Middle East Journal of Agriculture Research Volume : 09 | Issue : 02| April-June | 2020
EISSN: 2706-7955 ISSN: 2077-4605 Pages:468-478
DOI: 10.36632/mejar/2020.9.2.37

Effect of foliar application with some treatments on summer squash (*Cucurbita pepo, L.*) tolerance to high temperature stress

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Received: 20 April 2020/ Accepted 15 June 2020 / Publication date: 30 June 2020

ABSTRACT

Two field experiments were carried out in a private farm at Boqtares Village, Dakahlia Governorate, Egypt during the seasons of 2017 and 2018 on summer squash under open field conditions. The main objective was to study the effect of foliar application with some treatments i.e., vitamin C, vitamin E, potassium silicate, salicylic acid, glycine betaine, urea, calcium nitrate, boric acid, zn chelate and control (water spray) on summer squash (*Cucurbita pepo,* L. cv. Eskandarani) tolerance to high temperature stress. Generally, the foliar application of glycine betaine at 75 ppm resulted in vigor squash plant as expressed by vegetative growth parameters i.e., plant height, number of leaves per plant, leaf area, plant fresh weight and plant dry weight compared with other foliar treatments. Moreover, the highest values of fruit yield and quality components, i.e., fruit length, fruit diameter, average fruit weight, number of fruits per plant and fruit yield per plant and per feddan were recorded with potassium silicate application at 100 ppm followed by vitamin C at 100 ppm and vitamin E at 100 ppm treatments. Also, potassium silicate recorded the highest values of TSS % in squash fruits and total chlorophyll in leaves compared with other treatments. The highest percentage of N, P and K were recorded with glycine betaine and potassium silicate (K_2SiO_3). The obtained results indicated, generally, that foliar applications of glycine betaine at 75 ppm and potassium silicate at 100 ppm to squash plants might be considered as an optimal treatment for the production of high vegetative growth, yield and fruit quality of squash under the environmental conditions of Dakahlia Governorate and other similar regions.

Keywords: *summer squash, Cucurbita pepo,* vitamins, antioxidants, high temperatures, yield.

Introduction

Summer squash (*Cucurbita pepo*, L.) is one of the most popular vegetable crops for human nutrition and is a highly polymorphic vegetable grown during summer in Egypt and all over the world. Also, squash is one of the most important cash crops, especially, in newly reclaimed areas of Egypt. Summer squash fruits are very low in calories (19 Kcal/100 g), moisture (94.8 g), edible portion (94%) and have large amounts of fiber (0.8 g) (Tamer *et al*., 2010). Heat stress is defined as the rise in temperature beyond a threshold level for a period sufficient to cause permanent damage to plant growth and development. It is a complex function of intensity, duration, and the rate of the increase in temperature. The frequently exposed to heat stresses resulted in adverse effect on the growth of plants which affect the metabolism and yield (Dreesen *et al*., 2012; Rollins *et al.,* 2013). The soil temperature increase resulting from the increase in air temperature maybe even stronger when accompanied by a drought-induced decline in soil water content (Sekhon *et al.,* 2010). Hence, this study suppose that some treatments could be playing a major role in mitigation the advance effect of heat stress on squash growth and yield.

Vitamin C is a vitamin known as growth regulating factor which influences many biological processes. It is currently considered as a plant growth regulator due to its effect on cell division, differentiation and various growth factors (Amin *et al.,* 2007). It increases nucleic acid content, especially RNA and acts as co-enzyme in the enzymatic reactions and involved in photosynthesis and respiration (Mazher *et al.,* 2011 and Salama *et al.,* 2014). Vitamin E is a necessary ingredient for biosynthesis of the coenzyme thiamine pyrophosphate, which plays an important role in carbohydrate metabolism (Hendawy and Ezz El-Din, 2010) and helps to provide an optimal environment for photosynthetic machinery (Jaleel *et al*., 2006).

