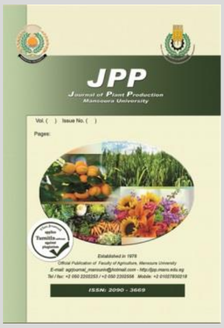
Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Productivity of some Tomato Hybrids Sprayed with Potassium Silicate Grown in Sandy Soil at Arid Regions

Alkharpotly, A. A.[1,2*] and K. G. Abdelrasheed[1]

[1] Horticulture Department, Faculty of Agriculture and Natural Resources, Aswan University, Egypt.
[2] Horticulture Department, Faculty of Desert and Environmental Agriculture, Matrouh University, Egypt



ABSTRACT

Two field experiments were conducted during winter seasons of 2018/2019 and 2019/2020 in the Experimental Farm, Faculty of Agriculture and Nature Resources, Aswan University, Aswan, Egypt. The main objective behind this study is to investigate the effectiveness of foliar application of potassium silicate (control , 1000, 2000, 3000 mg.l^{-1}) which were sprayed four times with two weeks intervals, on the performance of three tomato hybrids (Salymia (65010), 023 and El- Quds (E-448)) under arid conditions to overcome or alleviate the heat stress (temperature difference between day and night) during tomato growing seson at Aswan governorate, Egypt. Generally, the foliar application of potassium silicate at 3000 mg.l^{-1}resulted in vigor tomato plant as expressed by vegetative growth parameters *i.e*., number of leaves per plant, number of branches per plant and plant foliage fresh and dry weights as compared to other foliar treatments. Moreover, it gave the highest values of fruit yield and chemical composition of leaves and fruits. In addition, El-Quds (E-448) tomato hybrid gave the highest vegetative growth, yield parameters and chemical composition of leaves and fruits. The interaction effects among the studied treatments were significant in all studied parameters. Generally, results indicated, that El-Quds (E-448) tomato hybrid sprayed with potassium silicate at 3000 mg.l^{-1} might be considered as an optimal treatment to produce high vegetative growth, yield and fruit quality of winter tomato under the environmental conditions of the experimental condition at Aswan governorate and other similar regions.

Keywords: Tomato hybrids, potassium silicate, foliar application.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a member of the Solanaceae 'nightshade' family and one of the most important vegetables grown in Egypt. Due to its high nutritional value and various uses, tomato is the second most consumed vegetable crop after potato in the world (Siddiqui *et al*., 2020). International tomato production was 180,766,329 tons in 2019 produced from 5030545 hectares. The cultivated area of tomatoes in Egypt was 173276 hectares, and it produced 6,751,856 tons (FAOSTAT, 2019). It is, likewise, very important industrial raw material fruit crop for food processing and agricultural industry. In addition, it is used mostly as edible fresh fruits and as salad's constituents. It is an important source for the pigment of lycopene and carotein, minerals, and vitamins that have been shown to have a profound effect on some cancer cells (Helyes *et al*., 2012).

Increasing the tomato yield and fruits, quality are crucial factors for this important crop, especially at arid regions, where the high temperature at day and low at night (temperature difference between day and night) exerts an adverse effect on the growth of the whole plant, especially during flowering and fruit setting stages *via* restricting the supply of water and mineral nutrients and increasing transpiration rate, affecting the metabolism, growth and development (Boyer, 1982). Foliar applications of antitranspirants (such as potassium silicate) are used to reduce the transpiration rate and reduce these deleterious impacts of drought stress (del Amor *et al.*, 2010; Degif and Woltering, 2015). Potassium silicate (K silicate) is a source of highly soluble K and Si. It is used in agricultural production systems primarily as a silica amendment and added to the plants small amounts of K. Potassium, present within plants as the cation K plays an important role in the regulation of the osmotic potential of plant cells. It also activates many enzymes involved in respiration and photosynthesis (Marschner, 1995). Further, plants typically absorb bio-available silicon (Si) as a silicate, generally, known as monosilicic or orthosilicic acid. Silicon (Si) is deposited as silica in the plant cell walls, improving cell wall structural rigidity and strength, plant architecture and leaf erectness. Liang *et al.* (2015) reported that soluble potassium or sodium silicates are completely water soluble and can be used as foliar fertilizers, but are usually too expensive for soil application. It has been reported that Si applied by external foliar treatments or hydroponic supplementation has beneficial effects on plant growth and plays an important role in tolerance of plants to environmental stresses (Balahnina and Borkowsksa, 2013; Rizwan *et al*., 2015). However, further reports indicated that it plays a major role for a variety of plant species as solanaceae. A number of possible mechanisms through which silicate may increase salinity, heat and drought tolerance in plants have been proposed by various scientists as reviewed by Liang *et al.* (2015), including improved plant water status (Romero-Arnada *et al*., 2006); increased photosynthetic activity and ultra-structure of leaf organelles (Shu and Liu, 2001). Some investigators reported that plant foliar spray with silicon caused increase in vegetative growth, yield and quality of some vegetables as Abu El-Azm and Youssef (2015); Soundharya *et al.* (2019); Abd El-Aziz (2020) on tomato; El-Gazzar *et al.* (2020) on pepper. Weerahewa and David (2015) stated that soil application of Si to tomato at 50 and 100 mg/l showed a significantly higher fruit size, fruit firmness

* Corresponding author.
E-mail address: alkharpotly@gmail.com
DOI: 10.21608/jpp.2021.209339

and lower percentage of total acidity (TA %) compared to the untreated plants.

The development of new tomato cultivars has intended to improve productivity, quality and adaptation to different production conditions (Warnock, 1991). Rajasekar *et al*. (2013) reported the fact that growth, development, productivity and quality of any crop are heavily depending on the interaction between the plant genetics and the environmental conditions of plants growth. The optimal temperature for tomato growth and fruit set ranges from 25–30 °C to 22–25 °C (Camejo *et al*., 2005). In this regard, heat stress or high temperature is one of the most destructive abiotic stresses, and its intensity is increasing due to global warming (Masouleh *et al*., 2020), causing adverse effects on both the growth and reproduction of plants (Xu *et al*., 2017; Zhou *et al*., 2020). Moreover, increasing temperature in tomatoes can cause biochemical, morphological, and physiological alterations (Wahid *et al*., 2007). This raises the need for further studies to identify more cultivars with high yield, quality, and tolerance to heat-stressed environments. Several previous studies, *i.e*., (Mansour *et al*., 2009; Alam *et al*., 2010; Ayenan *et al*., 2021; Haque *et al*., 2021), have investigated the genetic performance of tomatoes under heat stress conditions. Hybrids of tomato differ from each other in nutrient absorption by roots and as foliar application (Weerahewa and David, 2015). Also, El-Sayed *et al*. (1990) observed significant differences among tomato hybrids in terms of both early and total yield, fruit size, weight, T.S.S., acidity and vitamin C content.

Therefore, the main objective behind this study is to investigate the effectiveness of foliar application of potassium silicate on the performance of three tomato hybrids under arid conditions to overcome or alleviate the heat stress (temperature difference between day and night) during tomato growing season at Aswan governorate, Egypt.

MATERIALS AND METHODS

Experimental sites and arrangement:

Two field experiments were conducted during winter seasons of 2018/2019 and 2019/2020 in the experimental farm, faculty of agriculture and nature resources, Aswan university, Aswan, Egypt. The geographical coordinates of the site are 23°59′56″N, 32°51′36″E and average altitude of 85 m above sea level. This study was aimed to investigate productivity of three tomato hybrids sprayed with four potassium silicate levels at arid regions.

