Effect of Humic Acid and Silicon on some Growth Characteristics of Maize (Zea mays L.)

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Abstract: A field experiment was conducted during the autumn season of 2018 at agricultural research station in Al- Qurna district (80 km north of Basra center). The aim was to study the effect of spraying different concentrations of humic acid (HA) and silicon on the some growth characteristics of maize (Zea mays L.). The experiment was conducted using Three Concentration of humic acid were used 0, 2 and 4 gm L⁻¹, which took the following symbols H₀, H₁, and H₂ respectively and four concentrations of silicon 0, 1, 2 and 3 mML⁻¹ which took the symbols S₀, S₁, S₂ and S₃ respectively. A factorial experiment was used in randomized completely block design with four replicates. Maize seeds cv. Fajir1 were planted at 20/7/2018 in a silty loam soil. The results showed that the concentrations of HA differed significantly in all most of the studied characteristics, plant height, leaf area and ear length with an increase by 11.69, 24.89 and 3.49% respectively as compared to the control treatment (H₀). The spraying with silicon showed a significant effect. Moreover, the concentration of S₃ gave the highest values for plant height, stem diameter, leaf area and ear length. The interaction between HA and silicon showed a significant effect on some of the studied characteristics, the combination of S₃×H₂ produced the highest values of plant high (174.42 cm) and leaf area (7390.65 cm²).

Keywords: Maize, Humic acid, Silicon, Growth characteristics.

Introduction

Maize (Zea mays L.) is one of the most important Cereal crops on the world for its numerous utilizations: in human or animal food as green fodder or silage. The use of grains in the food industry has led to high demand for them, giving impetus to search for ways to increase production. An expansion in yields can be get by animating common physiological procedures influencing plant attributes, One of these important and effective processes is the using of fertilizers or plant growth promoters as foliar spraying, especially when there are factors prevent or limit availability or absorption of nutrients through the roots, such presence of CaCO₃, high alkalinity, water stress or drought; These problems reduce the process of construction and lead to retard development of seedling and maturity (Eyheraguibel et al., 2008; Ertani et al., 2011; Rong, 2012). Humic acid (HA) is produced from various sources such as soil, humus, plant residues and oxidation of coal and positively affects the growth of plants and increases the growth of stems, roots and absorption of many nutrients and is not dangerous to plant and external...
environment (Haghighi et al., 2011). HA is a catalyst for plant growth through changes in root structure and growth dynamics, increasing the size and density of roots, so lead to increase the absorption surface (Canellas & Olivares, 2014).

The treatment of maize seeds with HA increases the production of dry matter, growth and rate of seedling (Rodrigues et al., 2017). Ragheb (2016) reported that there was a significant effect of spraying of HA in growth properties of maize plants; the concentration 2.5 ml l\(^{-1}\) gave the most elevated an incentive for plant height, stem diameter and ear length. Bilal et al. (2016) study the effect of four concentrations of HA on maize productivity, Their results showed a significant differences in leaf area, ear length, and biological yield.

Improving food production in areas prone to salinity and drought is essential to meeting growing food needs in the future. Studies have shown that silicon decreases stresses from drought and salinity in plants. It increases plant growth and grain yield and quality by reducing sodium uptake while increasing potassium absorption and transport within plant. In addition silicon increases plant resistance to lodging, enhancing photosynthesis, increases plant tolerance to strong sunlight or shading, decreases oxidative damage in stressful plants and decreases sodium and cadmium in bud and roots of stressful plants (Liang et al., 2015; Rizwan et al., 2015; Cooke & Leishman, 2016). It was found that foliar application of silicon at average of 4 mM. L\(^{-1}\) to maize plants cultivated in plastic pods gave a significant excess in the growth and physiological characteristics (Rohanipoor et al., 2013). In another study, it was observed that, the foliar application of 5 ml L\(^{-1}\) of potassium silicate on maize significantly affected; plant height, leaf area, stem diameter, and number of leaves in plant (Shedeed, 2018). Regarding to the lacks of studies of using spray fertilization of HA and silicon on maize in south of Iraq. Moreover, the soil in south of Iraq suffering from high salt, high CaCO3 and alkalinity. This study was conducted to revealed the influence of foliar application of humic acid and silicon and their interaction in some vegetative parameters of maize.

**Materials & Methods**

A field experiment was conducted during autumn season of 2018 at Agricultural Research Station located in the district of Qurna (80 km north of Basra center). A factorial experiment was applied according to the randomized complete block design with four replicates. The first factor included spraying with three concentrations of HA: (0, 2 and 4 gm L\(^{-1}\)) which were symbolized as H\(_0\), H\(_1\), and H\(_2\) respectively. Humic acid was used in the form of humiplant fertilizer (80% HA). The second factor was four concentrations of silicon 0, 1, 2 and 3 mM L\(^{-1}\), which were symbolized as S\(_0\), S\(_1\), S\(_2\) and S\(_3\) respectively, The silicon used in form of Armurox fertilizer (8% SiO\(_2\)). Spraying of humic acid and silicon were sprayed at three timing (25, 50 and 75 days after planting) Tween 20 was used to decrease the surface tension of the spray solution. Random samples were taken from field soil before planting, dried and passed through a sieve of 2 mm and tested for physical and chemical properties (Table 1). Soil was prepared by laying two orthogonal tillage, softening, and settling them, and then divided into four blocks, each block has 12 experimental units. The experimental unit area was 11.2 m\(^2\) and each unit include four rows of 4 m length, the
distance between each rows was 70 cm. Within the row, seeds were swing in distance of 25 cm. Nitrogen fertilizer applied at the average of 320 kg N h⁻¹, phosphate fertilizers at the average of 60 kg P h⁻¹ and the Potassium fertilizer at the average of 90 kg k h⁻¹. *Z. mays* seeds (cv. Fajir 1) were sowing at 20/7/2018; three seeds were placed in each hill. Then, the Plants defoliation two weeks after germination and one plant was left in each hill. Surface Irrigation was applied. Service processes were conducted out by continuously removing the weeds from the field. The concentrations of studied fertilizers were sprayed in the early morning using a hand spray and the control treatment was spray with distilled water only. The following characteristics have been studied: number of days to 50% tasselling, number of days to 50% silking, plant height (cm), stem diameter (mm), leaf area (cm²) and ear length (cm). Data was analyzed by using SPSS program ver.23 and the least significant difference (L.S.D) was used to compare the treatments means at P < 0.05.