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Salicylic acid (SA) is a phenolic compound and natural constituent of plant, it involves in plant resistance to different pathogen attacks. It plays physiological roles in plant growth, nutrients uptake, flower induction, stomata movement and activity of photosynthesis and enzymes (Iqbal *et al.,* 2014). Also, (Abd El-Mageed *et al.,* 2016 and Abd – Elaziz *et al.,* 2019) showed that, the vegetative growth, yield and its components were maximized due to salicylic acid foliar application. Silicon (Si) is deposited as silica in the plant cell walls, improving cell wall structural rigidity and strength, plant architecture and leaf erectness. It has been reported that Si applied by external foliar treatments has beneficial effects on plant growth and plays an important role in tolerance of plants to environmental stresses (Liang *et al*., 2015 and Rizwan *et al.,* 2015). Omar (2017) reported that, foliar application with silicon caused an increase in vegetative growth and yield and its components of cucumber and Abd – Elaziz *et al.* (2019) reported the same results on summer squash.

Zinc is one of the important elements necessary for the plant, it is includes in the composition of the essential amino acids and affects many vital operations of the plant. In addition, it plays a role in the formation of some important enzymes, stimulating the metabolism of proteins and carbohydrates and integrity of nucleic acids and cell membranes (Lalelou and Fateh, 2014). Moreover, calcium (Ca), one of the essential nutrients for plants, plays a major role in the initiation of many signal transduction processes in higher plant cells, polar growth, cell division and helps to maintain the chromosome structure and hormone regulated growth and development (Ashraf, 2004). It activates phospholipase, arginine kinase and adenosine tri phosphatase (ATPase) enzymes (Mumivand *et al.,* 2010).

Boron (B) has physiological important roles in the strength of cell wall which is a part of the cell membranes in addition to its vital role in respiration, cell wall structure, carbohydrate metabolism, cell division, hormonal regulation and fertilization thus boron supply is necessary for improving fruits yield and quality of vegetable crops (Esringü *et al.,* 2011). Likewise, several investigations showed that the vegetative growth, yield and quality of vegetable crops positively responded to boron foliar supplies (Abd El-Gawad and Osman 2014; Buczkowska *et al.,* 2016)...

Furthermore, the major source of protein in plant tissues is urea such source of nitrogen and amino acids. The requirement of nitrogen of amino acids in essential quantities is well known as a instrument to increase the vegetative growth, yield and its components. Amino acids are the fundamental ingredients for the process of protein synthesis. Studies have proved that amino acids can directly or indirectly influences the physiological activities in plant growth and development. The foliar application of urea caused an enhancement in plant growth, fruits yield and its components of cucumber (Xu *et al.*, 2004) and squash (Abd El-Aal *et al.,* 2010). Glycine betaine is amino acid which is considered as a vital activator that is rapidly absorbed and transported within the plant part, very common to be accumulated during salt stress and plays a fundamental role in osmotic adjustment in plants (Szabados and Savoure, 2010).

Therefore, this investigation aimed to improve plant growth and fruits yield and its components of squash grown under high temperature stress conditions by using different foliar applications.

Materials and Methods

Two field experiments were conducted in a private farm at Boqtares Village, Dakahlia Governorate, Egypt under open field conditions during the growing of seasons 2017 and 2018 to study the effect of foliar application with ten treatments i.e. vitamin C at 100 ppm, vitamin E at 100 pm, potassium silicate at 100 ppm, salicylic acid at 50 ppm, glycine betaine at 75 ppm, urea at 1 %, calcium nitrate at 0.5 %, boric acid at 60 ppm, zinc chelate at 50 ppm and control (water spray) on summer squash (*Cucurbita pepo,* L. cv. Eskandarani) tolerance to high temperature stress. Before sowing, random soil samples (0 - 30 cm depth) from different places of the planting field were collected and some important chemical and physical properties were analyzed according to A. O. A. C. (1990) is given in Table 1.