Before transplanting, 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 Page *et al.* (1982) and Jackson (1973). These properties are showen in Table (1). The field experiments were done in a sandy soil using the drip irrigation method and Nile River (located in the experimental area) is the source of irrigation water with pH about 7.4 and an average EC 0.66 dS cm^{-1}. The drip irrigation network consisted of lateral's GR of 16 mm in diameter, with emitters at 25 cm distance, with allocating one laterals for each ridge. The emitters had a discharge rate 4 l. h^{-1}.

Seeds were sown in seedling foam trays (209 eyes) filled with a mixture of Peatmoss : Vermiculite (1:1, v / v), supplemented with 300 g ammonium sulphate (20.5% N), 400 g calcium superphosphate (15% P_2O_5), 150 g potassium sulphate (50% K_2O), 50 ml micronutrient solution and 50 g of a fungicide (Thiophenate methyl) for each 50 kg of the soil mixture under nethouse conditions on 5th September during both seasons of the study. Tomato seedlings of 25 days old (at four-leaf stage) were transplanted in the open field at one side of the ridge on the first of October during the both seasons of the study. Seedlings were transplanted at 0.50 m apart and 1.50 m width of ridge (*i. e*. the number of plants/feddan were 5600 plants). All missing transplants were replaced by another ones of the same age, one week later after transplanting.

Table 1. Some physical and chemical properties of the experimental site during both seasons of the experiments (2018/2019 and 2019/2020)

Soil properties *	Season	
	2018/2019	2019/2020
Physical analysis:		
Clay (%)	3.00%	3.50%
Silt (%)	0.00%	0.00%
Sand (%)	97.00%	96.50%
Textural class	Sandy	Sandy
Chemical analysis:		
Soluble cations in (1:1) soil: water extract (meq/l)		
Ca^{++}	3.06	3.10
Mg^{++}	1.02	1.05
K^{+}	0.83	0.85
Na^{+}	0.76	0.80
Soluble anions in (1:1) soil: water extract (meq/l)		
CO_3^{--}	0.00	0.00
HCO_3^{-}	7.10	7.06
Cl^{-}	3.60	3.57
SO_4^{--}	0.40	0.44
pH (1:1 soil suspension)	7.64	7.70
EC (dS/m) at 25° C	0.33	0.32
Available N (mg/kg soil)	128.31	130.00
Available P (mg/kg soil)	8.00	10.00
Available K (mg/kg soil)	175.00	180.00

***The analyses were carried out at Soil Fertility Departement, Faculty of Agricultur (Saba Basha), Alexanderia University, Egypt.**

All other agro-management practices such as (fertilization, irrigation, weed control, pest and disease control) were performed whenever it was necessary as recommended in the commercial production of tomato by the Egyptian Ministry of Agriculture under the experimental site conditions.

The experimental treatments and design

Treatments were consisted of four concentrations of potassium silicate 33% K_2SiO_3 (22% SiO_2 and 11% K_2O) as control , 1000, 2000, 3000 mg.l^{-1}. The control plants were sprayed with distilled water. All foliar sprayings were carried out to cover completely the whole plant foliage to run off early in the morning. Foliar sprayings were applied four times at 2-week intervals, started after three weeks from transplanting and stopped 63 days afterward. Three tomato hybrids coined as Salymia (65010), 023 and El-Quds (E-448) were used in this study. Salymia (65010) was obtained from Technogreen Company for Agricultural Projects, 023 hybrid this was produced by Sakata company, Japan, and imported by Gaara seeds company, Egypt. whereas El-Quds (E-448) hybrid was obtained from Syngenta company, Egypt.

The experiment involved 12 treatments (four potassium silicate levels and three tomato hybrids). The experimental layout was split plots in a randomized complete blocks design with three replications. Potassium silicate concentrations were distributed randomly as the main plots, and the three tomato hybrids were considered as the sub-plots. Each sub- plot consisted of two ridges; each ridge was 6.00 m length and 1.50 m width so the plot area was 18 m^2.

Experimental data collection:

1.Vegetative growth-related traits:

After 85 days of transplanting, ten plants from each treatment, in each replications, were randomly taken for recording growth attributes; number of leaves per plant, number of branches per plant and foliage fresh weight were recorded. Also, foliage dry weight was conducted in an electrical oven at 70˚ C till the constant weight.

2. Flowering characters and percentage of fruit set:

The following data were recorded on the (aforementioned) ten plants for the following characteristic. The time to the appearance of first flower (days) was determined. The number of flowers per plant was expressed as total number of the opened flowers per plant all over the season. Fruit set percentage was calculated as number of fruits per plant divided by number of flowers per plant.

3. Yield and its components characteristics:

At harvest stage when tomato fruits reached red ripe stage (approximately after 120 days of transplanting), the mature fruits of tomato were harvested every week along the harvesting season (total 8 picking times). The number of fruits per plant and average fruit weight were determined. Also, early yield was estimated by averaging the weight of the harvested fruits from the earlier until all treatments started to harvest. Total fruit yield per plant and per feddan were calculated.

4. Chemical composition: was determined in a sample of five randomly taken fruits per treatment as follows:

Total soluble solids content (TSS%) was estimated in the juice of the fresh fruits using a hand refractometer and total titratable acidity (Citric acid %) according to AOAC (1992). Vitamin C (Ascorbic acid): Fruits' vitamin C content was measured by titration method with iodide potassium according to Ranganna (1986) and calculated as mg vitamin C / 100 cm^3 juice. Reducing, non-reducing, and total sugars in fruits were determined for each sample according to the method described by Malik and Singh (1980). Leaf content of a, b and total chlorophyll (a + b) were estimated after 85 days from transplanting from the fifth leaf from the growing tip by spectrocolorimeter as described by Moran and Porath (1980). Leaf's and fruit's N, P, K and Si contents: It were determined in plant tissues according to the methods described by Okalebo *et al.*, (2002), Pregl (1945), Murphy and Riley (1962) and APHA (1992).

Statistical Analysis:

The obtained data were analyzed using the Costat Statistic Package computer software program (version 6.400), CoHort Software (1998-2008). All data were statistical analysis accordance to the procedure out lined by Snedecor and Cochran (1989) and the treatment means were compared using the using Duncan's multiple range test at 0.05 level of probability as illustrated by Duncan (1955).

Meteorological data:

Meteorological data of the experimental site during time-course of the present study are illustrated in Table (2).

Table 2. The maximum, minimum and average air temperatures per week during the two winter seasons of 2018/2019 and 2019/2020

weeks	Air temperature [°C]			Air temperature [°C]		
	Max.	Min.	$\bar{x}$	Max.	Min.	$\bar{x}$
	2018/2019			2019/2020		
1-10 Oct.	40	24	32	40.3	24.9	32.6
11-20 Oct.	34.4	18.8	26.6	38.9	25.8	32.35
21 -31 Oct.	35.3	20.5	27.9	32.7	18.8	25.75
1- 10 Nov.	30	16.5	23.25	32.2	16.5	24.35
11- 20 Nov.	28	13.2	20.6	31.5	18.7	25.1
21 -30 Nov.	28.4	14.5	21.45	29.4	14.2	21.8
1-10 Dec.	23.2	10.3	16.75	25.7	11	18.35
11- 20 Dec.	23.7	8.5	16.1	24.9	9.9	17.4
21- 31 Dec.	22	7.4	14.7	22.5	7.7	15.1
1 – 10 Jan.	20.3	6.5	13.4	18.6	5.5	12.05
11-20 Jan.	21	5.8	13.4	22.6	8	15.3
21-31 Jan.	26.7	10.1	18.4	21.3	5.8	13.55
1-10 Feb.	26.5	10.9	18.7	23.2	7.5	15.35
11-20 Feb.	22.4	7.3	14.85	25.1	9	17.05
21-28 Feb.	26.3	11.3	18.8	24.5	8.8	16.65
1-10 Mar.	25.7	8.9	17.3	30.5	11.8	21.15
11-20 Mar.	28.8	11	19.9	29.1	12.7	20.9
21-31 Mar.	29.5	14.3	21.9	32.7	15.1	23.9

