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

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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 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 [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 m² (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

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>2016</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay (%)</td>
<td>3.00</td>
<td>3.50</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Sandy (%)</td>
<td>97.00</td>
<td>95.50</td>
</tr>
<tr>
<td>Textural class</td>
<td>Sandy</td>
<td>Sandy</td>
</tr>
<tr>
<td>Chemical properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble cations in (1:1) soil to water extract mmol/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca$^{2+}$</td>
<td>3.06</td>
<td>3.10</td>
</tr>
<tr>
<td>Mg$^{2+}$</td>
<td>1.02</td>
<td>1.05</td>
</tr>
<tr>
<td>K$^+$</td>
<td>0.83</td>
<td>0.85</td>
</tr>
<tr>
<td>Na$^+$</td>
<td>0.76</td>
<td>0.80</td>
</tr>
<tr>
<td>Soluble anions in (1:1) soil to water extract (mmol/L)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO$^3_2$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>HCO$^3_2$</td>
<td>7.10</td>
<td>7.06</td>
</tr>
<tr>
<td>Cl$^-$</td>
<td>3.60</td>
<td>3.57</td>
</tr>
<tr>
<td>SO$^4_2$</td>
<td>0.40</td>
<td>0.44</td>
</tr>
<tr>
<td>pH (1:1 soil suspension)</td>
<td>7.64</td>
<td>7.70</td>
</tr>
<tr>
<td>EC (dS/cm) at 25°C</td>
<td>0.33</td>
<td>0.32</td>
</tr>
<tr>
<td>Available N (mg/kg soil)</td>
<td>128.31</td>
<td>130.00</td>
</tr>
<tr>
<td>Available P (mg/kg soil)</td>
<td>8.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Available K (mg/kg soil)</td>
<td>177.00</td>
<td>180.00</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Month</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>Annual rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum degree °C (°F)</td>
<td>44.0 (111.2)</td>
<td>45.3 (113.5)</td>
<td>48.4 (119.1)</td>
<td>49.5 (121.1)</td>
<td>49.5 (121.1)</td>
</tr>
<tr>
<td>Mean temperature Major °C (°F)</td>
<td>29.5 (85.1)</td>
<td>34.9 (94.8)</td>
<td>38.9 (102)</td>
<td>41.4 (106.5)</td>
<td>33.6 (92.5)</td>
</tr>
<tr>
<td>Daily average °C (°F)</td>
<td>21.8 (71.2)</td>
<td>27 (81)</td>
<td>31.4 (88.5)</td>
<td>33.5 (92.3)</td>
<td>25.9 (78.6)</td>
</tr>
<tr>
<td>Mean minimum Temperature °C (°F)</td>
<td>13.8 (56.8)</td>
<td>18.9 (66)</td>
<td>23 (73)</td>
<td>25.2 (77.4)</td>
<td>18.5 (65.3)</td>
</tr>
<tr>
<td>Lowest temperature °C (°F)</td>
<td>4.6 (40.3)</td>
<td>7.5 (45.5)</td>
<td>13.6 (56.5)</td>
<td>16.4 (61.5)</td>
<td>-2 (28)</td>
</tr>
<tr>
<td>Precipitation (mm)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0.1 (0.004)</td>
<td>0 (0)</td>
<td>1.4 (0.055)</td>
</tr>
<tr>
<td>Mean rainy days (0.01 0.01 mm)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.85</td>
</tr>
<tr>
<td>Relative Humidity Indicator (%)</td>
<td>24</td>
<td>19</td>
<td>17</td>
<td>16</td>
<td>26.2</td>
</tr>
<tr>
<td>Hours of monthly sun brightness</td>
<td>321.6</td>
<td>316.1</td>
<td>346.8</td>
<td>363.2</td>
<td>3,862.8</td>
</tr>
</tbody>
</table>

Table 3: The chemical composition of the amino acids

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Value</th>
<th>Amino acid</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspartic acid</td>
<td>1.85</td>
<td>Lysine</td>
<td>0.48</td>
</tr>
<tr>
<td>Thiamine</td>
<td>1.4</td>
<td>Histidine</td>
<td>0.18</td>
</tr>
<tr>
<td>Serine</td>
<td>2.1</td>
<td>Arginine</td>
<td>1.8</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>2.33</td>
<td>Proline</td>
<td>1.92</td>
</tr>
<tr>
<td>Glycine</td>
<td>1.7</td>
<td>Phenylalanine</td>
<td>0.65</td>
</tr>
<tr>
<td>Alanine</td>
<td>1.03</td>
<td>Tyrosine</td>
<td>0.21</td>
</tr>
<tr>
<td>Valine</td>
<td>1.33</td>
<td>Total amino acid</td>
<td>17.13</td>
</tr>
<tr>
<td>Isolucine</td>
<td>0.59</td>
<td>Total N 7%</td>
<td></td>
</tr>
<tr>
<td>Lucine</td>
<td>0.67</td>
<td>K$_2$O 8 %</td>
<td></td>
</tr>
</tbody>
</table>