The prevailing climatic conditions of the meteorological station during the two growing seasons of squash at Dakahlia Governorate are listed in Table 2.

Table 1: Physical and chemical proprieties of the experimental soil during 2017 and 2018 seasons.

Soil proprieties	2017	2018
	1- Physical analysis	
Course sand (%)	1.49	1.51
Fine sand (%)	22.69	23.04
Silt	17.77	17.65
Clay (%)	58.05	57.80
Ca Co_3 (%)	1.71	1.75
Soil texture	Clay loam	Clay loam
	2- Chemical analysis	
pH	8.05	7.95
Ec (dsm^{-1} at 25 ºC)	1.38	1.40
Organic matter	1.44	1.67
Available N (ppm)	70.33	73.04
Available P (ppm)	14.5	15.08
Available K(ppm)	67.11	71.93
Available Fe (ppm)	3.05	3.22
Available Mn (ppm)	1.44	1.61
Available Zn (ppm)	1.50	1.60
Ca^{2+}	1.13	1.14
Mg^{2+}	0.87	0.84
Na^{2+}	1.08	1.10
So_4^{2+}	1.33	1.43

Table 2: Meteorological recorded of Dakahlia Governorate* during the seasons 2017 and 2018.

Month	2017			2018		
	Max. Temp.	Min. Temp.	Avg. Temp.	Max. Temp.	Min. Temp.	Avg. Temp.
June	32.1	20.1	26.1	33.7	22.5	28.1
July	38.5	25.0	31.7	41.0	25.3	33.1
August	35.3	23.8	29.5	38.7	22.6	30.6
September	32.1	20.9	26.5	34.3	21.0	27.6
October	26.7	17.6	22.2	29.8	21.2	25.5
November	22.6	13.3	18.0	30.0	17.1	20.1
December	20.2	11.9	17.0	22.0	14.8	18.4

* **Source:** Meteorology data from Central Lab. for Agricultural Climate, Agricultural Research Center, Egypt.

Squash seeds (*Cucurbita pepo*, L. cv. Eskandarani) were sown directly in the field on 1th week of July during both seasons of 2017 and 2018. The treatments were arranged in a randomized complete blocks design (RCBD) with three replicates. The plot area was (15 m^2) comprised of three ridges (5 m length and 1 m width) with 0.5 m spacing between plants in row. After germination, plants were thinned to one plant per hill. Squash plants were sprayed by the allocated treatments twice during the growing seasons, at 25 days after sowing (at the fourth true leaf stage) and one week later. The NPK fertilizers were added at a rate of 200 kg / fed. as ammonium sulphate (20.5 % N), 100 kg / fed. as super phosphate (15.5 % P_2O_5) and100 kg / fed. as potassium sulphate (48 % K_2O), nitrogen and potassium were added in three portions; first portion after one month, the second portion after two months from sowing and the third portion during the flowering stage. While, phosphorus fertilizer was added during soil preparation before sowing. The recommended cultural practices i.e., irrigation, pest and diseases control, etc. of summer squash plant for commercial squash production in the area were applied as recommended by the Ministry of Agriculture.

The recorded data:

Vegetative growth parameters:

A random sample of 5 plants from each plot was taken at 75 days after sowing to determine plant height (cm), number of leaves per plant, leaf area (cm^2), plant fresh weight (g) and plant dry weight (g).

Yield and its components:

At harvest stage the mature fruits of squash were harvested twice every week along the harvesting season. At the harvesting time, fruit length (cm), fruit diameter (cm), average fruit weight (g), number of fruits per plant, fruit yield per plant (kg) and fruit yield per feddan (ton) were calculated.