RESULTS AND DISCUSSION

Vegetative growth–related traits:

The foliar spray of 3000 mg.l^{-1} potassium silicate, as compared with the other treatments, resulted in the highest significant mean value of the studied vegetative growth characters as number of leaves per plant, number of branches per plant, foliage fresh and dry weights in both cropping seasons (Table 3). The favorable 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, freezing, UV, and chemical pressures as nutrient deficiencies, salinity, and metal toxicity (Zhu and Gong, 2014; Rizwan *et al.,* 2015). Also, the role of Si in protecting the plant cell membranes from oxidative damage when grown under stress as heating. Consequently, Si may be contributing in many physiological or metabolic changes that stimulate plant growth (Zhu *et al*., 2004). Regarding (Si) spraying, the present findings were similar, more or less, with those reported by Al-Aghabary *et al.* (2005) who found that Si foliar application; resulted in increasing dry matter accumulated in all parts of tomato plants under salt stress and the increase in leaf and total plant dry matter content was significant. The increase was to the extent of 19.5, 25.4, 13.4, and 21.2% with leaf, stem, root, and total plant, serially. Also, Romero-Aranda *et al.* (2006) demonstrated that the application of 2.5 mM silicon; gave rise to an increase in plant dry weight and leaf area of tomato plants. Further, Li *et al.* (2015) demonstrated that application of 2 mM Si in sand culture; was accounted with improved total root length, plant height, leaf area and dry weights of both shoots and roots of tomato plants.

The vegetative growth of the El-Quds (E-448) tomato hybrid exceeded the other two hybrids, Salymia (65010) and 023 hybrids, in the measured vegetative growth in both cropping seasons. These results might be attributed to the genetic variations among the three studied hybrids. In addition, tomato hybrids differ from each other in nutrient absorption by roots and as foliar application (Weerahewa and David, 2015).

The interaction between the tomato hybrids and potassium silicate levels on the studied vegetative growth characters of tomato plants reflected significant differences among all vegetative growth traits. The El-Quds (E-448) hybrid tomato plants sprayed with 3000 mg.l^{-1} potassium silicate produced the highest significant mean values for number of leaves per plant, number of branches per plant, foliage fresh and dry weights in both growing seasons.

Table 3. Vegetative growth-related characters of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during the winter seasons of 2018/2019 and 2019/2020.

Treatments		No. of leaves/plant		No. of branches/plant		Foliage fresh weight (g)		Foliage dry weight (g)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg. l^{-1})									
Control		72.11 D	69.78 C	5.22 B	4.00 C	523.19 D	511.93 D	70.27 D	67.66 D
1000		76.00 C	74.33 B	5.89 B	4.67 B	533.08 C	520.84 C	71.67 C	69.38 C
2000		82.56 B	81.11 A	6.78 A	5.56 A	547.85 B	533.37 B	73.82 B	71.95 B
3000		85.00 A	83.11 A	7.22 A	5.89 A	552.24 A	537.50 A	74.52 A	72.80 A
Hybrids									
65010		71.83 C	70.00 C	5.17 B	4.00 B	523.31 C	511.78 C	70.24 C	67.65 C
023		81.58 B	79.00 B	6.42 A	5.33 A	542.50 B	529.27 B	73.12 B	71.10 B
E-448		83.33 A	82.25 A	7.25 A	5.75 A	551.45 A	536.68 A	74.35 A	72.60 A
Interactions effects									
K_2SiO_3	Hybrids								
	65010	65.67 i	62.67 i	4.33 h	3.00 h	508.36 l	498.84 l	68.13 l	65.09 l
Control	023	82.33 e	79.00 e	6.33 cde	5.33 b-e	542.56 f	529.59 f	73.13 f	71.07 f
	E-448	68.33 h	67.67 h	5.00 fgh	5.67 a-d	518.64 j	507.35 j	69.55 j	66.83 j
	65010	66.00 hi	65.33 hi	4.67 gh	3.33 gh	513.50 k	503.38 k	68.83 k	65.96 k
1000	023	75.67 g	73.00 g	5.33 e-h	4.33 e-g	528.43 i	516.62 i	70.95 i	68.53 i
	E-448	86.33 bc	84.67 bc	7.67 ab	6.33 ab	557.32 c	542.53 c	75.24 c	73.66 c
	65010	76.33 g	75.00 fg	5.67 d-g	4.67 d-f	533.50 h	520.42 h	71.64 h	69.34 h
2000	023	83.33 de	80.67 de	6.67 bcd	5.67 a-d	547.62 e	533.31 e	73.85 e	71.97 e
	E-448	88.00 b	87.67 ab	8.00 a	6.33 ab	562.42 b	546.37 b	75.97 b	74.55 b
	65010	79.33 f	77.00 ef	6.00 def	5.00 c-e	537.88 g	524.46 g	72.36 g	70.22 g
3000	023	85.00 cd	83.33 cd	7.33 abc	6.00 a-c	551.40 d	537.54 d	74.54 d	72.84 d
	E-448	90.67 a	89.00 a	8.33 a	6.67 a	567.43 a	550.48 a	76.65 a	75.35 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Flowering characters and percentage of fruit set:

The potassium silicate treatments at the rate of 2000 or 3000 mg.l^{-1} delayed flowering and increased the number of flowers and percentage of fruit setting compared with other treatments (Table 4).

The El-Quds (E-448) tomato hybrid produced the highest magnitudes of number of flowers per plant and percentage of fruit setting, but Salymia (65010) tomato hybrid, flowered earlier in both seasons. The obtained results may be due to that El-Quds (E-448) tomato hybrid has good genetic performance under heat stress conditions. (Mansour *et al*., 2009; Alam *et al*., 2010; Ayenan *et al*., 2021; Haque *et al*., 2021), have investigated the effect of genetic make-up on the performance of tomatoes under heat stress conditions.

Table 4. Flowering characters and fruit set percentage of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during the winter seasons of 2018/2019 and 2019/2020

Treatments		Earliness (days)		Number of flowers/ Plant		Fruit set (%)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg.l^{-1})							
Control		25.56 D	23.33 C	44.00 C	40.78 C	58.01 D	57.19 B
1000		27.11 C	24.22 B	45.56 B	41.89 B	59.39 C	57.76 B
2000		28.89 B	25.89 A	47.56 A	43.33 A	60.68 B	59.71 A
3000		29.78 A	26.22 A	48.22 A	43.67 A	61.69 A	60.03 A
Hybrids							
65010		25.58 C	23.50 C	44.00 C	40.83 C	58.10 C	57.52 C
023		28.08 B	25.08 B	46.67 B	42.75 B	60.14 B	58.65 B
E-448		29.83 A	26.17 A	48.33 A	43.67 A	61.59 A	59.85 A
Interactions effects							
K_2SiO_3	Hybrids						
	65010	23.67 i	22.00 g	42.00 h	39.00 h	56.35 f	56.39 e
Control	023	28.00 de	25.00 cd	46.67 cde	42.67 cde	59.99 de	58.60 bcd
	E-448	25.00 gh	23.00 fg	43.33 gh	40.67 fg	57.68 f	56.57 de
	65010	24.67 hi	22.67 fg	42.67 h	40.00 gh	57.81 f	56.67 de
1000	023	26.00 fg	23.33 ef	44.67 fg	41.33 efg	58.20 ef	56.45 e
	E-448	30.67 b	26.67 ab	49.33 ab	44.33 ab	62.16 abc	60.15 ab
	65010	26.33 f	24.33 de	45.33 ef	42.00 def	58.08 ef	57.94 cde
2000	023	29.00 cd	26.00 bc	47.33 cd	43.33 bcd	61.27 bcd	60.01 ab
	E-448	31.33 ab	27.33 a	50.00 a	44.67 ab	62.68 ab	61.20 a
	65010	27.67 e	25.00c d	46.00d ef	42.33 cde	60.15 cde	59.06 bc
3000	023	29.33 c	26.00 bc	48.00 bc	43.67 abc	61.11 bcd	59.53 abc
	E-448	32.33 a	27.67 a	50.67 a	45.00 a	63.82 a	61.50 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

