 nm using Spectrophotometer device (UV/VIS Spectrophotometer, CT 200) as described by **Troug and Meyer (1939)**.

Potassium percent was measured via flame photometer device as mentioned by **Brwon and Lilliland (1946).** Also, calcium percent was measured through Flame photometer device according to the method described by **Chapman and Pratt (1961)**. Magnesium contents was determined using atomic absorption spectrophotometer according to **A.O.A.C. (2000).**

All corms from the three inner rows of each experimental plot were harvested. Corms were cleaned from the residual of soil and the corm weight and yield/ feddan were calculated. Water use efficiency (WUE) was calculated as the units of total yield produced from each unit volume of the used water (kg yield / m^3 water).

$$WUE = \frac{\text{Crop yield kg/fed.}}{\text{water (m3/fed.)}}$$

Corm samples were dried to constant weight at 70ºC for dry matter determination. Carbohydrates and starch content in corms were determined according to **A.O.A.C. (2000).**

Data analysis: All data were subjected to the analysis of variance with SAS statistical package [15]. Means of main effects and interactions were separated using least significance difference (LSD). All statistical determinations were made at P = 0.05.

RESULTS AND DISCUSSION

Vegetative growth parameters

Data in the **Table (2)** revealed that number of leaves and chlorophyll reading recorded descending values against decreasing irrigation levels during the two growing seasons. However, plant height, leaf area and leaf dry matter percent in the first season, irrigation levels of 80 % and 100% showed no significant differences in the remain parameters. On the other hand, the least values of all parameters were recorded with 60% irrigation level. **Al-Mansor et al (2015) and Abdelhady et al (2017)** established their experiments under the same area and climate and concluded that the irrigation level 80% of the crop evapotranspiration (ETc) or more maintained soil moisture in the readily available water range. Therefore, the impact of these irrigation levels on the crop behavior mostly was not significant. Meanwhile, under this investigation, 120% irrigation level was the best treatment in improving the vegetative performance of taro due to the higher water requirement of the plant **(Bussell and Bonin, 1998).** Where taro growth and yield of corms were improved well under the higher level of the irrigation **(El-Zohiri and Abd Elal, 2014).** On the other hand, applying deficit irrigation in taro clearly decrease vegetative growth so reflected negatively on the corm yield **(El-Zohiri and Abd Elal, 2014).**

Foliar sprayed seaweed extract conferred the superior improvement of all vegetative parameters followed by potassium silicate compared to abscisic acid or control. Meanwhile, leaf dry matter percent was not significantly affected by all the sprayed substances. These results were true in the two growing seasons.

For the interaction between irrigation levels and foliar sprayed substances, the effect of irrigation on the taro vegetative growth parameters was stronger than the foliar sprayed substances. So all measured parameters showed descending values with decreasing the irrigation levels even under the same foliar sprayed substance. Nevertheless, spraying seaweed extract on the taro plants still the best treatment under each irrigation level followed by potassium silicate but sometimes spraying abscisic acid decreased the measured parameters values than control treatment. It is worth noting that the measured parameters values were similar when spraying seaweed extract under both 80% and 100% irrigation levels. The data was consistency during the two seasons.

Based on the explained data, under reduction irrigation levels the used substances varied in its stimulation effect where seaweed extract was more effective in attenuating the adverse effect of reduction irrigation level meanwhile abscisic acid sometimes exhibited more reduction effect than control.

Table 2. Effect of irrigation levels and foliar-sprayed substances on plant height, leaf number, leaf area, chlorophyll readings (SPAD) and leaf dry matter of taro plants grown in 2014 and 2015 growing seasons

