American-Eurasian J. Agric. & Environ. Sci., 19 (2): 74-86, 2019
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2019.74.86

Potassium Silicate and Amino Acids Improve Growth, Flowering and Productivity of Summer Squash under High Temperature Condition

[1]Mona N. Shehata and [2]Karima F. Abdelgawad

[1]Horticulture Department, Faculty of Agriculture and Natural Research, Aswan University, Aswan, Egypt
[2]Vegetable Crops Department, Faculty of Agriculture Cairo University, Giza, Egypt

Abstract: The present investigation was conducted during the two summer seasons of 2016 and 2017 in the Experimental Station Farm, Faculty of Agriculture and Natural Resources, Aswan University, Egypt in sandy soil. High temperature above 43°C achieves the male flowers and increases the sex ratio which; lead to a decrease in the yield of squash. Thus, the purpose of this study was to investigate the effects of potassium silicate soaking seeds and foliar application of amino acid on improving the growth, flowering and production of summer squash under high temperature. Summer squash seeds cv. Eskandrany were soaked in potassium silicate at 0 (distilled water (as control , 2, 4 or 6 mM potassium silicate and foliar spray with amino acid at 0) distilled water), 500 or 1000 ppm three times after 25, 35 and 45 days from the sowing date. The experiment was arranged in split-plot in a randomized complete blocks design with three replicates. The obtained results revealed that the highest concentration of potassium silicate or amino acids enhanced plant growth, sex ratio and fruit yield and quality. Seeds soaked in 6 mM potassium silicate and foliar application of 1000 ppm of amino acid resulted in the highest values of vegetative growth, yield, vitamin C, TSS, leaf chemical content and female flowers and decreasing number of days to appearance first female flower and sex ratio compared to the other treatments and control treatment during the both seasons. Previous dual treatment could be recommended under similar environmental conditions.

Key words: *Cucurbita* · Amino acids · Potassium silicate · Vegetative growth · Yield · Fruit quality · Chemical composition

INTRODUCTION

In Egypt, summer squash (*Cucurbita pepo* L.) is one of the most important vegetable crops used for local consumption as well as for export. Eskandrany is the main cultivar of squash grown in the summer and autumn seasons. It is cultivated in Egypt in open field in the summer and in greenhouses or low tunnels in the winter [1]. Summer squash is a sensitive crop for unfavourable conditions such as low temperature or extreme high temperature (above 32°C). Squash is one of the crops that need to be cultivated for the warm weather, since high temperatures strongly affect it during germination and different stages of growth and development without indoor protection. Squash plants damaged by high temperatures when cultivating at temperatures higher than 32°C [2]. The most environmental factors affected the sex ratio and flowering habit are high temperature and photoperiod [3]. High night temperature and long day were increased the male flowers [4].

Silicon (Si) is the second abundant element in the soil and on the surface of earth. The benefits of silicon amendments have been well documented in plants. These include enhanced productivity and tolerance to various biotic and abiotic stress, such as freezing, heat, drought [5]. 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. K, 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

Corresponding Author: Mona N. Shehata, Horticulture Department, Faculty of Agriculture and Natural Research, Aswan University, Aswan, Egypt

photosynthesis [6]. Silicon is an essential micronutrient and its deficiencies affect significantly plant health and it was used in the form of potassium (K) salt. However and despite the documented beneficial effects of Si, its use in plant production is very limited. The principal reasons for this are the lack of commercial products on the market as well as the challenges associated with the standard form of application, which is supplying Si as an amendment to soils or nutrient solutions. Limited miscibility with other products and clogging of drip irrigation equipment has been reported problems when using Si fertilizers [7]. Thus, there is a commercial interest to develop more user- friendly means of application and foliar application could be an attractive alternative. Foliar spray with K silicate showed an increment in chlorophyll content and plant growth. Silicon can reduce salinity stress and reduce transpiration in plants [6, 8, 9]. Furthermore, in sugar cane, there was evidence that Si may play an important role in leaves protection from ultraviolet radiation damage by filtering out the harmful ultraviolet rays [8]. Thus, Si had been shown to ameliorate abiotic stresses in several ways. Potassium silicate increased plant proliferation, growth and yield of celery when the seeds soaking in potassium silicate solution [10].

The application of amino acids is a well-known biostimulant which has positive effects on plant growth, yield and significantly mitigates the injuries caused by abiotic stresses [11]. Amino acids foliar spray increased total soluble sugars and total free amino acids in *Antholyza aethiopica* [12]. Recently, great attention has been focused on natural and safety antioxidants substances, which have the ability quench to free radicals and thereby form a protective screen around plant cells and hence increasing plant resistance to stress, moreover, antioxidants provide adequate protection against the deleterious effect of activated oxygen species on sweet pea [13]. Plants need certain components for growth, whereas the basic components of living cells are proteins. The main source of protein in plant tissues is the amino acids. The requirement of nitrogen of amino acids in essential quantities is well known as a mean to increase growth and yield for all crops. Furthermore, amino acids are the fundamental ingredients for the process of protein synthesis [13]. The important of nitrogen or amino acids came from their widely use for the biosynthesis of large variety of non protein nitrogenous materials i.e., pigments, vitamins, coenzymes, purine and pyrimidine bases. Studies have proved that amino acids can directly or indirectly influences the physiological process in plant growth and development. Many researchers reported that, the foliar spray of amino acids caused an enhancement in plant growth, fruits yield and its components [1, 14-17].

Therefore, this work aims to improve growth, flowering and productivity of squash plants under high temperature and sandy soil conditions in Aswan Governorate by soaking seeds in different concentrations of potassium silicate solution and spraying plants with amino acids.

MATERIALS AND METHODS

Experiment Site: This experiment was conducted at the Experimental Station Farm, Faculty of Agriculture and Natural Resources, Aswan University, Aswan Governorate-Egypt during March 2016 and 2017 seasons. Some analytical data of studied soil before cultivation are presented in Table 1. Climate data for Aswan Governorate according to the National Oceanic and Atmospheric Administration are presented in Table 2.

Experiment Layout: The summer squash plant (*Cucurbita pepo L.*) cv. Eskandrany was selected for this study. The soil of experiment was ploughed, pulverized and ridged into rows with 4 m long and 1.0 m wide. Each experimental plot area was 12 m^2 (3 rows). After seed soaking in potassium silicate with different concentrations (mentioned below), the seeds were sown on 25th March at the both seasons on one side of the rows. The distance between plants was 40 cm. The drip irrigation was used. After germination, plants were thinned leaving one plant per hill. The experiment was consist of two factors i.e.; potassium silicate in the main plot and amino acid in sub plot. During soil preparation 150 kg of calcium super phosphate and 50 kg sulphur were added according to the recommendations of the Egyptian Ministry of Agriculture. The recommended doses of nitrogen (300 kg of ammonium sulphate) and potassium fertilizer (100 kg of potassium sulphate) were added in two equal portions during the growing season. Treatments were applied as follows: 1- Potassium silicate: Seeds of squash were soaked in distilled water as control and potassium silicate with concentrations 2, 4 or 6 Mm potassium silicate. Soaking process was achieved at the ambient room temperature for 6 hours before planting. Then the seeds were washed in distilled water for half hour before the sowing. The chemical composition of potassium silicate was potassium oxide 10 % and silicon oxide 25 %. It is a commercial compound was obtained from Union for Agricultural Development Company.