All the tested tomato hybrids showed highest number of flowers per plant and fruit set percentage in both seasons after being sprayed with 3000 mg.l^{-1} potassium silicate specially El-Quds (E-448) hybrid. Meteorological data (Table 2), showed decrease in the temperature at night during the flowering, fruit setting and fruit growth period, which extends from November to February, as well as the difference between the day and night temperature during these periods. Data in Table (2) illustrated that the average temperatures during November are (28.8 and 31.0 °C at the day and 14.7 and 16.5 °C at night), during December (26.0 and 24.4 °C during the day and 8.7 and 9.5 °C at night), during January (22.7 and 20.8 °C during the day and 7.5 and 6.4 °C at night) and during February 25.0 and 24.3 °C at day and 9.8 and 8.4 °C at night during the two growing seasons, respectively. The optimal temperature for tomato growth and fruit set ranges from 25–30 °C at day and not less than 17 °C at night (Camejo *et al*., 2005). So, increases in the number of flowers and percentage of fruit setting under the condition of this study may be due to the role of potassium silicate in alleviating heat stress of tomato hybrids as reported by (Marschner, 1995; Liang *et al*., 2015; Balahnina and Borkowsksa, 2013; Rizwan *et al*., 2015).

Yield and it's components characteristics:

Potassium silicate treatment increased number of fruits/plant, average fruit weight, yield/plant, early and total yield/feddan (Tables 5 and 6). The highest level of potassium silicate 3000 mg.l^{-1} treatment enhanced yield parameters during both seasons. In the present study, increasing of tomato fruit yield with 3000 mg.l^{-1} potassium silicate might be attributed to the increase of vegetative growth parameters as reported previously (Table 3). Also, due to foliar application with potassium silicate might be attributed to the increase in the number of flowers and percentage of fruit setting compared to the other treatments (Table 4). Also, these increases may be due to the role of potassium silicate in alleviating heat stress of tomato hybrids as mentioned-earlier.

Table 5. Yield characters of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during the winter seasons of 2018/2019 and 2019/2020

Treatments		No. of fruits /plant		Average fruit weight (g)		Total yield/plant (kg)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg.l^{-1})							
Control		24.44 C	23.22 C	121.51 D	114.11 D	2.98 D	2.66 D
1000		25.33 B	24.00 B	128.03 C	121.55 C	3.26 C	2.93 C
2000		26.44 A	24.89 A	139.46 B	131.20 B	3.70 B	3.27 B
3000		26.89 A	25.22 A	142.40 A	134.57 A	3.84 A	3.40 A
Hybrids							
65010		24.50 B	23.25 B	121.01 C	115.17 C	2.97 C	2.69 C
023		26.08 A	24.67 A	135.29 B	127.31 B	3.54 B	3.15 B
E-448		26.75 A	25.08 A	142.25 A	133.59 A	3.83 A	3.37 A
Interactions effects							
K_2SiO_3	Hybrids						
	65010	23.33 h	22.00 g	110.21 l	105.82 k	2.57 j	2.33 h
Control	023	26.00 c-e	24.67 a-d	135.70 f	124.75 f	3.53 ef	3.08 e
	E-448	24.00 f-h	23.00 e-g	118.61 j	111.77 i	2.85 i	2.57 g
	65010	23.67 gh	22.67 fg	113.89 k	108.59 j	2.70 ij	2.46 gh
1000	023	25.00 e-g	23.67 d-f	123.55 i	118.38 h	3.09 h	2.80 f
	E-448	27.33 a-c	25.67 ab	146.64 c	137.68 c	4.01 bc	3.53 bc
	65010	25.33 ef	24.00 c-f	128.46 h	121.79 g	3.25 gh	2.93 ef
2000	023	26.33 b-e	25.00 a-d	139.55 e	131.42 e	3.68 de	3.29 d
	E-448	27.67 ab	25.67 ab	150.38 b	140.38 b	4.16 ab	3.60 b
	65010	25.67 de	24.33 b-e	131.48 g	124.49 f	3.37 fg	3.03 e
3000	023	27.00 a-d	25.33 a-c	142.37 d	134.71 d	3.85 cd	3.41 cd
	E-448	28.00 a	26.00 a	153.35 a	144.52 a	4.29 a	3.76 a

- Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Respecting Si application, the obtained results agree, also, with those reported by Matichenkov and Bocharnikova (2008) found that cucumber yield was increased, significantly either by foliar silicon with 10 kg ha^{-1} at the 3rd leaf stage and subsequent bi-weekly applications during the season or by soil Si applications (40 kg ha^{-1}). There are additional benefits for Si include stimulation of fruit formation and accelerated fruit maturation.

El-Quds (E-448) tomato hybrid had a significantly higher mean values of fruit yield characters as average fruit weight, yield/plant, early and total yield/feddan during both seasons of the study. Concerning number of fruits/plant character results showed that El- Quds (E-448) and 023 tomato hybrids gave highest mean values compared with Salymia (65010) hybrid. The El-Quds (E-448) tomato hybrid gave the highest yield parameters during both seasons might be attributed to its owing vigorous highest vegetative growth parameters as reported earlier (Table 3). Also, due to the highest number of flowers and percentage of fruit setting compared with other hybrids (Table 4).

The highest mean values of yield parameters were obtained from El-Quds (E-448) tomato hybrid when sprayed with the highest level of potassium silicate 3000 mg.l^{-1} treatment in both seasons. The high significant values produced by some interaction treatments for in yield components characteristics i.e. (number of fruits/plant, average fruit weight, total yield/plant and early yield /fed.) surely will positively reflect on total yield/fed.) in both seasons.

Chemical composition

1. Chemical composition of leaves

The tabulated averages (Tables 7 and 8) disclosed that there is a direct proportionate relationship between chemical composition of leaves [as leaf's chlorophyll content (chlorophyll a, b and a+b) and leaf's nutrient content (N, P, K, Si content)] and potassium silicate concentrations especially at 3000 mg.l^{-1} during both seasons. This finding could be taken place due to the major role of potassium silicate on photosynthetic activity and ultra-structure of leaf organelles (Shu and Liu, 2001) and photosynthetic rate (Wang *et al*., 2006). Further, this event may be occurred owing to ability potassium silicate to regulate the leaf photosynthetic functions as in case of cucumber readings (Wei *et al*., 2009), or because of the functions of material sprayed in increase photosynthetic pigments in cucumber leaves as reported by Mady (2009). Also, foliar application with high concentration of potassium silicate showed higher leaves content of K% and Si% may be due to the composition of potassium silicate as 22% SiO_2 and 11% K_2O which absorbed through leaves by foliar application and accumulate in tomato leaves. Moreover, data in Table (1) showed high soil content from N (128.31 and 130.00 mg/kg soil) and K (175 and 180 mg/kg soil) in both seasons in addition to the applied fertilization on N and K during season may cause significant increases in N and K % in tomato leaves.

The obtained results are similar, more or less, to those reported by Al-Aghabary *et al.* (2005) who found that foliar application of Si increased both Chl a and Chl b contents of tomato plants after 10 days of treatment. After 27 days of treatment, the difference of both Chl a and Chl b content between treatments was not significant. Also, Hellal *et al.* (2012) and Kardoni *et al.* (2013) reported that silicon application increased chlorophyll contents in shoots of faba bean.