Treatments		Plant height (cm)		Number of leaves		Leaf area (cm^2)		Total chlorophyll (SPAD)		Leaf dry matter (%100)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigationlevel[a]											
120%		209.17a	212.92a	4.67a	5.42a	6010.4a	6494.2a	43.67a	46.65a	16.15a	16.98a
100%		181.67b	181.67b	4.25b	4.52b	5358.9b	5567.4b	40.9b	42.66b	15.62a	15.87b
80%		167.5c	175.0b	4.0b	4.42b	4581.6c	5168.6b	41.21b	41.77b	14.26b	15.18b
60%		131.67d	137.92c	3.42c	3.58c	3963.7d	4385.2c	38.53c	39.64c	12.52c	12.88c
Foliar spray substances[b]											
Seaweed		189.58a	191.67a	4.58a	5.17a	6083.3a	6229.2a	43.86a	45.42a	14.94a	15.66a
$KSiO_3$		179.17b	186.67a	4.17ab	4.67ab	4979.6b	5679.4a	43.23a	44.82a	14.75a	15.02a
ABA		160.83c	161.25b	3.66b	3.92c	4342.6c	4964.3b	40.34b	42.64b	14.49a	15.12a
Control		160.42c	167.92b	3.92b	4.25bc	4509.1c	4742.5b	36.90c	37.83c	14.37a	15.11a
Irrigation level[a] X Foliar spray substances[b]											
120%	**Seaweed**	220.0a	221.67a	5.33a	6.33a	7071.0a	7216.0a	48.33a	52.2a	18.85a	18.85a
	$KSiO_3$	218.3a	220.0a	4.67ab	5.67ab	5757.1bc	6768.4ab	45.83ab	46.53b	15.41cd	15.41cd
	ABA	208.3ab	213.33ab	4.33ab	4.67bcd	5237.8bcd	5883.5bcd	40.93def	45.53bc	17.07b	17.07b
	Control	190.0cde	196.67c	4.33ab	5.0bc	5975.6b	6109.0abc	39.33efg	42.33ced	16.61bc	16.61bc
100%	**Seaweed**	200.0bc	200.0bc	4.67ab	5.0bc	6990.1a	7110.0a	43.7bcd	44.1bcd	16.58bc	15.32cd
	$KSiO_3$	180.0de	191.67c	4.33ab	4.67bcd	4896.1cdef	5586.3cde	40.2defg	45.03bc	15.32cd	16.58bc
	ABA	160.0f	168.33d	3.67bc	4.0cde	4574.9def	4598.7ef	41.7bcde	42.5cd	15.79bcd	15.79bcd
	Control	186.67cde	166.67d	4.33ab	4.67bcd	4974.7	4974.7def	38.0efgh	39.0ef	15.78bcd	15.78bcd
80%	**Seaweed**	193.3bcd	193.33c	4.33ab	5.33ab	5200.2bcd	5804.0bcd	45.37abc	41.47de	15.09cd	15.09cd
	$KSiO_3$	167.67e	188.33e	4.0bc	4.67bcd	4796.4def	5077.2cdef	41.37cde	46.16b	14.91de	14.91de
	ABA	150.0fg	160.0de	3.67bc	3.67de	4188.8efg	5193.3cdef	42.03bcde	43.57bcd	15.38cd	15.38cd
	Control	150.0fg	158.33de	4.0bc	4.0cde	4141.0fg	4599.8ef	36.37gh	35.87fg	15.37cd	15.37cd
60%	**Seaweed**	145.0gh	151.67e	4.58a	4.0cde	5072.0cdef	5234.3cdef	42.03bcde	43.93bcd	13.38ef	13.38ef
	$KSiO_3$	141.67g	146.67e	4.17ab	3.67de	4469.0def	4838.0def	41.50bcde	41.53de	13.19f	13.19f
	ABA	123.33h	130.0f	3.66b	3.33e	3368.8gh	4181.8fg	36.70fgh	38.97ef	12.19f	12.19f
	Control	116.67h	123.33f	3.92b	3.33e	2945.0h	3286.7g	33.9h	34.13g	12.75f	12.75f

[a]Averages for each group within a column for the same factor followed by the same letter do not significantly differ (P = 0.05) according to Duncan's multiple range test.