Table 1: Mechanical and chemical analyses of the experiment soil

Soil properties	Season 2016	2017
Physical properties		
Clay (%)	3.00	3.50
Silt (%)	0.00	0.00
Sandy (%)	97.00	95.50
Textural class	Sandy	Sandy
Chemical properties		
Soluble cations in (1:1) soil to water extract mmol/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 to water extract (mmol/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/cm) at 25C	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)	177.00	180.00

*The analyses were carried out at Soil Fertility Department, Faculty of Agriculture (Saba Basha), Alexandria University, Egypt.

Table 2: Mean precipitation, air temperature and relative humidity for the experimental station during the two growing seasons

Month	March	April	May	June	Annual rate
Maximum degree °C (°F)	44.0 (111.2)	45.3 (113.5)	48.4 (119.1)	49.5 (121.1)	49.5 (121.1)
Mean temperature Major °C (°F)	29.5 (85.1)	34.9 (94.8)	38.9 (102)	41.4 (106.5)	33.6 (92.5)
Daily average °C (°F)	21.8 (71.2)	27 (81)	31.4 (88.5)	33.5 (92.3)	25.9 (78.6)
Mean minimum Temperature °C (°F)	13.8 (56.8)	18.9 (66)	23 (73)	25.2 (77.4)	18.5 (65.3)
Lowest temperature ° C (°F)	4.6 (40.3)	7.5 (45.5)	13.6 (56.5)	16.4 (61.5)	-2 (28)
Precipitation (mm)	0 (0)	0 (0)	0.1 (0.004)	0 (0)	1.4 (0.055)
Mean rainy days (0.01 0.01 mm)	0.0	0.0	0.1	0.0	0.85
Relative Humidity Indicator (%)	24	19	17	16	26.2
Hours of monthly sun brightness	321.6	316.1	346.8	363.2	3,862,8

Table 3: The chemical composition of the amino acids

Amino acid	Value	Amino acid	Value
Apartic acid	1.85	Lycine	0.48
Thiamine	1.4	Histidine	0.18
Serine	2.1	Arginine	1.8
Glutamic acid	2.33	Proline	1.92
Glysine	1.7	Phenylalanine	0.65
Alanine	1.03	Tyroslyine	0.21
Valine	1.33	Total amino acid	17.13
Isolucine	0.59	Total N 7%	
Lucine	0.67	K_2O 8 %	

Amino Acid: Foliar spray with three concentrations of amino acids (0, 500, or 1000 ppm) were used three times after 25, 35 and 45 days from the planting date. The chemical constituents of amino acid were presented in Table 3. Amino acid was procured from Union for Agricultural Development Company.

Data Recorded

Vegetative Growth: After 50 days from the sowing date, four plants were randomly pulled up with roots from each plot to measure the vegetative growth parameters. Plant length, number of leaves /plant, leaves fresh and dry weights /plants were recorded. Leaf area was measured by the planimeter. Leaf greenness was determined by SPAD meter.

Leaf Chemical Constituents: Leaf nitrogen and phosphorus content were measured colorimetrically according to A.O.A.C. [18]. Potassium content was measured in plants using flam photometer according to the method of Jackson [19] after 50 days from the sowing date. The protein content was determined as described by Stoscheck [20] and total amino acids were determined according to the method of Rosein [21] after 80 days from the sowing date.

Flowering Characteristics: Four plants from each plot were randomly selected and labeled for recording the following parameters: number of days from sowing until the appearance of the first female flower, number of female and male flowers/ plant and sex ratio was calculated according to the following equation:

$$\text{Sex ratio} = \frac{\text{No. male flowers/plant}}{\text{No. female flowers/plant}}$$

Yield and Fruit Quality: Early yield / plant was calculated from the sum of the first four pickings, number of total fruits / plant, total yield/ plant, average fruit weight, total yield/fadden, average fruit length, average fruit diameter, average fruit weight and shape index was measured according to the following equation:

$$\text{Fruit shape index} = \frac{\text{Fruit length}}{\text{Fruit diameter}}$$

Fruits Chemical Constituents: To estimate some composition of fruit characters, 5 fruits were used to extract their juice to estimate vitamin C (ascorbic acid) according to Ranganna [22] by using titration with iodide potassium and calculated as mg/100 cm^3 , total soluble solids (TSS) measured by using the digital refractometer.

Statistical Analysis: Data were subjected to the analysis of variance by using MSTAT-C computer software program prepared by Bricker [23]. Duncan method was used to compare the differences between means of the various combinations according to Duncan [24]

RESULTS AND DISCUSSION

Plant Growth Parameters Were Improved by Potassium Silicate and Amino Acids: Plant length, number of leaves per plant, fresh and dry weight of leaves, leaf area per plant and SPAD reading were significantly ($p \leq 0.05$) enhanced by potassium silicate and amino acids separately or in combination in 2016 and 2017 seasons (Figures 1 and 2 and Table 4). The highest concentration of potassium silicate (6Mm) or the highest concentration of amino acid recorded the highest values of vegetative growth (Figures 1 and 2). The highest value of plant length was recorded from plants treated with 6 mM potassium silicate plus 1000 ppm amino acids in both seasons. The treatments of 6 mM of potassium silicate plus 1000 ppm of amino acids caused increases in plant length of 33.3 % and 32.3 % in 2016 and 2017, respectively, compared to the control. The higher number of leaves per plant was obtained from plots received 6 mM of potassium silicate plus 1000 ppm of amino acids in both seasons. both leaf fresh weight and leaf dry weight were significantly increased by 6 mM of potassium silicate plus 1000 ppm of amino acids treatment compared to the other lower concentrations (2 and 4 mM of potassium silicate and 500 ppm of amino acids) or the control treatments. Also, leaf area per plant and SPAD reading in both seasons were significantly increased by 6 mM of potassium silicate plus 1000 ppm of amino acids compared to other treatments or the control.These results are in line with those obtained by Adatia [25] on cucumber. These results are due to the fact that silicon nutrition has many benefits in vegetable growth due to the physiological role of silicon in the plant [26]. The root length and weight increased when seeds were treated with potassium silicate which, leads to more growth [27]. Si application promotes cell elongation [28]. Belanger [29] reported that leaf thickness, leaf dry matter and leaf area increased by Si application. Also vegetative growth of celery increased by increasing the potassium silicate concentrations [10]. Si improves the photosynthesis efficiency by its vital role in leaf stability and exposes more leaves to light so; it induced increasing in plant canopy and photosynthysis. Potassium silicate contains K with 10% . K play important role in photosynthysis and enzyme activation which also leading to improve the growth [6]. Increasing the vegetative growth of squash by foliar spray of amino acids was reported by Abd El-Aal [1]. Amino acids improve cell growth and it is a fundamental ingredient in chlorophyll synthesis [30]. The important role of amino acid in improvement of growth due to its role in plastids ultra structure leading to improvement of photosynthsise and producing more assimilates needed for formation of new cell [31]. Also, amino acids are activators of phytohormones and growth substance [32].