Results declared that El-Quds (E-448) tomato hybrid had a significantly higher mean values of chlorophyll a, b, a+b and leaf's N, P, K, Si content compared with other two hybrids during both seasons. Also results showed that the El-Quds (E-448) tomato hybrid treated sprayed with potassium silicate concentrations at 3000 mg.l^{-1} gave a significantly higher mean values of chlorophyll a, b, a+b and leaf's N, P, K, Si content during both seasons of the study.

Table 6. Yield characters of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during the winter seasons of 2018/2019 and 2019/2020

Treatments		Early yield/feddan (ton)		Total yield/feddan (ton)	
		2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg. l^{-1})					
Control		5.25 D	5.13 D	16.70 D	14.89 D
1000		6.22 C	6.07 C	18.28 C	16.42 C
2000		7.70 B	7.24 B	20.70 B	18.32 B
3000		8.19 A	7.68 A	21.49 A	19.04 A
Hybrids					
65010		5.22 C	5.23 C	16.45 C	15.04 C
023		7.14 B	6.80 B	19.79 B	17.61 B
E-448		8.15 A	7.57 A	21.43 A	18.85 A
Interactions effects					
K_2SiO_3	Hybrids				
Control	65010	3.83 j	4.00 h	14.40 j	13.04 h
	023	7.12 ef	6.57 e	19.76 ef	17.23 e
	E-448	4.78 i	4.83 g	15.94 i	14.39 g
1000	65010	4.26 ij	4.45 gh	15.09 ij	13.78 gh
	023	5.61 h	5.63 f	17.29 h	15.69 f
	E-448	8.77 bc	8.14 bc	22.45 bc	19.79 bc
2000	65010	6.18 gh	6.05 ef	18.22 gh	16.37 ef
	023	7.63 de	7.29 d	20.58 de	18.40 d
	E-448	9.30 ab	8.38 ab	23.30 ab	20.18 ab
3000	65010	6.59 fg	6.40 e	18.90 fg	16.96 e
	023	8.21 cd	7.72 cd	21.53 cd	19.11 cd
	E-448	9.75 a	8.91 a	24.04 a	21.04 a

Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Table 7. Leaf's chlorophyll content of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during the winter seasons of 2018/2019 and 2019/2020

Treatments		Leaf's chlorophyll content (mg/g, f.w.)					
		Chlorophyll a		Chlorophyll b		Total chlorophyll (a + b)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg. l^{-1})							
Control		0.573 D	0.557 D	0.383 D	0.361 D	0.956 D	0.918 D
1000		0.590 C	0.573 C	0.398 C	0.376 C	0.988 C	0.949 C
2000		0.615 B	0.598 B	0.421 B	0.397 B	1.036 B	0.995 B
3000		0.625 A	0.606 A	0.428 A	0.405 A	1.053 A	1.010 A
Hybrids							
65010		0.574 C	0.556 C	0.383 C	0.361 C	0.957 C	0.917 C
023		0.607 B	0.590 B	0.413 B	0.391 B	1.020 B	0.980 B
E-448		0.622 A	0.604 A	0.426 A	0.403 A	1.048 A	1.007 A
Interactions effects							
K_2SiO_3	Hybrids						
Control	65010	0.548 l	0.532 l	0.361 l	0.339 i	0.909 l	0.871 l
	023	0.606 f	0.591 f	0.413 f	0.392 d	1.019 f	0.982 f
	E-448	0.564 j	0.548 j	0.375 j	0.354 g	0.939 j	0.902 j
1000	65010	0.556 k	0.539 k	0.368 k	0.346 h	0.924 k	0.885 k
	023	0.582 i	0.565 i	0.391 i	0.368 f	0.973 i	0.933 i
	E-448	0.633 c	0.615 c	0.434 c	0.413 b	1.067 c	1.028 c
2000	65010	0.591 h	0.573 h	0.399 h	0.375 f	0.990 h	0.948 h
	023	0.615 e	0.598 e	0.421 e	0.392 d	1.036 e	0.996 e
	E-448	0.640 b	0.623 b	0.443 b	0.420 ab	1.083 b	1.042 b
3000	65010	0.600 g	0.581 g	0.405 g	0.383 e	1.005 g	0.965 g
	023	0.624 d	0.605 d	0.428 d	0.405 c	1.052 d	1.009 d
	E-448	0.652 a	0.631 a	0.451 a	0.426 a	1.103 a	1.057 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

2. Chemical composition of fruits

Results in Tables (9, 10 and 11) express the average values of chemical composition of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) concentration. The results declare that concentrations of K_2SiO_3 affected significantly the traits under study. Also, it is obvious that there is a direct proportionate relationship between K_2SiO_3 level and the given traits. Foliar application of K_2SiO_3 at 3000 mg.l^{-1}, brought about the highest average values for TSS, vitamin C, reducing, non-reducing, total sugars and N, P, K, Si fruit's nutrient contents compared to the other treatments, especially the control (untreated) plants during both seasons. Contrary, foliar application of K_2SiO_3 at 3000 mg.l^{-1}, brought about the lowest average values for fruit acidity during both seasons. The gained results could be attributed to foliar application of potassium silicate caused increased in nutrient contents of leaves (source) as illustrated in Table (8) then transferred to tomato fruits (sink).

Table 8. Leaf's nutrient content of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during winter seasons of 2018/2019 and 2019/2020

Treatments		Leaf's nutrient content (% d.w.)							
		N		P		K		Si	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg.l^{-1})									
Control		2.39 D	2.18 D	0.311 D	0.294 D	2.41 D	2.30 D	2.42 D	2.27 D
1000		2.51 C	2.31C	0.328 C	0.310 C	2.60 C	2.47 C	2.56 C	2.74 C
2000		2.76 B	2.53 B	0.356 B	0.336 B	2.84 B	2.73 B	2.74 B	2.85 B
3000		2.89 A	2.62 A	0.364 A	0.344 A	2.94 A	2.81 A	2.90 A	2.99 A
Hybrids									
65010		2.38 C	2.18 C	0.311 C	0.294 C	2.41 C	2.29 C	2.64 B	2.68 B
023		2.69 B	2.47 B	0.346 B	0.327 B	2.76 B	2.64 B	2.65 B	2.70 B
E-448		2.82 A	2.59 A	0.363 A	0.343 A	2.92 A	2.79 A	2.68 A	2.77 A
Interactions effects									
K_2SiO_3	Hybrids								
Control	65010	2.11 k	1.93 k	0.285 l	0.269 l	2.15 l	2.03 l	2.09 l	2.22 i
	023	2.73 e	2.51 e	0.346 f	0.327 f	2.77 f	2.65 f	2.43 i	2.39 h
	E-448	2.32 i	2.11 i	0.302 j	0.285 j	2.32 j	2.22 j	2.74 f	2.20 i
1000	65010	2.20 j	2.01 j	0.292 k	0.277 k	2.25 k	2.13 k	3.01 c	3.02 c
	023	2.45 h	2.26 h	0.319 i	0.301 i	2.51 i	2.37 i	2.14 k	2.73 e
	E-448	2.89 c	2.66 c	0.374 c	0.353 c	3.04 c	2.90 c	2.52 h	2.46 j
2000	65010	2.56 g	2.35 g	0.330 h	0.312 h	2.56 h	2.46 h	2.85 e	2.83 d
	023	2.73 e	2.51 e	0.356 e	0.336 e	2.84 e	2.73 e	3.11 b	2.62 f
	E-448	2.99 b	2.75 b	0.382 b	0.361 b	3.12 b	3.00 b	2.25 j	3.11 b
3000	65010	2.66 f	2.43 f	0.337 g	0.319 g	2.68 g	2.54 g	2.59 g	2.63 f
	023	2.83 d	2.59 d	0.364 d	0.343 d	2.94 d	2.81 d	2.92 d	3.04 c
	E-448	3.08 a	2.83 a	0.393 a	0.371 a	3.20 a	3.06 a	3.19 a	3.29 a

Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Table 9. Fruit's chemical quality determination of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during the winter seasons of 2018/2019 and 2019/2020

Treatments		TSS % (Brix)		Acidity (%)		Vitamin C (mg/100 g)	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg.l^{-1})							
Control		5.27 D	5.11 D	1.03 A	0.97 A	31.54 D	30.21 D
1000		5.41 C	5.23 C	0.99 B	0.93 B	31.77 C	30.42 C
2000		5.64 B	5.42 B	0.91 C	0.85 C	32.15 B	30.87 B
3000		5.71 A	5.48 A	0.88 D	0.83 D	32.28 A	33.75 A
Hybrids							
65010		5.27 C	5.47 C	1.03 A	0.98 A	31.52 C	32.90 C
023		5.56 B	5.36 B	0.93 B	0.88 B	32.02 B	30.84 B
E-448		5.70 A	5.47 A	0.89 C	0.84 C	32.25 A	32.90 A
Interactions effects							
K_2SiO_3	Hybrids						
Control	65010	5.05 l	4.91 k	1.11 a	1.04 a	31.14 j	29.85 i
	023	5.57 f	5.36 e	0.92 ef	0.87 d	32.04 ef	30.65 e
	E-448	5.19 j	5.05 i	1.06 b	1.01 a	31.43 i	30.12 h
1000	65010	5.11 k	4.97 j	1.09 ab	1.03 a	31.25 j	29.97 hi
	023	5.34 i	5.16 h	1.01 c	0.96 b	31.65 h	30.33 g
	E-448	5.78 c	5.55 c	0.86 h	0.81 fg	32.42 bc	30.96 cd
2000	65010	5.41 h	5.23 g	0.98 cd	0.93 bc	31.78 gh	30.43 fg
	023	5.64 e	5.43 d	0.91 fg	0.85 de	32.14 de	39.75 a
	E-448	5.87 b	5.61 b	0.84 h	0.78 gh	32.52 ab	31.07 bc
3000	65010	5.49 g	5.29 f	0.95 de	0.91 c	31.93 fg	30.55 ef
	023	5.71 d	5.47 d	0.88 gh	0.83 ef	32.26 cd	30.86 d
	E-448	5.94 a	5.66 a	0.81 i	0.75 h	32.64 a	31.20 b

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Results declared that El-Quds (E-448) tomato hybrid had a significantly higher mean values of TSS, vitamin C, reducing, non-reducing, total sugars and N, P, K, Si fruit's nutrient contents compared to the other two hybrids during both seasons.

Also results showed that the El-Quds (E-448) tomato hybrid sprayed with potassium silicate concentrations at 3000 mg.l^{-1} gave a significantly higher mean values of TSS, vitamin C, reducing, non-reducing, total sugars and N, P, K, Si fruit's nutrient content during both seasons of the study.

The gained results may be due to that El-Quds (E-448) owing highest vegetative growth, yield and leaves chemical composition parameters as reported earlier and subset quantity then more fruit quality characters.

Table 10. Fruit's chemical quality determination of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during the winter seasons of 2018/2019 and 2019/2020

Treatments		Fruit sugars (% d.w.)					
		Reducing sugars		Non-reducing sugars		Total sugars	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg.l^{-1})							
Control		1.83 D	1.52 D	2.71 D	2.69 D	4.54 D	4.21 D
1000		1.91 C	1.59 C	2.92 C	2.78 C	4.83 C	4.37 C
2000		2.01 B	1.72 B	3.25 B	2.90 B	5.26 B	4.62 B
3000		2.04 A	1.77 A	3.36 A	2.95 A	5.41 A	4.71 A
Hybrids							
65010		1.83 C	1.52 C	2.71 C	2.69 C	4.54 C	4.21 C
023		1.97 B	1.67 B	3.14 B	2.87 B	5.12 B	4.54 B
E-448		2.04 A	1.76 A	3.33 A	2.93 A	5.37 A	4.69 A
Interactions effects							
K_2SiO_3	Hybrids						
Control	65010	1.73 i	1.41 i	2.38 l	2.55 i	4.11 l	3.97 l
	023	1.98 de	1.68 de	3.14 f	2.86 e	5.12 f	4.54 f
	E-448	1.80 h	1.47 h	2.61 j	2.65 h	4.41 j	4.12 j
1000	65010	1.76 hi	1.43 hi	2.49 k	2.62 h	4.25 k	4.05 k
	023	1.87 g	1.54 g	2.82 i	2.75 g	4.69 i	4.29 i
	E-448	2.09 b	1.81 b	3.47 c	2.97 bc	5.56 c	4.78 c
2000	65010	1.91 fg	1.60 f	2.93 h	2.76 g	4.84 h	4.37 h
	023	2.01 cd	1.71 d	3.25 e	2.92 d	5.26 e	4.63 e
	E-448	2.11 ab	1.85 b	3.57 b	3.02 b	5.68 b	4.87 b
3000	65010	1.94 ef	1.64 ef	3.04 g	2.81 f	4.98 g	4.45 g
	023	2.03 c	1.76 c	3.36 d	2.95 cd	5.39 d	4.71 d
	E-448	2.15 a	1.91 a	3.68 a	3.08 a	5.83 a	4.98 a

Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

Table 11. Fruit's chemical determination of three tomato hybrids as affected by foliar application with potassium silicate (K_2SiO_3) during winter seasons of 2018/2019 and 2019/2020

Treatments		Fruit's nutrient content (% d.w.)							
		N		P		K		Si	
		2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020	2018/2019	2019/2020
K_2SiO_3 (mg.l^{-1})									
Control		1.70 D	1.44 D	0.193 D	0.168 D	2.03 D	1.74 D	1.01 D	1.25 D
1000		1.87 C	1.59 C	0.210 C	0.186 C	2.20 C	1.89 C	1.11 C	1.40 C
2000		2.12 B	1.80 B	0.235 B	0.213 B	2.45 B	2.12 B	1.21 B	1.47 B
3000		2.20 A	1.88 A	0.243 A	0.222 A	2.53 A	2.19 A	1.33 A	1.53 A
Hybrids									
65010		1.71 C	1.43 C	0.193 C	0.170 C	2.04 C	1.74 C	1.15 A	1.33 C
023		2.04 B	1.73 B	0.226 B	0.204 B	2.37 B	2.03 B	1.17 A	1.41 B
E-448		2.18 A	1.86 A	0.242 A	0.218 A	2.51 A	2.18 A	1.18 A	1.50 A
Interactions effects									
K_2SiO_3	Hybrids								
Control	65010	1.46 l	1.21 l	0.167 k	0.141 i	1.78 l	1.53 l	0.78 l	1.01 k
	023	2.04 f	1.74 f	0.227 e	0.203 e	2.37 f	2.03 f	1.02 i	1.34 g
	E-448	1.62 j	1.36 j	0.185 i	0.161 h	1.95 j	1.66 j	1.23 f	1.41 e
1000	65010	1.54 k	1.29 k	0.176 j	0.154 h	1.86 k	1.58 k	1.42 d	1.59 c
	023	1.80 i	1.51 i	0.202 h	0.178 g	2.12 i	1.80 i	0.84 k	1.38 f
	E-448	2.29 c	1.96 c	0.251 c	0.228 c	2.61 c	2.28 c	1.07 h	1.22 j
2000	65010	1.87 h	1.57 h	0.210 g	0.188 f	2.21 h	1.88 h	1.27 e	1.45 d
	023	2.12 e	1.81 e	0.235 d	0.212 d	2.44 e	2.11 e	1.48 b	1.31 h
	E-448	2.36 b	2.02 b	0.260 b	0.238 b	2.70 b	2.36 b	0.89 j	1.64 b
3000	65010	1.96 g	1.66 g	0.218 f	0.198 e	2.28 g	1.97 g	1.11 g	1.28 i
	023	2.20 d	1.87 d	0.241 d	0.221 c	2.53 d	2.17 d	1.34 c	1.59 c
	E-448	2.45 a	2.11 a	0.270 a	0.246 a	2.78 a	2.43 a	1.54 a	1.72 a

-Values having the same alphabetical letter (s) in common, within each column, do not significantly differ, using Duncan's multiple range test at 0.05 level of probability.