Chemical constituents:

N, P, K and Si contents of leaves were determined according to the methods described by Okalebo *et al.* (2002), Pregl (1945), Murphy and Riley (1962) and APHA (1992). Total chlorophyll was estimated in leaves accordance to Marquard and Tipton, (1987). Total soluble solids content (TSS %) was estimated in the juice of the fresh fruits using a hand refractometer and Vitamin C content was estimated accordance to Mazumdar and Majumder, (2003).

Statistical Analysis:

All data were statistical analysis accordance to the procedure out lined by Snedecore and Cochran (1982) and the treatment means were compared using significant at 0.05 and 0.01 levels of probability (LSD). Data were statistically analyzed using Co- STAT computer software program

Results and Discussion

Vegetative growth:

The present data in Table 3 illustrated the effect of foliar treatments (vitamin C at 100 ppm, vitamin E at 100 ppm, potassium silicate at 100 ppm, salicylic acid at 50 ppm, glycine betaine at 75 ppm, urea at 1 %, ca nitrate at 0.5 %, boric acid at 60 ppm, zn chelate at 50 ppm and control (water spraying)) on vegetative growth of summer squash. The vegetative growth traits (plant height, number of leaves per plant, leaf area and fresh and dry weight of plant) were positively influenced by all foliar application treatments during the first and second seasons compared with control (untreated plants). Whereas, the best plant growth was obtained when glycine betaine sprayed at 75 ppm followed by urea at 1 % compared with other treatments and the lowest values were correlated with the control (untreated plants) during the first and second seasons under this study. Generally, glycine betaine at 75 ppm gave the highest mean magnitudes during the both seasons as (25.00 and 25.33; 2452.61 and 2476.14; 645.00 and 645.00; 105.90 and 106.38) for number of leaves per plant, leaf area, fresh and dry weight traits, respectively during the two seasons. The positive effect of glycine betaine on squash growth may be due to playing a major role in increase plant tolerance to some abiotic stress such as drought and high temperatures (Salem, 2018). The main cause for that vigour of squash in response to urea foliar application compared to the other treatments might be due to that the urea contains the most nutritional element such as nitrogen which is more needed if compared with the requirements of plant to amino acids, also, it is a source of nitrogen fertilizer had a major role in improvement the metabolism processing due to the importance of nitrogen in building carbohydrates, protein and fats in the plant tissues (Abd El- All *et al.,* 2013). In addition, the favorable impact of Si application resulted in its ability to hamper both biotic pressures caused by pest attacks and plant diseases, as well as biotic pressures, including physical pressures such as water logging, drought, high temperature and chemical pressures as nutrient deficiencies and metal toxicity (Rizwan *et al.,* 2015; Abd-Elaziz *et al.* 2019). Also, Elwan and El-Shatoury (2014) and Abd El-Mageed *et al.* (2016) illustrated that exogenous salicylic acid (SA) application, significantly, increased all squash growth parameters (plant length, number of leaves per plant, leaf area per plant and fresh and dry weights per plant). Furthermore, the increased vegetative growth parameters might be attributed to increased cell division and cell elongation induced by aforementioned treatments. The tabulated results indicated, clearly, their modes of action in regulating and modulating the physiological processes on growth and development of summer squash under the study via ion uptake and transport, photosynthetic rate, membrane permeability and transpiration. El-Tohamy *et al.* (2008) found that foliar application of vitamin C increases plant fresh weight of eggplant. Vitamin E could be attributed to the influence of these components upon the endogenous phytohormones specially the growth promoters such as Auxins, cytokinins and gibberellins (Mady, 2009). The obtained results are in agreement with those reported by Majeed, (2010) on calcium; Noman (2011) on vitamin C in pumpkin; Jafari *et al.* (2015)

Middle East J. Agric. Res., 9(2): 468-478, 2020
EISSN: 2706-7955 ISSN: 2077-4605 *DOI: 10.36632/mejar/2020.9.2.37*

on silicon; Nasrollahzadeh *et al.* (2015) on boric acid; Abd El-Mageed *et al.* (2016) on salicylic acid and Al-Rubaye and Atia, (2016) on zinc.