Chemical Compositions of Leaf Were Improved by Potassium Silicate and Amino Acids: Leaf protein content, total soluble amino acids and leaf NPK contents were enhanced by potassium silicate and amino acids treatments separately or in combination in both seasons (Figures 3 and 4 and Table 5). Leaf chemical compositions increased by increasing the potassium silicate concentration or amino acid concentration (Figures 3 and 4). The highest leaf protein content was recorded from plants treated with 6 mM of potassium silicate plus 1000 ppm of amino acids while the control

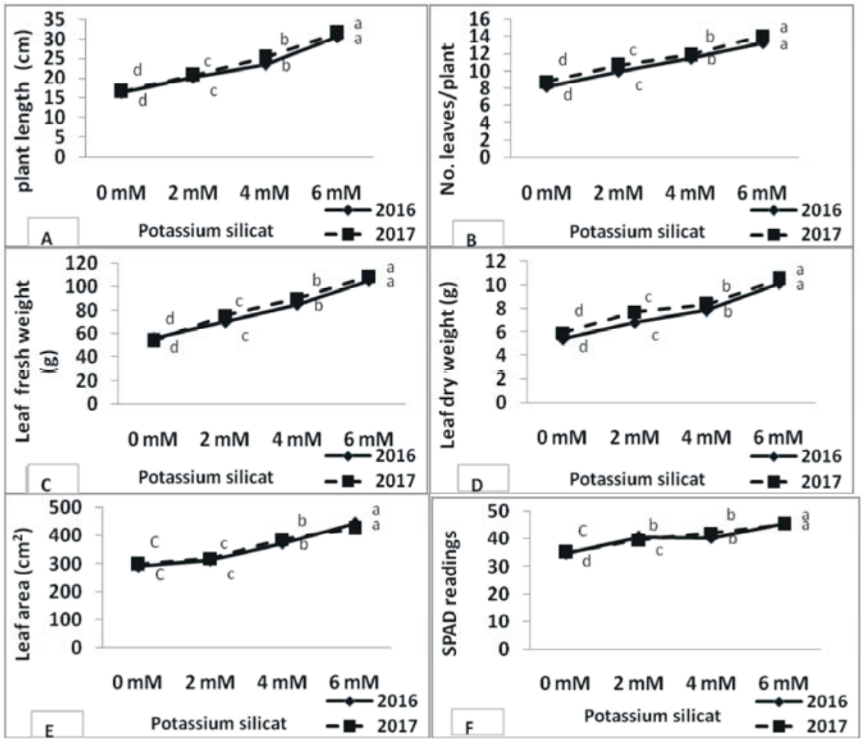

Fig. 1: Effect of different potassium silicate concentrations on A) plant length, B) number of leaves/plant, C) leaf fresh weight, D) leaf dry weight, E) leaf area and F) leaf SPAD readings after 50 days from the sowing date in 2016 and 2017 seasons

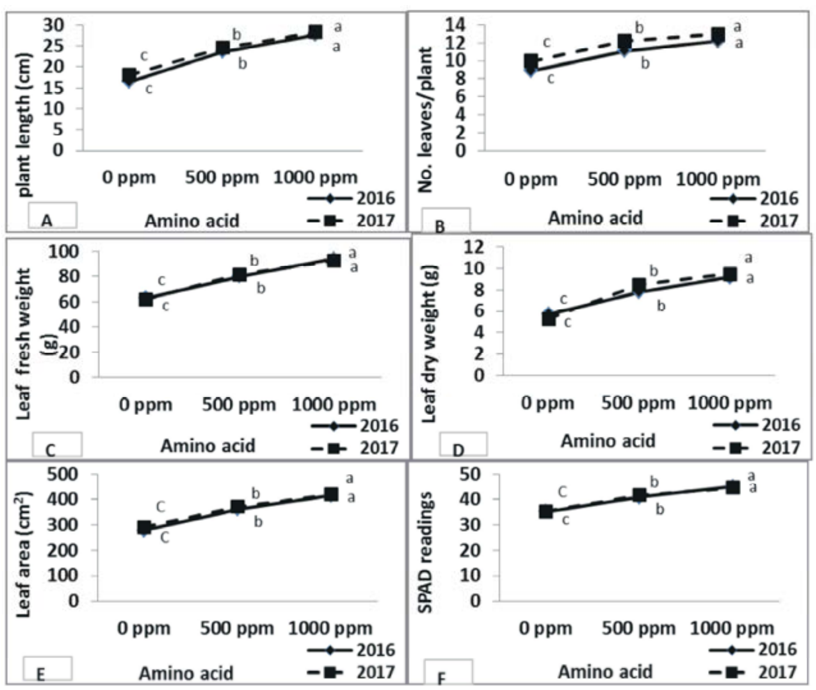

Fig. 2: Effect of different amino acid concentrations on A) plant length, B) number of leaves/plant, C) leaf fresh weight, D) leaf dry weight, E) leaf area and F) leaf SPAD readings after 50 days from the sowing date in 2016 and 2017 seasons

Table 4: Growth parameters after 50 days from the sowing date as affected by the interaction between potassium silicate and amino acid concentrations during 2016 and 2017 seasons

		Plant length (cm)	No.	Leaf leaves/plant		Leaf fresh weight (g)		Leaf area/ dry weight (g)		Leaf plant (cm^2)		SPAD readings	
Potassium silicate (Mm)	Amino acids (ppm)	2016	2017	2016	2017	2016	2016	2017	2017	2016	2017	2016	2017
0 mM	0	13.27k	12.61i	7.523h	6.440l	45.00k	42.70l	4.383j	4.120j	238.0g	243.9g	30.40h	29.80g
	500	16.50i	16.78j	8.480g	9.003j	55.97i	57.10j	5.450i	6.230g	305.5ef	312.8de	32.65gh	35.55f
	1000	19.48g	20.46i	8.613g	9.350i	66.07h	62.13i	6.437g	7.163f	327.1de	330.9d	41.15cde	39.86d
2 mM	0	14.14j	15.55k	7.780h	7.580k	53.17j	54.00k	5.227i	5.487i	264.0g	260.0fg	35.17fg	33.78f
	500	21.80f	21.11g	10.673e	9.723h	73.93g	76.23g	7.197f	7.007f	326.1de	334.9d	41.72cd	42.08c
	1000	24.54e	25.73e	11.340d	11.790d	83.23e	81.83e	8.103e	7.673e	347.4d	344.1cd	45.29bc	43.34c
4 mM	0	17.27h	20.49h	9.807f	10.780g	75.17g	73.07h	6.010h	5.693hi	292.8f	335.6d	36.81efg	37.88e
	500	25.59d	26.73d	11.823d	11.310e	86.80d	87.80d	8.453d	9.143d	381.7c	375.9c	40.90cde	42.80c
	1000	27.56c	28.74c	12.773c	12.240c	93.47c	96.87c	9.107c	10.283c	443.0b	437.8b	43.74c	45.77b
6 mM	0	21.34f	23.36f	10.450e	11.003f	79.23f	77.80f	7.323f	5.823h	320.5def	288.5ef	38.45def	39.87d
	500	30.59b	29.54b	13.347b	14.710b	103.7b3	105.23b	10.10b7	11.513b	470.2b	459.2b	48.07ab	46.50b
	1000	39.37a	38.54a	16.003a	16.370a	133.53a	129.20a	13.003a	12.717a	541.4a	530.7a	50.40a	49.62a

Table 5: Leaf chemical composition as affected by the interaction between potassium silicate and amino acid concentrations during 2016 and 2017 seasons.