CONCLUSION

This study recommends that foliar spraying of potassium silicate (K_2SiO_3) at 3000 mg.l^{-1} could enhance the productivity and quality of tomato plants grown under arid regions. Also, El-Quds (E-448) tomato hybrid gave the highest yield and quality specially when treated with potassium silicate (K_2SiO_3) at 3000 mg.l^{-1} compared with other tested treatments. However, on farm trials using this combination should be done with bona fide tomato growers before commercial large scale recommendation.

REFERENCES

Abd El-Aziz, A. (2020). The Effect of Silicon on minimizing the implications of water Stress on Tomato Plants. Env. Biodiv. Soil Security, *4*, 137-148. 10.21608/jenvbs.2020.28732.1092

Abu El-Azm, N. A. and S. M. Youssef (2015). Spraying potassium silicate and sugar beet molasses on tomato plants minimizes transpiration, relieves drought stress and rationalizes water use, Middle East J. Agric. Res., 4 (4): 1047-1064.

Al-Aghabary, K.Z. Zhu and Q. Shi (2005). Influence of silicon supply on chlorophyll content, chlorophyll fluorescence, and antioxidative enzyme activities in tomato plants under salt stress. J. Pl. Nutr. 27 (12): 2101-2115.

Alam, M. S., Sultana, N., Ahmad, S., Hossain, M. M. and A. K. M. A. Islam (2010). Performance of heat tolerant tomato hybrid lines under hot, humid conditions. Bangladesh Journal of Agricultural Research, 35(3), 367-373.

AOAC. (1992). Official methods of analysis of the Association of the Agricultural Chemistis. 11th ed. Washington: AOAC. 1115p

APHA. (1992). Standard Methods for Examination of Water and Wastewater. 18th Edition. American Public Health Association. Washington DC.

Ayenan, M.A.T., Danquah, A., Hanson, P., Asante, I.K. and E.Y. Danquah (2021). Identification of new sources of heat tolerance in cultivated and wild tomatoes. Euphytica, 217, 1–16. https://doi.org/10.1007/s 10681-021-02772-5

Balahnina, T. and A. Borkowska (2013). Effects on Plant Resistance to Environmental Stresses: review. Int. Agrophys., 27: 225 – 232.

Boyer, J.S. (1982) Plant productivity and environment. Science, 218, 443– 448.

Camejo, D., Rodríguez, P., Morales, M.A., Dell'Amico, J.M., Torrecillas, A. and J. J. Alarcón (2005). High temperature effects on photosynthetic activity of two tomato cultivars with different heat susceptibility. J. Plant Physiol., 162, 281–289. https :// doi .org /10.1016/j. jplph.2004.07.014

Degif, A.B., and E. Woltering (2015). Ethylene, 1-MCP and the antitranspirant effect of active compound-film forming blend. Malaysian Journal of Medical and Biological Research, 2 (3): 256- 261. doi: 10.18034/mjmbr.

del Amor, F.M., Cuadra-Crespo, P., Walker, D.J., Cámara, J. M. and V. Madrid (2010). Effect of foliar application of antitranspirant on photosynthesis and water relations of pepper plants under different levels of CO2 and water stress J. Plant Physiol., 167 (2010), pp. 1232-1238.

Duncan, D. B. (1955). "Multiple Range and Multiple F Tests". Biometrics, 11: 1–42. doi :10. 2307/ 3001478

El-Gazzar, N., Almaary, K., Ismail, A. and G. Polizzi (2020). Influence of Funneliformis mosseae enhanced with titanium dioxide nanoparticles (TiO_2NPs) on *Phaseolus vulgaris* L. under salinity stress.

El-Sayed, M. M., Midan, A. A., Khalil, R. and N. M. Malash (1990). Evaluation programme of tomato genotypes in Minufiya province, Egypt. 2.-The second part of evaluation [Egypt]. Zagazig J. Agric. Res. (Egypt).12(2), 181-204.

FAOSTAT. (2019). Crops:Tomatoes. Available online: http://www.fao.org/faostat/ar/#data/QC (accessed on 9 August 2019).

Haque, M.S., Husna, M.T., Uddin, M.N., Hossain, M.A., Sarwar, A.K.M.G., Ali, O.M., Abdel Latef, A.A.H. and A. Hossain (2021). Heat Stress at Early Reproductive Stage Differentially Alters Several Physiological and Biochemical Traits of Three Tomato Cultivars. Horticulturae, 7, 330. https://doi. org/10.3390/horticulturae7100330

Hellal, F. A., Abdelhamid, M. T., Abo-Basha, D. M. and R. M. Zewainy (2012). Alleviation of the adverse effects of soil salinity stress by foliar application of silicon on Faba bean (*Vicia faba* L.). J. Appl. Sci. Res. 8 4428–4433.

Helyes, L., Lugasi, A. and Z. Pék (2012). Effect of irrigation on processing tomato yield and antioxidant components Turk. J. Agric. For., 36 (2012), pp. 702-709. https://doi.org/10.3329/bjar.v35i3.6442

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice Hall of India. New Delhi. pp. 498.

Kardoni, F., Mosavi, S.J.S., Parande, S. and M.E. Torbaghan (2013). Effect of salinity stress and silicon application on yield and component yield of faba bean (*Vicia faba*). Int J Agric Crop Sci 6:814–818.

Li, H., Zhu, Y., Hu, Y., Han, W. and H. Gong (2015). Beneficial effects of silicon in alleviating salinity stress of tomato seedlings grown under sand culture. Acta Physiol Plant 37(4):1–9

Liang, Y., Nikolic, M., Bélanger, R., Gong, H., and A. Song (2015). Silicon in agriculture. *Springer Science*, 225-232. https://doi.org/10.1007/978-94-017-9978-2_13.

Mady, M.A. (2009). Effect of foliar Application with salicylic acid and vitamin E on growth and productivity of tomato (*Lycopersicon escylentym*, Mill.) plant. J. Agric. Sci. Mansoura Univ., 34 (6): 6735 – 6746.

Malik, C.P. and M.B. Singh (1980). Plant enzymology and histoenzymology. Kalyani Publishers, New Delhi. 286 pp.

Mansour, A., Ismail, H.M., Ramadan, M.F. and G. Gyulai (2009). Variations in tomato (*Lycopersicon esculentum*) cultivars grown under heat stress. J. Consum. Prot. Food Saf., 4, 118–127. https://doi. org/10.1007/s00003-009-0474-5

Marschner, M. (1995). Mineral nutrition of higher plants. 2nd ed. London: Academic Press.

Masouleh, S.S.S. and Y.N. Sassine (2020). Molecular and biochemical responses of horticultural plants and crops to heat stress. Ornam. Hortic., 26, 148–158. https://doi.org/10.1590/2447-536X.v26i2.2134.

Matichenkov, V. and E. Bocharnikova (2008). New generation of silicon fertilizers. PP. 71. In Malcolm Keeping (ed.) silicon in Agriculture Conference sout Africa (2008), 4th International conference Abstracts .University of Kwazulu –Natal, Wild cost sun, port Edward, KwazuluNatal, South Africa.