Table 3: Effect of foliar application with some treatments on the vegetative growth traits of summer squash plants during two seasons of 2017 and 2018.

Treatments / Traits	Plant height (cm)		Number of leaves / plant		Leaf area (cm^2)	
	2017	**2018**	**2017**	**2018**	**2017**	**2018**
Control	38.33	40.00	10.33	11.33	2060.39	2068.79
Vitamin C at 100 ppm	50.33	52.00	19.00	21.67	2307.10	2311.62
Vitamin E at 100 ppm	48.33	49.00	16.67	19.00	2345.54	2349.89
Potassium silicate at 100ppm	51.00	52.67	17.67	18.33	2336.82	2336.59
Salicylic acid at 50ppm	47.33	46.00	20.33	20.33	2289.77	2294.61
Glycine betaine at 75ppm	60.00	62.33	25.00	25.33	2452.61	2476.14
Urea at 1 %	55.67	57.33	22.00	24.67	2406.45	2421.47
Ca nitrate at 0.5 %	52.00	51.33	20.67	23.33	2336.78	2342.39
Boric acid at 60 ppm	49.67	52.33	19.67	21.33	2357.24	2355.62
Zn chelated at 50 ppm	53.00	54.67	20.67	20.33	2374.86	2384.06
LSD 1 %	**3.483**	**3.990**	**2.077**	**3.820**	**46.594**	**47.490**
LSD 5 %	**2.542**	**2.910**	**1.516**	**2.793**	**34.008**	**34.660**

Table 3: Continued

Treatments / Traits	Plant fresh weight (g)		Plant dry weight (g)	
	2017	**2018**	**2017**	**2018**
Control	345.00	344.67	49.18	50.82
Vitamin C at 100 ppm	591.67	593.33	86.20	87.67
Vitamin E at 100 ppm	508.33	511.67	72.23	72.93
Potassium silicate at 100 ppm	527.67	538.67	77.07	78.76
Salicylic acid at 50 ppm	581.00	589.67	81.92	84.66
Glycine betaine at 75 ppm	645.00	645.00	105.90	106.38
Urea at 1 %	626.00	630.00	97.79	101.31
Ca nitrate at 0.5 %	575.30	580.00	89.17	88.67
Boric acid at 60 ppm	580.67	585.00	78.84	79.70
Zn chelated at 50 ppm	594.33	611.67	79.38	82.93
LSD 1 %	**10.635**	**21.940**	**4.020**	**6.39**
LSD 5 %	**7.762**	**16.014**	**2.934**	**4.66**

2- Yield and its components:

The results in Table 4 showed that all treated plants exhibited the highest significant means of fruit length, average fruit weight, number of fruits per plant, total yield per plant and total yield per feddan, expect for fruit diameter compared to untreated plants (control) during the first and second seasons. Potassium silicate at 100 ppm exhibited the highest means for all studied traits expect for fruit diameter traits followed by vitamin C at 100 pm during the both seasons, respectively. Generally, summer squash plants treated with 100 ppm potassium silicate recorded the highest mean of fruit length (14.94 and 15.86 cm), average fruit weight (125.64 and 134.05 g), number of fruits per plant (10.33 and 12.33), total yield per plant (1.30 and 1.65 kg) and total yield per feddan (10.39 and 12.23 ton) followed by 100 ppm vitamin C (13.98 and 15.47; 121.88 and 127.72; 9.67 and 11.33; 1.18 and 1.45; 9.42 and 11.58) for aforementioned traits, respectively in both seasons. The obtained results showed that the increasing of fruit length, average fruit weight, number of fruits per plant, total yield per plant and per feddan (fruit yield) were obtained due to foliar application with potassium silicate at 100 ppm followed by vitamin C at 100 ppm and other treatments might be attributed to the increase of vegetative growth traits compared to untreated plants during the two seasons. These results are in agreement with those illustrated by Omar (2017) who illustrated that foliar application of potassium silicate at 100 ppm caused; significant increase on cucumber fruit yield compared to control plants. With respect to total yield per plant and total yield per feddan, the lowest significant mean values for total yield per plant and total yield per feddan traits of squash fruits were derived from untreated plants compare to treated plants during the two seasons. Matichenkov and Bocharnikova (2008) found that cucumber yield was increased, significantly either by silicon application during the season or by soil Si applications. There are additional benefits for Si includes stimulation of fruit formation and accelerated fruit maturation. The positive effect of vitamin C at 100 ppm squash growth may be due to it is effect on cell division, differentiation and different growth parameters and increases nucleic acids content in the enzymatic reactions by which proteins, carbohydrates metabolized and interested in photosynthesis (Mazid *et al.,* 2011). Youssef *et al.* (2017) showed that increasing vitamin C foliar application levels significantly increased fruit length, average fruit weight and total yield in both seasons as compared with untreated plants. (Abd El-Aal *et al.,* 2010; Abd El- All *et al.*, 2013) illustrated that increasing in total fruits as well as its physical properties might be attributed to that urea resulted a promotion effect on vegetative growth traits. Therefore, might be reflected on the yield and its components such as fruit length, fruit diameter, average fruit weight and number of fruits per plant. Al-Rubaye and Atia, (2016) exhibited that foliar spraying with salicylic acid caused the highest of number of fruits, total yield per plant and total yield per hectare compared to the untreated plants. In addition, Sahin *et al.,* (2015) exhibited that, calcium and boron treatments increased the yield and its components. The present results are in agreement with those obtained by Mady, (2009) and Hendawy and Ezz El-Din (2010) on vitamin E, Shafeek *et al.* (2013) on calcium nitrate, Nasrollahzadeh *et al.* (2015) on boric acid, Al-Rubaye and Atia, (2016) on zinc, Salem (2018) on glycine betaine .

Table 4: Effect of foliar application with some treatments on yield and fruit quality traits of summer squash plants during two seasons of 2017 and 2018.

Treatments / Traits	Fruit length (cm)		Fruit diameter (cm)		Average fruit weight (g)	
	2017	**2018**	**2017**	**2018**	**2017**	**2018**
Control	10.97	10.39	3.55	3.67	90.87	94.20
Vitamin C at 100 ppm	13.98	15.47	2.93	3.33	121.88	127.72
Vitamin E at 100 ppm	13.60	14.12	2.83	2.70	116.39	117.37
Potassium silicate at100ppm	14.94	15.86	2.44	2.80	125.64	134.05
Salicylic acid at 50ppm	13.98	14.73	2.33	2.70	112.14	113.04
Glycine betaine at 75ppm	12.98	13.80	2.67	2.60	107.15	110.34
Urea at 1 %	12.57	13.75	2.54	2.90	100.59	100.23
Ca nitrate at 0.5 %	13.65	14.00	2.70	2.96	123.13	132.04
Boric acid at 60 ppm	12.29	13.01	3.05	3.27	102.42	103.00
Zn chelated at 50 ppm	12.97	12.56	2.91	3.17	107.38	110.96
LSD 1 %	**0.533**	**1.950**	**0.105**	**0.707**	**1.503**	**5.140**
LSD 5 %	**0.389**	**1.430**	**0.077**	**0.516**	**1.097**	**3.752**