Deficit irrigation as saving irrigation water strategy, at least under the Egyptian conditions where shortage of fresh water for irrigation, is a must. According to **Abu El-Azm and Youssef (2015)** and **Abdelhady et al (2017)**, applying deficit irrigation led to a certain stress on the plant depending on the stress severity. However, many agronomic practices could be carried out to alleviate the drought stress as using more efficient irrigation method mainly drip irrigation and applying stress alleviator substances (**El-Zohiri and Abd Elal, 2014; Abu El-Azm and Youssef, 2015; Abdelhady et al 2017).** In this work seaweed extract, potassium silicate and abscisic acid were used to attenuating the negative effect of the drought stress. Abscisic acid showed a poor stress alleviating effect but sometimes led to increasing the drought stress effect because of abscisic acid-mediated the drought stress response where abscisic acid closes the stomata **(Hetherington and Woodward 2003).** Stomatal closure results in a reduction of stomatal conductance and CO_2 availability, which reduces rates of photosynthesis **(Chaves et al 2003).** Meanwhile, the seaweed extract showed a superior effect in drought stress alleviation where it was used in numerous studies for nutrient supplementation and as biostimulant or biofertilizer to increase plant growth and yield **(Blunden et al 1997).** Also other studies have revealed a wide range of other beneficial effects of seaweed extract applications on plants, such as improve plant performance and yield, elevated resistance to biotic and abiotic stress, and other benefits in the plant production **(Khan et al 2009; Abu Seif et al 2016; Ertani et al 2018)**. As described by **Blunden et al (1997)**, the application of seaweed extract increased chlorophyll content, improved photosynthesis and nutrient uptake so, under our work, seaweed foliar spray enhanced taro plant performance **(Tables 2, 3)** especially leaf chlorophyll content and nutrients uptake particularly under low irrigation levels. This effect was accompanied by a clear improvement in the plant height, number of leaves, leaf area and leaf dry matter. **Abu El-Azm and Youssef (2015)** cited that the stimulus effect of potassium silicate my be due to the role of both potassium and silicon in plant growth, especially under stresses. Where potassium plays important roles in alleviating the damaging effects of drought stress through its effects on enzyme activation, protein synthesis, photosynthesis, stomatal movement and water-relation (turgor regulation and osmotic adjustment) in plants **(Marschner, 2011)**. Moreover, the beneficial roles of silicon in combating various biotic and abiotic stresses have been widely reported **(Zhu and Gong, 2014).** Under our study, the enhancing effect of potassium silicate either as absolute or combined with irrigation was less than that of seaweed, especially under less watering.

Mineral content in the leaves

Data in **Table (3**) exhibited that nitrogen, phosphorus, potassium, calcium and magnesium content in taro leaves were decreased with decreasing the irrigation level. The highest values of the nutrients content were recorded with the irrigation level of 120% of the ETc while the least values were recorded with 60% ETc irrigation level. The highest content of nitrogen, phosphorus, potassium, calcium and magnesium in taro leaves were achieved with seaweed extract foliar spraying followed by spraying with potassium silicate, while no significant differences were recorded with abscisic acid spraying or control treatment. The interaction between irrigation levels and foliar spray substances affected significantly the nutrients content in taro leaves. It is clear that seaweed extract spraying modified the adverse effect of decreasing the irrigation levels than spraying with either of potassium silicate or abscisic acid.

Corm yield and water use efficiency

Data in **Table (4)** revealed that corm yield per feddan was significantly affected by irrigation level, foliar spray substances and their interaction. Due to the synchronization of vegetative growth and corm formation in taro, corm yield was also affected by the experimental factors similarly to the vegetative growth. Where the highest corm yield was obtained with higher irrigation level. In other words, corm yield was positively correlated by the amount of irrigation water.

Table 3. Effect of irrigation levels and foliar spray substances on nitrogen, phosphorus, potassium, calcium and magnesium of taro leaves grown in 2014 and 2015 growing seasons