Moran, R. and D. Porath (1980). Chlorophyll determination in intact tissues using N,N352 dimethylformamide. Plant Physiology, 65, 478-479

Murphy, J. and J. P. Riely (1962). A modified single solution method for determination of phosphate in natural waters. Anal. Chim. Acta. 29: 31-36.

Okalebo, J. R., Cuthua, K.W. and P. J. Woomer (2002). Laboratory methods of soil and plant analysis- A working manual. TSBF- CIAT and SACRED Africa, Nairobi, Kenya. Pp. 128.

Page, A.L., Miller, R.H., and D.R. Keeney (1982). Methods of soil analyses. Part 2. Chemical and microbiological properties. American Society of Agronomy Inc.; Soil Science Society of America Inc., Madison, WI.

Pregl, E. (1945). Quantitative organic micro analysis. 4th Ed. J. Chundril, London.

Rajasekar, S., Philominaathan, P. and V. Chinnathambi (2013). Research Methodology. Retrieved April 8, 2015, from http://arxiv.org/pdf/physics/0601009.pdf

Ranganna, S. (1986). Handbook of analysis and quality control for fruit and vegetable Products, New Delhi: Tata McGraw-Hill Book Co, pp. 106

Rizwan, M., Ali, S., Ibrahim, M., Farid, M., Adrees, M., Bharwana, A. and S. A. Etal (2015). Mechanisms of silicon–mediated alleviation of drought and salt stress in plants: a review. Environ. Sci. Pollut. Res., 22: 15416 – 15431.

Romero-Arnada, M.R., Jourada, O. and J. Cuartero (2006). Silicon alleviates the deleterious salt effects on tomato plant growth by improving plant water status. J. Plant Physio. 163:847-855.

Shu, L.Z. and Y.H. Liu (2001). Effects of silicon on growth of maize seedlings under salt stress. Agro. Environmental Protection, 20:38-40.

Siddiqui, M.H., Alamri, S., Alsubaie, Q.D., Ali, H.M., Khan, M.N., Al-Ghamdi, A., Ibrahim, A.A. and A. Alsadon (2020). Exogenous nitric oxide alleviates sulfur deficiency-induced oxidative damage in tomato seedlings. Nitric Oxide, 94, 95–107. https://doi.org/10.1016/j.niox.2019.11.002

Snedecor, G.W. and W.G. Cochran (1989). Statistical Methods, Eighth Edition. Iowa State University Press. pp.491

Soundharya, N., Srinivasan, S., Sivakumar, T. and P. R. Kamalkumaran (2019). Effect of Foliar Application of Nutrients and Silicon on Yield and Quality Traits of Tomato (*Lycopersicon esculentum* L), *Int. J. Pure App. Biosci.* 7(2): 526-531. doi: http:// dx. doi. Org /10.18782/2320-7051.7491.

Wahid, A., Gelani, S., Ashraf, M., and M. Foolad (2007). Heat tolerance in plants: An overview. Environ. Exp. Bot., 61, 199–223. https :// doi. Org / 10. 1016/j. envexpbot. 2007.05.011

Wang, L.J., Chen, S. J., Kong, W.F., Liu, S. H. and D. D. Archibold (2006). Salicylic acid pretreatment alleviates chilling injury and affects the antioxidant system and heat shock proteins of peaches during cold storage. Postharvest. Biol. Technol., 41:244–25.

Warnock, S. J. (1991). Natural habitats of *Lycopersicon* species HortScience, 26 (1991), pp. 466-471.

Weerahewa, D. and D. David (2015). Effect of silicon and potassium on tomato anthracnose and on the postharvest quality of tomato fruit (*Lycopersicon esculentum* Mill.). *J. Natn. Sci. Foundation Sri Lanka, 43 (3),273-280*. DOI: http: // dx. doi. org/ 10.4038/ jnsfsr.v43i3.7959**.**

Wei, L., Xi-Zhen, A. Wen-Juan, L. Hong-Tao, W., Sheng-Xue, L. and Z. Nan (2009). Effects of salicylic acid on the leaf photosynthesis and antioxidant enzyme activities of cucumber seedlings under low temperature and light intensity. Yingyong Shengtai Xuebao, 20(2):441-445.

Xu, J., Driedonks, N., Rutten, M.J.M., Vriezen,W.H., De Boer, G.-J. and I. Rieu (2017). Mapping quantitative trait loci for heat tolerance of reproductive traits in tomato (*Solanum lycopersicum*). Mol. Breed., 37, 1–9. https://doi.org/10.1007/s11032-017-0664-2

Zhou, R., Yu, X., Li, X., Dos Santos, T.M., Rosenqvist, E. and C. O. Ottosen (2020). Combined high light and heat stress induced complex response in tomato with better leaf cooling after heat priming. Plant Physiol. Biochem. 151, 1–9. https :// doi .org /10. 1016/j. plaphy. 2020.03.011

Zhu, Y. and H. Gong (2014). Beneficial effects of silicon on salt and drought tolerance in plants. Agron. Sustain. Dev., 34:455-472.

Zhu. Z., Wei, G., Qian, Q. and J. Yu (2004). Silicon alleviates salt stress and increases antioxidant enzymes activity in leaves of salt stressed cucumber. Plant Sci., 167:527-553.

إنتاجية بعض هجن الطماطم التي تم رشها بسيليكات البوتاسيوم المنزرعة في تربة رملية في المناطق الجافة

عبد الباسط عبد السميع أحمد الخربوطلي[1،2] و خالد جمال عبد الرشيد[1]

[1]قسم البساتين – كلية الزراعة والموارد الطبيعية – جامعة أسوان.

[2]قسم البساتين- كلية الزراعة الصحراوية والبيئية – جامعة مطروح.

أجريت تجربتان حقليتان خلال موسمي شتاء 2019/2018 و 2020/2019 في المزرعة البحثية بكلية الزراعة والموارد الطبيعية، جامعة أسوان، أسوان ، مصر. وكان الهدف الرئيسي من هذه الدراسة هو دراسة تأثير الرش الورقي لسيليكات البوتاسيوم (بتركيزات ، 1000 ، 2000 ، 3000 مجم لتر -1) والتي تم رشها بعد ثلاث أسابيع من الشتل أربع مرات بفواصل زمنية لمدة أسبوعين ، على إنتاجية ثلاث هجن للطماطم وهي (Salymia (65010) و 023 والقدس (E-448)) في ظل ظروف المناطق الجافة وذلك للتغلب على الإجهاد الحراري أو تخفيفه (فرق درجة الحرارة بين النهار والليل) أثناء زراعة الطماطم في محافظة أسوان ، مصر. عموماً، أدى الرش الورقي بسيليكات البوتاسيوم عند 3000 مجم / لتر إلى تحسين النمو للطماطم كما هو مشار إليه بمقاييس النمو الخضري ، مثل عدد الأوراق لكل نبات ، وعدد الأفرع لكل نبات ، الوزن الطازج والجاف للنبات (جم) مقارنة بمعاملات الرش الأخرى. علاوة على ذلك ،وأظهرت تلك المعاملة أيضاً أعلى قيم محصول الثمار والتركيب الكيميائي للأوراق والثمار. كما أعطت نفس المعاملة التي مع هجين الطماطم (E-448) القدس أعلى معدل نمو خضري ، والصفات المحصولية والتركيب الكيميائي للأوراق والثمار. أشارت النتائج، بشكل عام، إلى أن هجين طماطم القدس (E-448) التي تم رشها بسيليكات البوتاسيوم عند 3000 ملجم / لتر يمكن اعتبارها العاملة المثلى لإنتاج نمو خضري عالي، محصول وجودة ثمار الطماطم الشتوية تحت الظروف البيئية لمنطقة التجربة لمحافظة أسوان والمناطق المشابهة لها.