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 cm³, 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 \((p<0.05)\) 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 \((6\text{Mm})\) 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 photosynthesis. Potassium silicate contains K with 10% . K play important role in photosynthesis 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 photosynthesis 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

<table>
<thead>
<tr>
<th>Potassium silicate (Mm)</th>
<th>Amino acids (ppm)</th>
<th>Plant length (cm)</th>
<th>Leaf No.</th>
<th>Leaf leaves/plant</th>
<th>Leaf fresh weight (g)</th>
<th>Leaf area/ dry weight (g)</th>
<th>Leaf plant (cm²)</th>
<th>SPAD readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 mM</td>
<td>0</td>
<td>13.27k</td>
<td>12.61i</td>
<td>7.523h</td>
<td>45.00k</td>
<td>42.70j</td>
<td>4.383j</td>
<td>4.120j</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>16.50i</td>
<td>16.78j</td>
<td>8.480g</td>
<td>90.003</td>
<td>55.97i</td>
<td>5.450i</td>
<td>6.230g</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>19.48g</td>
<td>20.46i</td>
<td>8.613g</td>
<td>9.350</td>
<td>60.07h</td>
<td>6.213j</td>
<td>6.437g</td>
</tr>
<tr>
<td>2 mM</td>
<td>0</td>
<td>14.14j</td>
<td>15.55k</td>
<td>7.780j</td>
<td>7.850</td>
<td>53.17j</td>
<td>5.400k</td>
<td>5.227i</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>21.80f</td>
<td>21.11g</td>
<td>10.673e</td>
<td>9.723h</td>
<td>73.93g</td>
<td>7.179f</td>
<td>7.007f</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>24.54e</td>
<td>25.73e</td>
<td>11.340d</td>
<td>11.790d</td>
<td>83.23e</td>
<td>8.185e</td>
<td>8.103e</td>
</tr>
<tr>
<td>4 mM</td>
<td>0</td>
<td>17.27h</td>
<td>20.49h</td>
<td>9.807f</td>
<td>10.780g</td>
<td>75.17j</td>
<td>7.307h</td>
<td>6.010h</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>25.59d</td>
<td>26.73d</td>
<td>11.823d</td>
<td>11.310e</td>
<td>86.80d</td>
<td>8.708d</td>
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</tr>
<tr>
<td></td>
<td>1000</td>
<td>27.56c</td>
<td>28.74e</td>
<td>12.773c</td>
<td>12.240e</td>
<td>93.47c</td>
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<tr>
<td>6 mM</td>
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<td>7.323f</td>
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<tr>
<td></td>
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<td>38.54a</td>
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<td>16.370a</td>
<td>133.53a</td>
<td>12.920a</td>
<td>13.003a</td>
</tr>
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</table>

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

<table>
<thead>
<tr>
<th>Potassium silicate (Mm)</th>
<th>Plant length (cm)</th>
<th>Leaf No.</th>
<th>Leaf leaves/plant</th>
<th>Leaf fresh weight (g)</th>
<th>Leaf area/ dry weight (g)</th>
<th>Leaf plant (cm²)</th>
<th>SPAD readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 mM</td>
<td>13.27k</td>
<td>12.61i</td>
<td>7.523h</td>
<td>45.00k</td>
<td>42.70j</td>
<td>4.383j</td>
<td>4.120j</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>16.50i</td>
<td>16.78j</td>
<td>8.480g</td>
<td>90.003</td>
<td>55.97i</td>
<td>5.450i</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>19.48g</td>
<td>20.46i</td>
<td>8.613g</td>
<td>9.350</td>
<td>60.07h</td>
<td>6.213j</td>
</tr>
<tr>
<td>2 mM</td>
<td>14.14j</td>
<td>15.55k</td>
<td>7.780j</td>
<td>7.850</td>
<td>53.17j</td>
<td>5.400k</td>
<td>5.227i</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>21.80f</td>
<td>21.11g</td>
<td>10.673e</td>
<td>9.723h</td>
<td>73.93g</td>
<td>7.179f</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>24.54e</td>
<td>25.73e</td>
<td>11.340d</td>
<td>11.790d</td>
<td>83.23e</td>
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</tr>
<tr>
<td>4 mM</td>
<td>17.27h</td>
<td>20.49h</td>
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<td>7.307h</td>
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</tr>
<tr>
<td></td>
<td>500</td>
<td>25.59d</td>
<td>26.73d</td>
<td>11.823d</td>
<td>11.310e</td>
<td>86.80d</td>
<td>8.708d</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>27.56c</td>
<td>28.74e</td>
<td>12.773c</td>
<td>12.240e</td>
<td>93.47c</td>
<td>9.107c</td>
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<td>6 mM</td>
<td>21.34f</td>
<td>23.36f</td>
<td>10.450e</td>
<td>11.003f</td>
<td>79.25f</td>
<td>7.323f</td>
<td>5.823f</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>30.59b</td>
<td>29.54a</td>
<td>13.347b</td>
<td>14.710b</td>
<td>103.73b</td>
<td>10.107b</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>39.37a</td>
<td>38.54a</td>
<td>16.003a</td>
<td>16.370a</td>
<td>133.53a</td>
<td>12.920a</td>
</tr>
</tbody>
</table>