Treatments		Nitrogen (%)		Phosphourus (%)		Potassium (%)		Calcium (%)		Magnesium (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigationlevel[a]											
120%		2.603a	2.610a	0.312a	0.320a	1.943a	2.031a	3.170 a	3.332 a	0.349 a	0.378 a
1000%		2.561ab	2.582b	0.307b	0.314b	1.940b	2.029b	2.888 b	3.081 b	0.275 b	0.306 b
80%		2.541ab	2.579c	0.305c	0.307c	1.938c	2.027c	2.369 c	2.524 c	0.259 c	0.276 c
60%		2.476b	2.512d	0.268d	0.277d	1.931d	1.999d	1.505 d	1.750 d	0.213 d	0.233 d
Foliar spray substances[b]											
Seaweed		2.661a	2.683a	0.316a	0.323a	1.948a	2.036a	3.165 a	3.289 a	0.314 a	0.342 a
$KSiO_3$		2.541ab	2.553b	0.309b	0.315b	1.939b	2.028b	2.855 b	3.063 b	0.290 b	0.313 b
ABA		2.525b	2.549c	0.298c	0.303c	1.935c	2.025c	2.142 c	2.342 c	0.260 c	0.283 c
Control		2.441c	2.498d	0.269d	0.277d	1.929d	1.998d	1.771 d	1.992 d	0.233 d	0.254 d
Irrigation level[a] X Foliar spray substances[b]											
120%	**Seaweed**	2.820a	2.829a	0.327a	0.338a	1.953a	2.041a	3.990 a	4.034 a	0.422 a	0.435 a
	$KSiO_3$	2.533b	2.539cd	0.318 cd	0.325d	1.945cd	2.033cd	3.770 ab	3.970 b	0.361 b	0.393 b
	ABA	2.551b	2.557f	0.308e	0.315e	1.940ef	2.029ef	2.740 c	2.948 d	0.346 c	0.387d
	Control	2.510b	2.516j	0.294h	0.303g	1.935gh	2.024gh	2.078 c	2.378 d	0.268 c	0.281 d
100%	**Seaweed**	2.640b	2.644 b	0.323b	0.332b	1.950b	2.038b	3.748 ab	3.965 ab	0.322 a	0.361a
	$KSiO_3$	2.560b	2.563de	0.316cd	0.323cd	1.941de	2.030de	3.605 b	3.748 c	0.298 b	0.331c
	ABA	2.536b	2.555gh	0.302f	0.300j	1.938ef	2.028ef	2.113 d	2.323 d	0.245 d	0.265 d
	Control	2.508b	2.568j	0.289i	0.301gh	1.932hi	2.022hi	2.088 e	2.288 e	0.236 e	0.267 e
80%	**Seaweed**	2.604b	2.640c	0.322bc	0.323bc	1.948bc	2.037bc	3.128 ab	3.168 ab	0.291 ab	0.299 ab
	$KSiO_3$	2.548b	2.561e	0.314d	0.313d	1.939ef	2.028ef	2.350 b	2.550 c	0.238 b	0.298 c
	ABA	2.525b	2.553h	0.298g	0.300f	1.935fg	2.023h	2.188 f	2.380 f	0.240 f	0.251f
	Control	2.442b	2.562k	0.288i	0.293i	1.930hi	2.021hi	1.812 g	1.998 f	0.224 f	0.256 f
60%	**Seaweed**	2.582b	2.620gh	0.293hi	0.302gh	1.942fg	2.028gh	1.791 g	1.990 g	0.221 g	0.255 g
	$KSiO_3$	2.526b	2.550h	0.288i	0.299h	1.933gh	2.023gh	1.698 h	1.987 h	0.218 h	0.230 h
	ABA	2.490b	2.532i	0.284j	0.297i	1.928i	2.020i	1.528 i	1.720 i	0.211 i	0.232 i
	Control	2.306c	2.346i	0.208k	0.213k	1.921j	1.925j	1.005 j	1.305 j	0.205 j	0.215 j

[a]Averages for each group within a column for the same factor followed by the same letter do not significantly differ (P = 0.05) according to Duncan's multiple range test.

Table 4. Effect of irrigation levels and foliar spray substances on yield and water use efficiency of taro grown in 2014 and 2015 growing seasons

Treatments		Yield of corms per Feddan (ton)		Water use efficiency Kg / m^3	
		1st season	2nd season	1st season	2nd season
Irrigation level[a]					
120%		20.175 a	21.915 a	3.85	4.18
1000%		16.710 b	18.750 b	3.83	4.33
80%		15.375 b	17.52 b	4.60	5.04
60%		13.218 c	14.205 c	3.80	3.92
Foliar spray substances[b]					
Seaweed		18.343 a	21.199 a	4.45	4.99
$KSiO_3$		17.831 a	19.043 b	4.26	4.55
ABA		15.250 b	16.562 c	3.84	4.11
Control		14.062 b	15.615 c	3.60	3.83
		Irrigation level[a] X Foliar spray substances[b]			
120%	**Seaweed**	22.5 a	25.24 a	4.30	4.82
	$KSiO_3$	21.945 a	24.195 a	4.19	4.62
	ABA	18.24 b	19.5 b	3.48	3.72
	Control	18.00 b	18.75b	3.44	3.58
100%	**Seaweed**	20.62a b	22.17ab	4.76	5.08
	$KSiO_3$	17.745 bc	18.84 bc	4.06	4.30
	ABA	15.75 cd	17.505 cd	3.61	4.01
	Control	14.745 def	17.250 cd	3.38	3.95
80%	**Seaweed**	18.24 b	21.00 ab	5.22	6.02
	$KSiO_3$	16.740 bcd	18.375 bcd	4.79	5.26
	ABA	14.875 de	16.375 cde	4.26	4.69
	Control	14.500 de	14.749 def	4.15	4.22
60%	**Seaweed**	13.74 def	13.99 ef	4.05	4.06
	$KSiO_3$	13.245 def	13.75 def	4.04	4.05
	ABA	12.0 efg	12.75 fg	4.02	4.02
	Control	10.74 fg	12.0 gh	3.44	3.58

[a]Averages for each group within a column for the same factor followed by the same letter do not significantly differ (P = 0.05) according to Duncan's multiple range test.