		Leaf total protein (mg/g DW)		Total soluble amino acids (mg/g DW)		Leaf N (%)		Leaf P (%)		Leaf K (%)	
Potassium silicate (Mm)		2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
0 mM	0	10.00l	10.12l	1.028l	1.101k	1.546i	1.651l	0.123h	0.135i	1.224k	1.177i
	500	16.55h	16.26h	1.309h	1.224h	2.672f	3.029g	0.282e	0.260f	2.306h	1.967f
	1000	19.11d	18.12e	1.488f	1.520f	3.374d	3.549d	0.370c	0.343d	3.078e	3.265cd
2 mM	0	11.07k	10.40k	1.234i	1.117k	1.789h	2.147k	0.163g	0.204h	1.332k	1.241hi
	500	16.73g	17.00f	1.416g	1.373g	3.119e	2.877h	0.221f	0.242g	2.611g	3.076e
	1000	19.50c	19.70c	1.664d	1.592e	3.639c	3.371e	0.387c	0.418c	3.303d	3.265cd
4 mM	0	11.41j	12.00j	1.204j	1.151j	2.072g	2.179j	0.127h	0.143i	1.535j	1.377h
	500	17.08f	16.85g	1.606e	1.659d	3.165e	3.336f	0.284e	0.307e	2.926f	3.123de
	1000	20.40b	20.16b	1.780b	1.716c	4.461b	3.969c	0.453b	0.471b	3.853b	3.554b
6 mM	0	12.11i	12.39i	1.166k	1.170i	2.147g	2.284i	0.158g	0.228g	2.093i	1.808g
	500	17.42e	18.14d	1.687c	1.745b	4.626b	4.269b	0.347d	0.405c	3.695c	3.329c
	1000	21.30a	20.73a	1.871a	1.804a	5.117a	4.799a	0.518a	0.491a	4.390a	3.841a

Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) according to Duncan?s multiple range test.

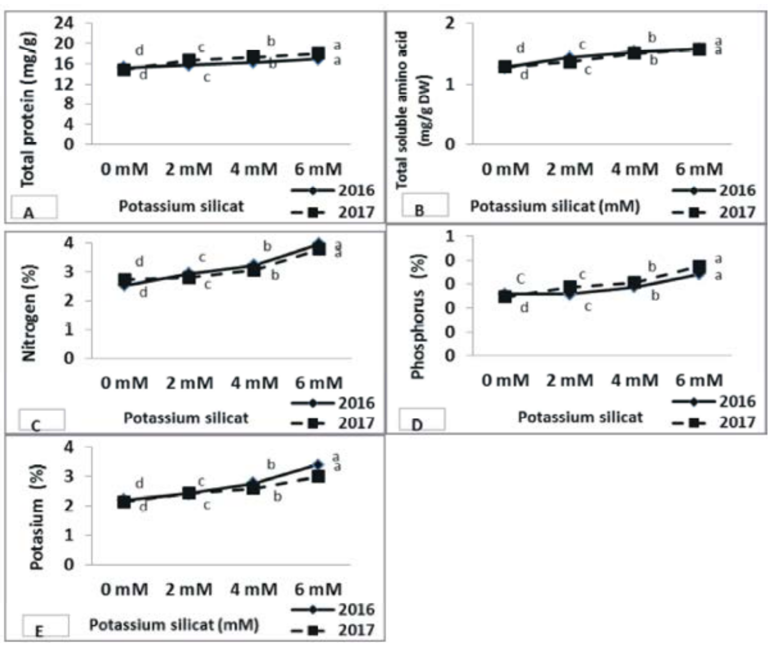

Fig. 3: Effect of different potassium silicate concentrations on A) leaf total protein, B) leaf total soluble amino acids, C) leaf nitrogen %, D) leaf phosphorus % and E) leaf potassium % in 2016 and 2017 seasons

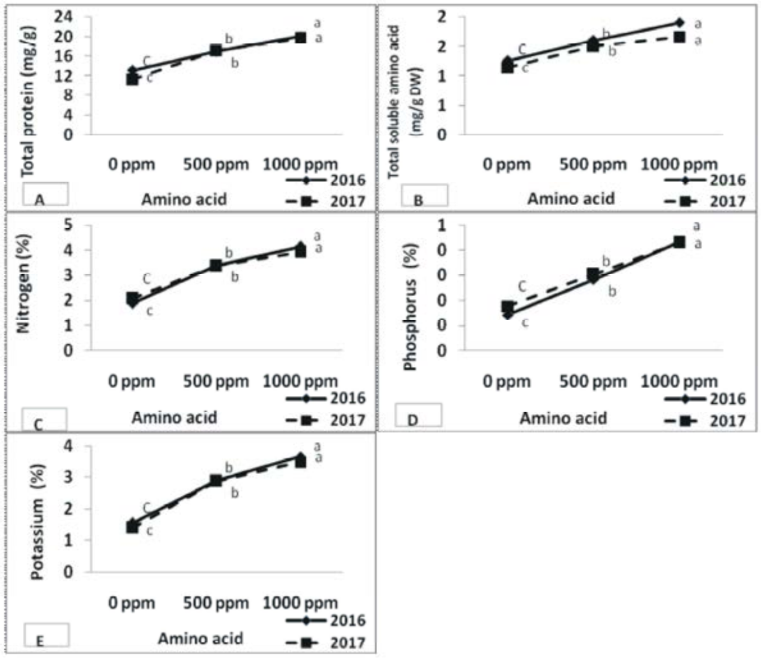

Fig. 4: Effect of different amino acid concentrations on A) leaf total protein, B) leaf total soluble amino acids, C) leaf nitrogen %, D) leaf phosphorus % and E) leaf potassium % in 2016 and 2017 seasons

plants had the lowest value in both season. Total soluble amino acids content was significantly increased by the foliar application of potassium silicate and amino acids by using the highest concentrations in both seasons. Leaf NPK contents were increased with increasing of potassium silicate and amino acids application dosages. The highest concentrations of potassium silicate (6 mM) plus amino acids (1000 ppm) caused a significant increase of NPK content in leaves compared to the other concentrations and control. Si application increased the water use efficiency and nutrient uptake under water stress and salinity [33, 34]. Although, Si is not listed among the essential elements for plant growth, its beneficial role in plant nutrition is well established [35, 36]. Silicon is absorbed by plants as monosilicic acid (H_2SiO_4) and accumulates to higher concentrations in leaf epidermal cells than in any other cell type [37]. Dragisic [38] showed that Si have a benefit role in modulation and metabolism of different compounds in plants. Potassium is important for many physiological and biological processes in plants and takes part in protein synthesis [6]. Amino acids are the main source of protein in plant tissue and it is the fundamental ingredients for the process of protein synthesis [13].

Sex Ratio and Yield Were Enhanced by Potassium Silicate and Amino Acids: Figures 5 and 6 and Table 6 indicated that number of days to flowering and number of male flowers were significantly decreased by potassium silicate or amino acids application while number of female flowers, number of fruit per plant, early yield, total yield per plant and total yield per feddan were significantly increased. Number of days to flowering and number of male flowers were decreased by using 6 mM of potassium silicate plus 1000 ppm of amino acids treatment compared to the other treatments and control in both seasons. The high concentration of potassium silicate plus amino acids significantly increased number of female flowers, number of fruit per plant, early yield, total yield per plant and total yield per feddan in both seasons. These results are in agreement with Adatia [25] and Ryszard [39] who reported that Si increased the yield of cucumber. Beneficial effects of Si have been detected in plants exposed to both biotic and a biotic stresses [40, 41]. Si involved in thermal stability of lipids in membranes of cell and reduced the electrolyte leakage of leaf under high temperature [42]. These functions of Si improve the vegetative growth and made the plants more healthy which lead to increasing the yield. K plays roles in flowering and germination of pollen as well as in seed development [43]. Increasing the yield by foliar application of amino acids due to their role in adaptation to the environmental conditions and many physiological processes inside the plants [1, 14-17].