Table 4: continued

Treatments / Traits	Number of fruits / plant		Total yield / plant (kg)		Total yield / *Feddan (ton)	
	2017	**2018**	**2017**	**2018**	**2017**	**2018**
Control	8.33	8.33	0.76	0.79	6.06	6.27
Vitamin C at 100 ppm	9.67	11.33	1.18	1.45	9.42	11.58
Vitamin E at 100 ppm	9.33	10.67	1.09	1.25	8.69	10.02
Potassium silicate at100ppm	10.33	12.33	1.30	1.65	10.39	12.23
Salicylic acid at 50ppm	9.33	11.00	1.05	1.25	8.37	9.96
Glycine betaine at 75ppm	8.33	9.67	0.90	1.07	7.15	8.56
Urea at 1 %	9.67	10.00	0.97	1.00	7.78	8.02
Ca nitrate at 0.5 %	8.33	9.33	1.03	1.23	8.21	9.87
Boric acid at 60 ppm	8.33	9.67	0.86	1.00	6.83	7.97
Zn chelated at 50 ppm	9.33	10.33	1.00	1.15	8.02	9.19
LSD 1 %	**1.270**	**1.842**	**0.140**	**0.239**	**1.120**	**1.719**
LSD 5 %	**0.927**	**1.345**	**0.102**	**0.175**	**0.819**	**1.201**

***1 feddan = 0.42 hectares = 4200 m^2**

Chemical constituents:

The obtained results in Table 5 showed the chemical constituents (Total chlorophyll, N, P, K, Si, TSS and Vitamin C) of summer squash as influenced by the foliar application of different treatments during the seasons of 2017 and 2018. Concerning chlorophyll index, the results revealed that, the highest readings values were found when plants treated with 100 ppm potassium silicate followed by treating plants with urea at 1 % compared to untreated plants during the first and second seasons. This finding could be taken place due to the major role of potassium silicate on photosynthetic activity, ultra-structure of leaf organelles, photosynthetic rate and photosynthetic pigments in leaves (Mady 2009).

Table 5: Effect of foliar application with some treatments on chemical constituent's traits of summer squash during two seasons of 2017 and 2018.

Treatments / Traits	Total chlorophyll (SPAD)		Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	2017	2018	2017	2018	2017	2018	2017	2017
Control	19.74	20.11	0.85	0.87	0.296	0.300	2.09	2.06
Vitamin C at 100 ppm	30.83	32.29	1.28	1.29	0.460	0.462	2.56	2.58
Vitamin E at 100 ppm	29.41	31.22	1.38	1.41	0.468	0.472	2.40	2.43
Potassium silicate at 100ppm	32.46	33.39	1.29	1.31	0.459	0.462	3.14	3.13
Salicylic acid at 50ppm	31.70	33.81	1.46	1.49	0.499	0.502	2.56	2.63
Glycine betaine at 75ppm	35.96	36.99	1.61	1.59	0.530	0.533	2.96	3.00
Urea at 1 %	33.80	34.26	1.58	1.59	0.510	0.512	2.40	2.42
Ca nitrate at 0.5 %	26.48	28.48	1.48	1.50	0.475	0.474	2.33	2.37
Boric acid at 60 ppm	29.52	30.81	1.54	1.52	0.489	0.492	2.49	2.51
Zn chelated at 50 ppm	28.49	30.64	1.52	1.53	0.479	0.483	2.46	2.50
LSD 1 %	**1.654**	**2.566**	**0.041**	**0.060**	**0.006**	**0.007**	**0.079**	**0.052**
LSD 5 %	**1.207**	**1.872**	**0.030**	**0.044**	**0.005**	**0.002**	**0.057**	**0.038**

Table 5: Continued

Treatments / Traits	Silicon (%)		Total soluble solid (%)		Vitamin C (mg/100g)	
	2017	2018	2017	2018	2017	2018
Control	0.28	0.29	2.84	2.60	9.82	9.86
Vitamin C at 100 ppm	0.53	0.54	4.65	4.91	13.88	13.91
Vitamin E at 100 ppm	0.56	0.58	4.31	4.28	13.55	13.59
Potassium silicate at 100 ppm	0.66	0.67	5.09	5.90	11.58	11.69
Salicylic acid at 50 ppm	0.52	0.54	4.81	4.93	11.37	11.51
Glycine betaine at 75 ppm	0.47	0.48	4.11	4.29	12.24	11.35
Urea at 1 %	0.43	0.42	4.00	4.48	12.56	12.62
Ca nitrate at 0.5 %	0.48	0.50	4.29	4.33	12.84	12.91
Boric acid at 60 ppm	0.59	0.58	3.58	3.87	12.59	12.70
Zn chelated at 50 ppm	0.58	0.60	3.95	4.14	13.59	13.64
LSD 1 %	**0.024**	**0.051**	**0.129**	**0.440**	**0.346**	**0.216**
LSD 5 %	**0.017**	**0.037**	**0.094**	**0.321**	**0.253**	**0.158**