For the impact of foliar spray substances (seaweed extract, potassium silicate and abscisic acid) it was observed that substances increased corm yield than control treatment. The highest corm yield was recorded with seaweed followed by potassium silicate then abscisic acid.

Regarding the effect of the interaction between irrigation level and foliar spray substances, results it is appered that at 120% ETc irrigation level, both seaweed extract and potassium silicate were superior and equally in their effect on the corms yield. But with the lower irrigation levels, seaweed extract was still superior to other substances with all irrigation levels. Abscisic acid, especially under low irrigation levels, showed no enhancing effect but it might increase the adverse effect of irrigation level reduction.

Water use efficiency is considered a true criterion for distinguishing between the experimental treatments. Therefore, the highest WUE was obtained with 80% irrigation level. Seaweed extract foliar spray recorded the highest WUE compared to other used substances. The combination of seaweed and 80% irrigation level conferred the surpassed WUE than other combinations. These results were true during the two growing seasons.

Corm quality

Fresh weight, dry matter percent and carbohydrates and starch percent in taro corm responded significantly to irrigation levels **(Table 5)**. The response was compatible with irrigation level. Where

Table 5. Effect of irrigation levels and foliar spray substances on dry matter, fresh weight, total carbohydrates and starch of taro corms grown in 2014 and 2015 growing seasons

Treatments		Fresh weight of corm (gm)		Corm dry matter (%)		Starch content in corms (%)		Total carbohydrates in corms (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigationlevel[a]									
120%		1345.0a	1461.67a	20.38a	21.93a	52.86a	53.28a	54.6a	55.51a
1000%		1114.58b	1250.42b	19.73ab	20.91b	51.32ab	52.31ab	52.73b	53.58b
80%		1025.0b	1168.75b	19.66ab	20.97b	49.89b	51.28b	51.43b	52.36b
60%		881.25c	947.92d	18.61b	18.65c	46.13c	45.85c	47.13c	47.59c
Foliar spray substances[b]									
Seaweed		1222.92a	1413.33a	20.40a	21.31a	54.08a	54.68a	55.42a	56.15a
$KSiO_3$		1188.75a	1269.58b	20.19ab	20.82a	52.28b	52.78a	54.09a	55.67a
ABA		1016.67b	1104.17c	19.24bc	21.85a	47.93c	49.39b	49.89b	50.41b
Control		937.5b	1041.67c	18.653	19.24b	45.80d	45.85c	46.49c	46.81c
Irrigation level[a] X Foliar spray substances[b]									
120%	**Seaweed**	1500.0a	1683.33a	21.18a	22.67a	57.81a	56.98a	58.79a	59.33a
	$KSiO_3$	1463.33a	1613.3a	21.03a	22.29a	54.17bc	53.69abcd	56.15ab	58.50ab
	ABA	1216.67b	1300.0cd	20.02abc	21.53a	50.04ef	52.17cdef	53.11bcdef	53.24cd
	Control	1200.0b	1250.0de	19.27abcd	21.24a	49.43ef	50.28ef	50.35efgh	50.96de
100%	**Seaweed**	1241.67b	1478.33b	20.27ab	22.60a	54.33b	54.70abc	55.15bc	56.15abc
	$KSiO_3$	1183.33bc	1256.67de	19.69abcd	21.24a	53.50bcd	54.59abc	54.94bcd	56.07abc
	ABA	1050.0bcde	1167.0fg	19.43abcd	21.33a	49.08ef	50.91def	50.80efgh	51.78d
	Control	983.33cde	1150.0efg	19.54abcd	19.26a	48.39efg	49.04fg	50.04fgh	50.31de
80%	**Seaweed**	1216.67b	1400.0bc	20.73a	21.83a	53.68bcd	55.65ab	54.96bcd	55.94bc
	$KSiO_3$	1116.67bcd	1225.0def	20.10abc	21.56a	50.54def	53.52bcde	53.50bcde	55.28bc
	ABA	991.67cde	1091.67gh	19.54abcd	21.80a	48.13efg	49.13fg	47.24ghi	50.02de
	Control	966.67hi	983.33hi	18.29bcd	17.86bc	47.58fg	46.80gh	48.04hi	48.21ef
60%	**Seaweed**	916.67ij	933.33ij	1942abcd	19.31b	51.33bcde	51.39cdef	52.793cdef	53.2cd
	$KSiO_3$	883.33ef	916.67ij	19.54abcd	19.25b	50.91cde	49.35fg	51.78defg	52.85cd
	ABA	800.00j	850.00ef	17.96cd	18.50bc	45.17g	45.37h	46.41i	46.58f
	Control	716.67f	800.0j	17.51d	17.56c	37.1h	37.3i	37.53j	37.75g

[a]Averages for each group within a column for the same factor followed by the same letter do not significantly differ (P = 0.05) according to Duncan's multiple range test.

the highest values of all parameters were obtained with 120% irrigation level then the values were decreased with decreasing the irrigation level to 60% of the ETc.