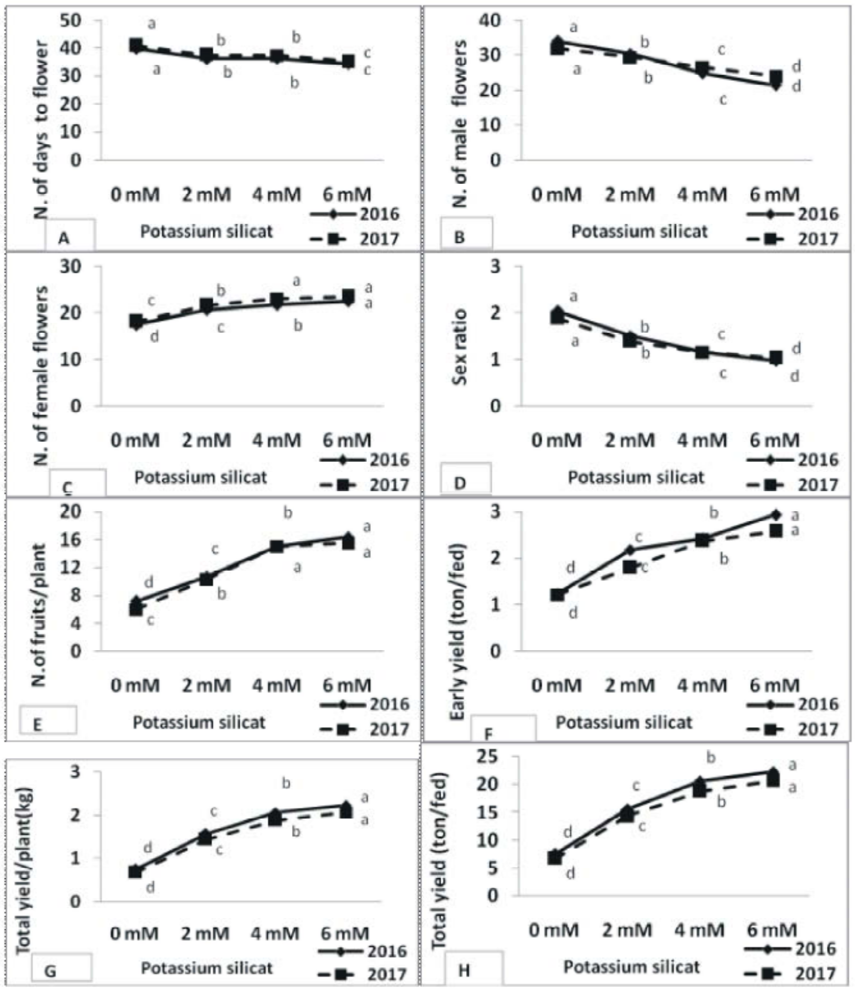

Fig. 5: Effect of different potassium silicate concentrations on A) No. days to flowering, B) number of male flowers/plant, C) number of female flowers/plant, D)sex ratio E) number of fruits/plant, F) early yield/feddan, G) total yield/plant and H) total yield /feddan in 2016 and 2017 seasons

Physical and Chemical Fruits Parameters Were Improved by Potassium Silicate and Amino Acids: Fruit length, fruit diameter, fruit shape index, fruit weight, TSS and vitamin C in fruits were significantly influenced by potassium silicate and amino acids applications (figures 7 and 8 and Table 7). The highest fruit length was recorded for 6 mM of potassium silicate plus 1000 ppm of amino acids treatment compared to the other treatments. No significant difference was observed between 500 and 1000 ppm of amino acid and between 4 and 6 mM of potassium silicate in both seasons. The highest fruit diameter values were observed in the 4 mM of potassium silicate plus 0 ppm of amino acid in both seasons. In addition, no significant difference was observed among 2, 4, or 6 mM of potassium silicate treatments in both seasons. Also, the difference between 500 and 1000 ppm of amino acids treatments was not significant. The highest fruit shape index was observed in the fruits obtained from plants treated with 6 mM of potassium silicate plus 1000 ppm of amino acids. The highest values of fruit weight were recorded in 6 mM of potassium plus 500 ppm of amino acids in both seasons. There were no significant differences in fruit weight between 500 and 1000 ppm of amino acid treatments and between 2 and 4 mM of potassium silicate treatments in both seasons. Fruit TSS and vitamin C were significantly increased by increasing potassium silicate and amino acids dosages in both seasons. The highest TSS and vitamin C values were recorded in 6 mM of potassium silicate plus 1000 ppm amino acids treatments. Si promotes cell elongation which may be due to increasing the fruit length [28]. Increasing the fruits firmness by silicon supply is due to

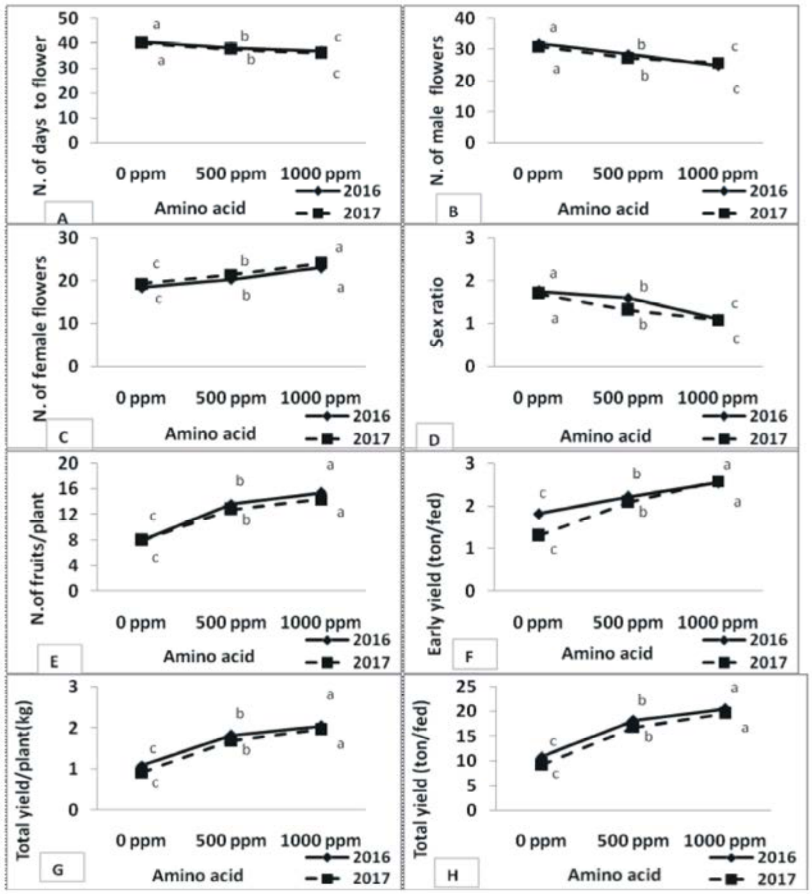

Fig. 6: Effect of different amino acid concentrations on A) no. days to flowering, B) number of male flowers/plant, C) number of female flowers/plant, D) sex ratio E) number of fruits/plant, F) early yield/feddan, G) total yield/plant and H) total yield/feddan in 2016 and 2017 seasons