Further, this event may be occurred owing to ability salicylic acid and / or potassium silicate to regulate the leaf photosynthetic functions as in case of cucumber readings (Wei *et al.,* 2009). Photosynthetic pigments in leaves of wheat plants were significantly increased by application of vitamin C (Amin *et al.,* 2007). El-Tohamy *et al.* (2006) found that foliar application of calcium chloride maintained higher total chlorophyll content. The stimulative influence of vitamin E may be due to their antioxidantal scavenging effect to be forfended chloroplasts and prevented chlorophyll degradation by the toxic reactive oxygen radicals (Mady 2009). The obtained results reported that the lowest content of N, P, K and Si in leaves were obtained from untreated plants during both seasons. While, the highest percentages of N and P were obtained when plants treated with 75 ppm glycine betaine during the two seasons, respectively followed by urea at 1 % in both seasons, consequently. Regarding K content in leaves, the results showed that the highest percentages were obtained from plants treated with 100 ppm potassium silicate followed by 75 ppm glycine betaine in both seasons. Concerning to leaves content of Si, plants treated with 100 ppm potassium silicate exhibited the highest concentration in both seasons followed by 60 ppm boric acid. It is also due to the foliar urea fertilization during crop growth can improve the mineral status of plants and increase the vigor of plant. These results agree with those reported by Mady, (2009) on vitamin E; Jafari *et al.* (2015) reported that under osmotic stress silicon treatment significantly increased non-enzymatic antioxidants, total phenolic compounds, anthocyanins, flavonoids, Si, K^+ and Ca^{+2} content in cucumber plants. Omar (2017) illustrated that foliar application of silicon caused significant increase in cucumber N, P, K and Si leaves percentage compared to untreated plants.

The results in the same table revealed that the lowest TSS values of fruits were recorded during both seasons from untreated plants compared to other treatments. The highest values were gained from the plants sprayed with 100 ppm potassium silicate (5.09 and 5.90) followed by 50 ppm salicylic acid (4.81 and 4.93), respectively in both seasons of the study. In addition, the results cleared that the highest vitamin C values are associated with the plant which sprayed by vitamin C at 100 ppm followed by 100 ppm vitamin E compared to untreated plants (control) during both seasons. In general, it could be summarized that, the highest nutritional magnitudes were associated with that plants which sprayed with potassium silicate at 100 ppm but, the lowest values were resulted with untreated plants (control). Foliar application of salicylic acid at 200 ppm or potassium silicate at 100 ppm caused; significant increase in total soluble solids of cucumber fruits compared to control plants (Al-Rubaye and Atia 2016; Omar 2017). Furthermore, on squash plants Abd -Elaziz *et al.* (2019) found that total soluble solids of fruits had significantly affected by the application of potassium silicate and salicylic acid. Similar results were obtained by Noufal *et al.* (2018) on vitamin C. These results are in harmony with those reported by Al-Rubaye and Atia (2016) on zinc, Abd El-Mageed *et al.* (2016) and Abd- El aziz *et al.* (2019) on salicylic acid.

In general, it could be said that spraying potassium silicate at 100 ppm and glycine betaine at 75 ppm can be recommended for improving growth, yield and quality of summer squash under heat stress conditions of Dakahlia Governorate and other similar regions.

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