It was clear that the foliar spray with seaweed extract was superior, thereafter potassium silicate, but the least values of the corm parameters were recorded by abscisic acid or control treatments.

Taro corm parameters were significantly affected by the interaction between irrigation levels and foliar spraying substances. The irrigation levels exhibited a clear effect compared to the foliar spraying substances because of the descending response of the corm parameters to each foliar spraying substance with decreasing the irrigation level.

Corm parameters values were similar when spraying seaweed extract with each irrigation levels of 80% and 100%, the same result was obtained by spraying potassium silicate. The same trend of data was obtained during the two growing seasons starch content in the corm showed the highest values under each 100% and 120% irrigation levels compared to irrigation levels of 80% and 60% of the ETc. Taro vegetative growth and corms formation (yielding) are synchronized. So that, according to **Paul and Bari (2011)** vegetative growth indicating to corms yield and quality. Therefore, our results demonstrated that higher corm yield and quality (corm fresh and dry weight as well as starch and carbohydrate contents) appeared to be concomitant with irrigation levels (120% and 100% ETc) and foliar spry substances (seaweed extract and potassium silicate) and their combinations which also enhanced the vegetative growth parameters.

CONCLUSION

Taro cultivation in Egypt earns an important situation especially in some areas. Therefore, the result of this study support continuing taro production even under the fresh water shortage with some modifications in the irrigation system and agronomic practices. So using drip irrigation as a higher efficient irrigation method is preferable and increases water use efficiency. Otherwise, minimizing the irrigation water quantity by about 20% can heighten the water use efficiency but may cause a drought stress on the plants which could be attenuated via foliar spraying mainly by seaweed extract and alternatively by potassium silicate.

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تأثير مستويات الرى والرش الورقى بمستخلص الاعشاب البحرية وسيليكات البوتاسيوم وحمض الابسيسك على النمو ومحصول الكورمات وجودة القلقاس

[165]

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الموجـــــز

أقيمت تجربة حقلية فى المزرعة البحثية لمعهد بحوث البساتين بمحطة القناطر فى محافظة القليوبية خلال موسمى النمو 2014 و 2015 لتقييم تأثير مستويات الرطوبة (120% ،100 ،80 ،60 من البخر نتح) ومواد تخفيف الإجهاد (مستخلص الأعشاب البحرية، سيليكات البوتاسيوم، وحمض الابسيسك بالإضافة لمعاملة الكنترول) على النمو ومحصول الكورمات وجودة القلقاس البلدى مع محاولة لتطبيق إستراتيجية توفير مياه الري في مزراع القلقاس وقد أشارت النتائج إلى انخفاض متزايد في نمو النبات ومحصول الكورمات والجودة بسبب التقليل من مستوى الري من 120٪ إلى 60٪. ولكن تم الحصول على أعلى كفاءة استخدام للمياه (WUE) مع مستوى الري 80٪. أظهر مستخلص الأعشاب البحرية تحسينًا فائقًا في جميع القياسات الخضرية والمحصول والجودة المقاسة تليها سيليكات البوتاسيوم مقارنة بحمض الأبسيسيك أو الكنترول. زاد مستخلص الأعشاب البحرية من كفاءة استخدام المياه (WUE) مقارنة بالمواد الأخرى. أدى استخدام مستوى الري بنسبة 80٪ مصحوبًا برش مستخلص الأعشاب البحرية إلى انخفاض معتدل في نمو النبات والمحصول والجودة، ولكنه أعطى أعلى مستوى لكفاءة استخدام المياه (WUE) مقارنةً بمعاملات التفاعل الأخرى.

الكلمات الدالة: القلقاس، النمو الخضرى، نقص مستوى الرطوبة، مواد تخفيف الاجهاد، مستخلص الأعشاب البحرية، سيليكات البوتاسيوم، أبسيسيك، محصول الكورمات، كفاءة استخدام الماء

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