Table 6: Flowering and yield parameters as affected by the interaction between potassium silicate and amino acid concentrations during 2016 and 2017 seasons

Potassium silicate (Mm)	Amino acids (ppm)	No. days to flowering		No. male flowers/plant		No. female flowers/plant		Sex ratio		No. fruits/ plant		Early yield (ton/feddan)		Total yield /plant (kg)		Total yield (ton/feddan)	
		2016	2017	2016	2017	2016	2016	2016	2017	2016	2017	2017	2017	2016	2017	2016	2017
0 mM	0	43.82a	44.17a	37.74a	35.11a	14.34l	13.71g	2.643a	2.582a	4.46j	3.66g	1.012l	0.916k	0.446k	0.424i	4.46k	4.24i
	500	39.28b	38.99b	33.02c	31.14c	16.64k	17.35f	1.991b	1.796b	7.44h	6.35f	1.191k	1.090j	0.746j	0.682h	7.46j	6.82h
	1000	36.36de	36.63ef	31.07d	29.31d	21.37e	23.07bcd	1.457d	1.271cd	9.68g	7.97e	1.505j	1.632g	1.034h	0.901g	10.34h	9.01g
2 mM	0	38.27c	38.69bc	33.90b	34.11b	18.75j	20.13e	1.812c	1.696b	6.38i	5.88f	2.035i	1.291i	0.915i	0.675h	9.15i	6.75h
	500	36.74de	37.26de	30.63d	27.87e	20.57g	21.28de	1.492d	1.311c	12.2e8	11.91d	2.171f	1.812f	1.737e	1.540d	17.37e	15.40d
	1000	36.31e	36.61ef	26.68f	26.30f	22.33d	23.38bc	1.197f	1.126de	13.39d	13.15c	2.335e	2.292e	2.036d	2.104c	20.36d	21.04c
4 mM	0	38.59bc	38.70bc	27.65e	28.99d	20.53h	21.90cde	1.350e	1.324c	9.78g	11.05d	2.062h	1.483h	1.397g	1.202f	13.97g	12.02f
	500	37.17d	37.62cde	25.06g	25.51g	21.34f	23.05bcd	1.177f	1.108de	16.20c	15.66b	2.485d	2.574d	2.314c	2.118c	23.14c	21.18c
	1000	36.04e	35.88f	21.78i	24.69h	23.24b	23.95ab	0.939g	1.031ef	19.17a	18.32a	2.717c	3.078b	2.475b	2.335b	24.75b	23.35b
6 mM	0	37.21d	38.07bcd	23.97h	25.45g	19.95i	21.33de	1.204f	1.198cde	11.27f	11.17d	2.150g	1.537gh	1.549f	1.349e	15.49f	13.49e
	500	35.14f	35.85f	20.78j	23.97i	22.48c	23.52bc	0.926g	1.019ef	18.54b	17.39a	3.021b	2.874c	2.486b	2.363b	24.86b	23.63b
	1000	34.02g	34.48g	19.57k	22.67j	24.76a	25.47a	0.791h	0.890f	19.39a	18.02a	3.640a	3.323a	2.652a	2.482a	26.52a	24.82a

Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) according to Duncan's multiple range test.

strong bounding of Si to cellulose framework [44]. Potassium plays important role in plant growth and yield [6] and increase the plant response to abiotic stress [45]. K increased the TSS of pepper fruits due to increasing the dry matter in fruits [46]. The vital role of amino acid in improving the photosynthesis and plant growth leads to increasing the TSS and VC in the fruits and increase the TSS in onion bulbs [47-49].

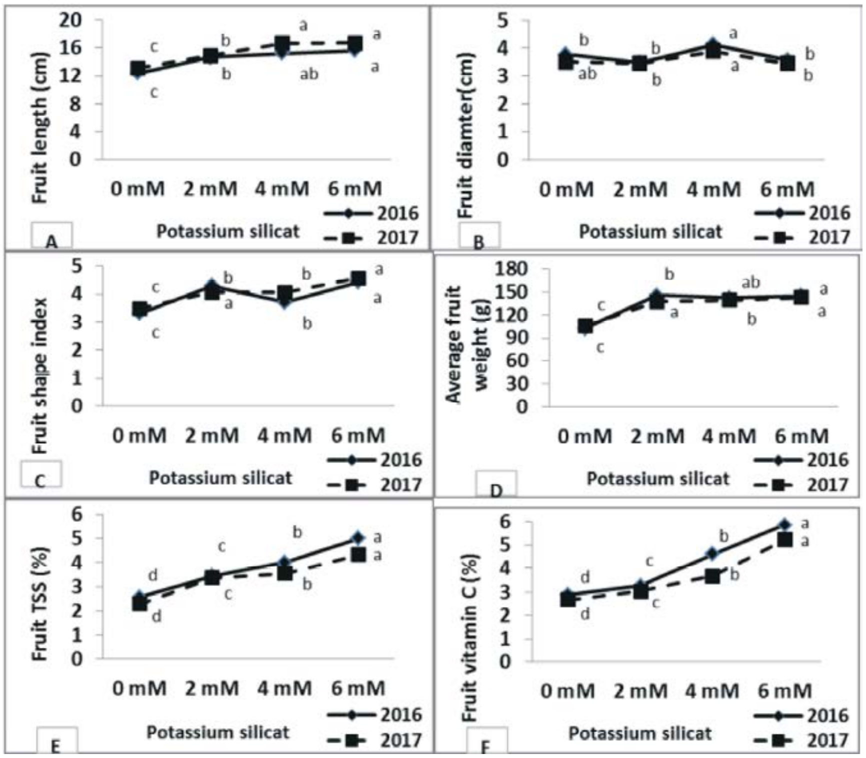

Fig. 7: Effect of different potassium silicate concentrations on A) fruit length, B) fruit diameter, C) fruit shape, D) average fruit weight E) fruit TSS and F) fruit vitamin C in 2016 and 2017 seasons