Means within a column followed by the same letter are not significantly different (p > 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.
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\textsubscript{4}SiO\textsubscript{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].
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

<table>
<thead>
<tr>
<th>Potassium silicate (Mm)</th>
<th>Amino acids (ppm)</th>
<th>No. days to flowering</th>
<th>No. male flowers/plant</th>
<th>No. female flowers/plant</th>
<th>Sex ratio</th>
<th>No. fruits/plant</th>
<th>Early yield (ton/feddan)</th>
<th>Total yield/plant (kg)</th>
<th>Total yield (ton/feddan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Mm</td>
<td>0</td>
<td>43.82a</td>
<td>35.74a</td>
<td>13.71g</td>
<td>2.643a</td>
<td>1.012l</td>
<td>0.446k</td>
<td>4.46k</td>
<td>4.46k</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>39.28b</td>
<td>33.02c</td>
<td>16.64k</td>
<td>1.991l</td>
<td>1.191k</td>
<td>0.746l</td>
<td>7.46l</td>
<td>7.46l</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>36.36ed</td>
<td>31.07d</td>
<td>21.37b</td>
<td>1.457d</td>
<td>1.505j</td>
<td>1.034h</td>
<td>10.34h</td>
<td>10.34h</td>
</tr>
<tr>
<td>2 Mm</td>
<td>0</td>
<td>38.27c</td>
<td>33.90b</td>
<td>11.57b</td>
<td>1.812c</td>
<td>1.796b</td>
<td>0.913k</td>
<td>1.012l</td>
<td>1.012l</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>36.74de</td>
<td>30.62c</td>
<td>12.87d</td>
<td>1.921b</td>
<td>1.126e</td>
<td>0.746j</td>
<td>10.34h</td>
<td>10.34h</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>36.31e</td>
<td>26.61f</td>
<td>20.57g</td>
<td>1.037f</td>
<td>1.812f</td>
<td>0.746j</td>
<td>10.34h</td>
<td>10.34h</td>
</tr>
<tr>
<td>4 Mm</td>
<td>0</td>
<td>38.59bc</td>
<td>27.65c</td>
<td>20.33d</td>
<td>1.356e</td>
<td>1.296j</td>
<td>0.746j</td>
<td>10.34h</td>
<td>10.34h</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>37.17d</td>
<td>25.06e</td>
<td>12.87d</td>
<td>1.921b</td>
<td>1.126e</td>
<td>0.746j</td>
<td>10.34h</td>
<td>10.34h</td>
</tr>
<tr>
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<td>1000</td>
<td>36.04e</td>
<td>21.78f</td>
<td>20.57g</td>
<td>1.037f</td>
<td>1.812f</td>
<td>0.746j</td>
<td>10.34h</td>
<td>10.34h</td>
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<tr>
<td>6 Mm</td>
<td>0</td>
<td>37.21d</td>
<td>23.97h</td>
<td>20.57g</td>
<td>1.356e</td>
<td>1.296j</td>
<td>0.746j</td>
<td>10.34h</td>
<td>10.34h</td>
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<tr>
<td></td>
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<td>20.78j</td>
<td>20.57g</td>
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<td>34.02g</td>
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<td>22.67l</td>
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<td>1.812f</td>
<td>0.746j</td>
<td>10.34h</td>
<td>10.34h</td>
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</table>

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

strong bonding 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

<table>
<thead>
<tr>
<th></th>
<th>Potassium silicate (Mm)</th>
<th>Amino acids (ppm)</th>
<th>Fruit length (cm)</th>
<th>Fruit diameter (cm)</th>
<th>Fruit shape index</th>
<th>Average fruit weight (g)</th>
<th>Fruit TSS (%)</th>
<th>vitamin C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 11.79f 10.84e 3.757abc 3.317bcd 3.138e 3.335fg 100.0g 99.0g 2.155h 1.964j 2.329g 2.09h</td>
<td>500 12.57ef 12.23d 3.947ab 3.473abcd 3.184e 3.555fg 100.2g 102.4g 2.393g 2.168i 3.133f 2.830f</td>
<td>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</td>
<td></td>
<td></td>
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</table>

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 plus 1000 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