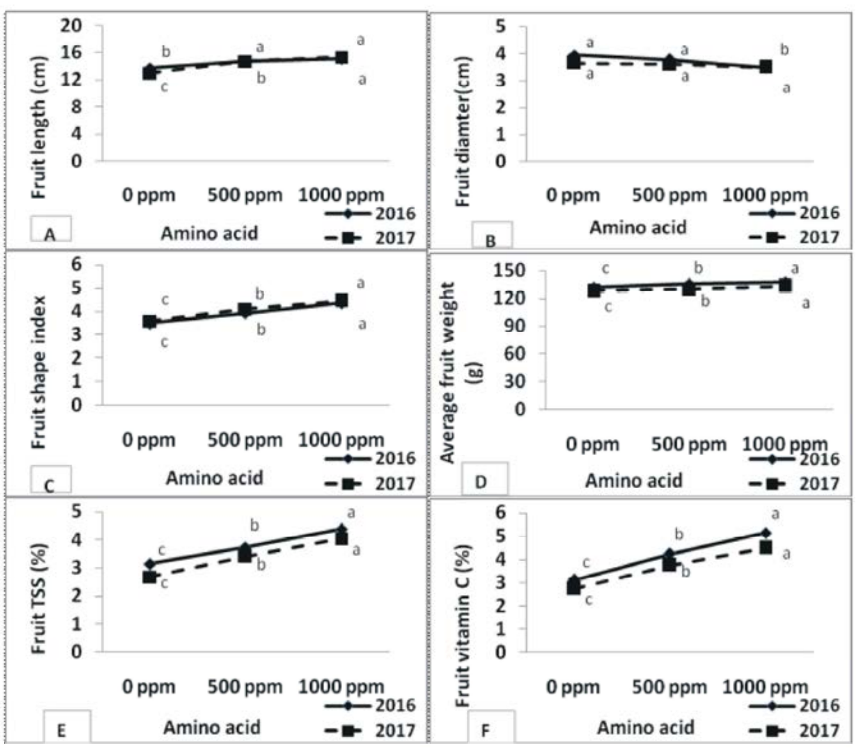

Fig. 8: Effect of different amino acid concentrations on A) fruit length, B) fruit diameter, C) fruit shape, D) average fruit weight E) fruit TSS and F) fruit vitamin C in 2016 and 2017 seasons

Table 7: Fruit quality as affected by the interaction between potassium silicate and amino acid concentrations during 2016 and 2017 seasons

Potassium silicate (Mm)	Amino acids (ppm)	Fruit length (cm) 2016	Fruit length (cm) 2017	Fruit diameter (cm) 2016	Fruit diameter (cm) 2017	Fruit shape index 2016	Fruit shape index 2017	Average fruit weight (g) 2016	Average fruit weight (g) 2017	Fruit TSS (%) 2016	Fruit TSS (%) 2017	Fruit vitamin C (%) 2016	Fruit vitamin C (%) 2017
0 mM	0	11.79f	10.84e	3.757abc	3.317bcd	3.138e	3.335fg	100.0g	99.0g	2.155h	1.964j	2.329g	2.090h
	500	12.57ef	12.23d	3.947ab	3.473abcd	3.184e	3.555efg	100.2g	102.4g	2.393g	2.168i	3.133f	2.830f
	1000	12.90e	13.28c	3.612bcde	3.721abc	3.595de	3.573efg	106.8f	115.6f	3.160f	2.704h	3.180ef	3.110e
2 mM	0	13.55de	12.20d	3.880abc	3.750ab	3.578de	3.255g	143.6bc	137.8cd	3.048f	2.666h	2.428g	2.495g
	500	14.85bc	14.34b	3.348cde	3.422abcd	4.441b	4.198cd	141.5cd	137.9cd	3.173f	3.228f	3.303e	3.181e
	1000	15.55abc	15.18b	3.195de	3.218cd	4.867a	4.716b	152.1a	136.3de	4.073e	4.148c	4.069d	3.433d
4 mM	0	14.47cd	14.57b	4.254a	3.844a	3.415de	3.845def	142.8bc	141.7abc	3.102f	2.766g	3.308e	2.208h
	500	15.72ab	16.04a	4.075ab	3.883a	3.864cd	4.136cd	142.9bc	136.1de	4.193de	3.736d	4.194e	3.518d
	1000	15.54abc	16.41a	4.041ab	3.924a	3.845cd	4.182cd	139.5de	139.0bcd	4.683c	4.125c	6.378b	5.336b
6 mM	0	14.96bc	14.35b	3.885abc	3.690abc	3.857cd	3.889de	137.5e	133.4e	4.228d	3.311e	4.379c	4.155c
	500	15.68ab	16.21a	3.706abcd	3.614abc	4.234bc	4.483bc	153.9a	144.9a	5.127b	4.478b	6.262b	5.468b
	1000	16.25a	16.50a	3.150e	3.094d	5.162a	5.331a	144.0b	142.9ab	5.563a	5.178a	6.915a	6.083a

Means within a column followed by the same letter are not significantly different (p=0.05) according to Duncan?s multiple range test.

CONCLUSION

Many crops in the summer season suffer from high temperature effects, especially in the flowering stage, which affects the final yield. The most affected crop is squash, which suffers from heat stress when the temperature rises to more than 32 ° C, so it was necessary to use some treatments that help the plant to withstand heat stress with achieving the highest productivity and improve the process of flowering. Soaking the seeds of squash in 6 mM potassium silicate plus1000 ppm amino acid as foliar spray improved vegetative growth, sex ratio, total yield and fruit quality. The study recommends the application of this treatment to squash cultivation under the conditions of Aswan Governorate and similar conditions.

REFERENCES

1. Abd El-Aal, F.S., A.M. Shaheen, A.A. Ahmed and R.A. Mahmoud, 2010. Effect of foliar application of urea and amino acids mixtures as antioxidants on growth, yield and characteristics of squash. Research Journal of Agriculture and Biological Sciences, 6(5): 583-588.
2. Rab, A. and M.E. Saltveit, 1996. Sensitivity of seedling radicals to chilling and heat – shock induced chilling tolerance. Journal of the American Society for Horticultural Science, 121(4): 711-715.
3. Swiader, J.M., S.K. Sipp and R.E. Brown, 1994. Pumpkin growth, flowering and fruiting response to nitrogen and potassium sprinkler fertigation in sandy soil. Journal of the American Society for Horticultural Science, 119: 414-419.
4. Kooistra, E., 1967. Femaleness in breeding glasshouse cucumbers. Euphytica, 6: 1-17.
5. Jacob, R.M., C. Phyfer, B.A.M. Potier and D. Watt, 2009. Investigating and manipulating silicon uptake in sugarcane. SASRI, Tuesday, 4 August, 2009. KwaShukela Auditorium, South African Sugar Association, Durban.
6. Marschner, H., 1995. Beneficial mineral elements. In: Mineral nutrition of higher plants. Inc. Sandiego. USA.
7. Guevel, M.H., J.G. Menzies and R.R. Belanger, 2007. Effect of root and foliar applications of soluble silicon on powdery mildew control and growth of wheat plants. Eur. J. Plant Pathol., 119: 429-436.
8. Tisdale, S.L., W.J. Nelson and J.D. Beaton, 2013. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Pearson; 8 Edi., pp: 528.
9. Epstein, E., 1994. The anomaly of silicon in plant biology, Proceedings of the National Academy of Sciences USA, 91: 11-17.
10. Iman, A.F., S.O. Hussein and E.H. Yousra, 2014. Improvement seedling growth of celary (*Apium graveolens* L.) using humic acid, potassium silicate and low gamma irradiation doses. Zagazige J. Agric. Res., 41(4): 737-745.
11. Kowalczyk, K. and T. Zielony, 2008. Effect of aminoplant and asahi on yield and quality of lettuce grown on rockwool. Proc. Conf. of Biostimulators in Modern Agriculture, 7-8 Febuary, Warsaw, Poland.
12. Wahba, H.E., M.M. Safaa, G.E. Attoa and A.A. Farahat, 2002. Response of *Antholyza acthipoica* L. to foliar spray with some amino acids and mineral nutrition with sulphur. Annals of Agric.Sci. Cairo Univ., 47(3): 929-944.

13. Al-Said, M.A. and A.M. Kamal, 2008. Effect of foliar spray with folic acid and some amino acids on flowering yield and quality of sweet pepper. J. Agric. Sci. Mansoura Univ., 33(10): 7403-7412.
14. Kamar, M.E. and A. Omar, 1987. Effect of nitrogen levels and spraying with aminal-forte (amino acids salvation) on yield of cucumber and potatoes. J. Agric. Sci. Mansoura Univ., 12(4): 900-907.
15. Karuppaiah, P., K. Manivonnar, M.V.S. Andrasakaron and G. Kuppusamy, 2000. Responses of cucumber to foliar application of nutrients on light mine spoil. J. the Indian Society of soil Science, 49(1): 150-153.
16. El-Shabasi, M.S., S.M. Mohamed and S.A. Mahfouz, 2005. Effect of foliar spray with amino acids on growth, yield and chemical composition of garlic plants. The 6th Arabian Conf. for Hort. Ismailia, Egypt.
17. Awad, El-M.M., A.M. Abd El-Hameed and Z.S. Shall, 2007. Effect of glycine, lysine and nitrogen fertilizer rates on growth, yield and chemical composition of potato. J. Agric. Sci. Mansoura Univ., 32(10): 8541-8551.
18. A.O.A.C., 1992. Official methods of analysis of the Association official Analytical Chemists, 1sth Ed. Published by The Association of Analytical Chemists 111. North Nineteenth suite 210 Arlington Virginia 2220/U.S.A. Macmillan Publishing Company, New York.
19. Jackson, A., 1973. Soil Chemical Analysis. Prentice-Hall. India Private Limited, New Delhi.
20. Stoscheck, C.M., 1990. Quantitation of protein. Meth. Enzymol., 182: 50-68.
21. Rosein, H., 1957. A modified ninhydrine colormetric analysis for amino acids. Arch. Biochem. Biophys., 67: 10-15.
22. Ranganna, S., 1986. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. 2nd Edition. Tata McGraw-Hill Publ. Comp. Ltd., New Delhi, India, pp: 1112.
23. Bricker, B., 1991. MSTATC: A Micro Computer Program from the Design Management and Analysis of Agronomic Research Experiments. Michigan State University, USA.
24. Duncan, D., 1965. Multiply range and multiple F test. Biometrics, 11: 1-42.
25. Adatia, M.H. and R.T. Besford, 1986. The effects of silicon on cucumber plants grown in recirculating nutrient solution. Ann. Bot., 58: 343-351.
26. Takahashi, E., I.F. Ma and Y. Miyake, 1990. The possibility of silicon as an essential element for higher plants. Comments Agric. Food Chem., 2: 99-122.
27. Sivanesan, I., M.S. Sook, C.L. Shin and B.J. Ryong, 2011. Effect of soaking of seeds in potassium silicate and uniconazole on germination and seedling growth of tomato cultivars, Seogeon and Seokwang. African Journal of Biotechnology, 10(35): 6743-6749.
28. Ma, J.F. and N. Yamaji, 2006. Silicon uptake and accumulation in higher plants. Trends Plant Science, 11: 392-397.
29. Belanger, R.R., P.A. Bowen, D.L. Ehret and J.G. Menzies, 1995. Soluble silicon - Its role in crop and disease management of greenhouse crops. Plant Dis., 79: 329-336.
30. Öpik, H. and S. Rolfe, 2005. The Physiology of flowering plants. Cambridge Univ. Pres 5. Plant Growth Hormones, pp: 177-194.
31. Kandil, A.A., A.E. Sharief and F.H. Fathalla, 2013. Onion yield as affected by foliar application with amino and humic acids under nitrogen fertilizer levels. Crop Production, 2(2): 62-72.
32. Marschner, H., 1995. Mineral nutrition of higher plants", 2nd ed. London, UK: Academic Press. Nelson, N., (1994). "A photomorphic adaption of the semogyi method for determine of glucose", J. Biol. Chem., 153: 373-377.
33. Gao, X., C. Zou, L. Wang and F. Zhang, 2006. Silicon decreases transpiration rate and conductance from stomata of maize plants. Journal of Plant Nutrition, 29: 1637-1647.
34. Romero-Aranda, M.R., O. Jurado and J. Cuartero, 2006. Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. Journal of Plant Physiology, 163: 847-855.
35. Epstein, E., 1999. Silicon. Annu. Rev. Plant Physiol. Plant Mol. Biol., 50: 641-664.
36. Marschner, H., 1995. Mineral Nutrition of Higher Plants. 2nd edn. Academic Press, London, pp: 889.
37. Currie, H.A. and C.C. Perry, 2007. Silica in plants: Biological, biochemical and chemical studies. Ann. Bot., 100: 1383-1389.
38. Dragisic, M., J., J. Bogdanowic, V. Makimowic and M. Nikolic 2007. Silicon modulates the metabolism and utilization of phenolic compounds in cucumber (*Cucumis sativus* L.) grown at excess manganese. J. Plant Nutr. Soil Sci., 170: 739-744.

39. Ryszard, S.G. and W. Danielski-Busch, 2009. Effect of silicate fertilizers on yielding of greenhouse cucumber (*Cucumis sativus* L.) in container cultivation. J. Elementol., 14(1): 71-78
40. Ashraf, M.R., M. Afzal, R. Ahmed, F. Mujeeb, A. Sarwarand and L. Ali, 2010. Alleviation of detrimental effects of NaCl by silicon nutrition in salt-sensitive and salt-tolerant genotypes of sugarcane (*Saccharum officinarum* L.). Plant Soil, 326: 381-391.
41. Datnoff, L.E., G.H. Snyder and G.H. Korndörfer, 2001. Silicon in Agriculture. Elsevier Science, Amsterdam.
42. Agarie, S., N. Hanaoka, O. Ueno, A. Miyazaki, F. Kubota, W. Agata and P.B. Kaufman, 1998. Effect of silicon on tolerance to water deficit and heat stress in rice plants (*Oryza sativa* L.), monitored by electrolyte leakage. Plant Prod. Sci., 1: 96-103.
43. Fan, L., Y. Wang, H. Wang and W. Wu, 2001. *In vitro* Arabidopsis pollen germination an characterization of inward potassium currents in Arabidopsis pollen grain protoplasts. J. Exp. Bot., 52: 1603-1614.
44. Lewin, J. and B.E.F. Reimann, 1969. Silicon and plant growth, Annual Review of Plant Physiology, 20: 289-304.
45. Wang, Y. and W.H. Wu, 2010. Plant sensing and signaling in response to K^+ deficiency. Mol. Plant, 3: 280-287.
46. Shehata, S.A., M.M. El-Mogy and H.F. Mohamed, 2019. Postharvest quality and nutrient contents of long sweet pepper enhanced by supplementary potassium foliar application. . International Journal of Vegetable Science, 25(2): 196-209.
47. Ahmad, S.K., B. Ahmad, J.J. Muhammad, R. Ahmad and A.U. Malik, 2012. Foliar application of mixture of amino acids and seaweed (*Ascophylum nodosum*) extract improve growth and Physicochemical properties of grapes. International Journal of Agriculture & Biology. 14(3): 383-388.
48. Less, H. and G. Galili, 2008. Principal transcriptional programs regulating plant amino acid metabolism in response to abiotic stresses. Plant Physiol., 147: 316-330.
49. Shehata, S.A., K. F. Abdelgawad and M.M. El-Mogy, 2017. Quality and shelf-life of Onion bulbs influenced by biostimulants. International Journal of Vegetable Science, 23(4): 362-371.