### Table (1): Some Chemical and Physical Properties of Soil.

| properties        | unit  | value | Properties       | Unit    | Value |
|-------------------|-------|-------|------------------|---------|-------|
| pH                | \     | 7.66  | Ca⁺⁺             | 13.0    |
| E.C.e             | ds m⁻¹| 7.20  | Mg⁺⁺             | 16.5    |
| Organic matter    | g kg⁻¹| 11.8  | Na⁺              | 45.6    |
| Sand              | g kg⁻¹| 60    | K⁺               | 1.99    |
| Silt              | g kg⁻¹| 688   | Cl⁻              | 65.5    |
| Clay              |       | 252   | SO₄²⁻            | 12.0    |
| Soil texture      |       | Silty loam | HCO₃⁻ | 1.80    |
| Available (mg kg⁻¹) |  | NO₃⁻ | 22.0             |         |
|                   |       | NH₄⁺ | 14.0             |         |
|                   |       | P    | 11.5             |         |

### Results & Discussion

#### Number of days to 50% tasselling

The outcomes of table (2) showed that spraying of humic acid had a significant effect on this character. The increasing of humic acid concentration, lead to reduced days number to reach 50% tasselling. Spraying the plants by H₂ level lead the plants to reached to 50% tasselling by the lowest days number 61.31 days, with a decrease reached to 4.58% compared to the control treatment which recorded the longest period to reach 50% tasselling 64.25 days. This is could be due to the chemical structure of humic acid and its mineral content, nitrogen and some another nutrients which
lead to increase; photosynthesis rate, accumulation of dry matter and crop growth that is reflect in early flowering. These results are concurrence with El-Mekser et al. (2014) and Khan et al. (2015).

The results of table (2) indicated that spraying of silicon significantly affected the period from planting to 50% tasselling. Plants that were sprayed with S3 level required lowest period from planting to 50% 61.83 days with a decrease of 2.87% compared to S0, which required 63.66 days. The reason due to the role of the silicon in increasing efficiency of photosynthesis and increase activity of antioxidant enzymes, modify balance of plant hormones, and increase content of proteins and sugars in leaves. While, data in table (2) revealed that, the interaction between concentrations of HA and silicon did not affect significantly on this character.

Table (2): Effect of concentrations of humic acid and silicon in number of days to 50% tasselling.

| HA | Si | S0  | S1  | S2  | S3  | Average of Humic acid |
|----|----|-----|-----|-----|-----|-----------------------|
| H0 | S0 | 65.00 | 64.25 | 63.75 | 64.00 | 64.25 |
| H1 | S1 | 63.75 | 62.00 | 62.25 | 61.50 | 62.37 |
| H2 | S2 | 62.25 | 61.75 | 61.25 | 60.00 | 61.31 |
| H3 | S3 | 61.83 | 62.41 | 61.83 | 61.83 | 61.83 |
| Average of Silicon | 63.66 | 62.66 | 62.41 | 61.83 | 61.83 | 61.83 |

| L.S.D | Humic acid | Silicon | Interaction |
|-------|------------|---------|-------------|
| ≤ 0.05 (P) | 0.61 | 0.71 | N.S. |

Number of days to 50% silking

The results of table (3) demonstrated a reduction in days from planting to 50% silking with increase concentration of HA. Plants treated with H2 concentration required 64.31 days to reach this stage compared to the control treatment (H0) which required 67.12 days, and that means a decrease by 4.19%. Treat plants with HA lead to increase the amount of nutrients in plant, thus affecting the biological processes within the plant, including increased photosynthesis, accumulation of dry matter and increase the chlorophyll content, thus affecting the period required to reach this stage.

These results are concurrence with results of El-Mekser et al. (2014) and Khan et al. (2015). The results of table (3) exhibited that spraying the plants by S3 and S2 silicon levels led to reduce days number from planting to 50% silking, reached to 64.58 and 65.15 days respectively with a decrease of 3.37 and 2.51% compared to S0, which gave the longest period of days number to 50% silking (66.83). The results of table (3) revealed that the interaction between humic acid and silicon did not have a significant effect in this trait.

Table (3): Effect of concentrations of humic acid and silicon in number of days to 50% silking.
Table (4): Effect of concentrations of humic acid and silicon and their interaction in plant height (cm).

| HA | Si | S0   | S1   | S2   | S3   | Average of Humic acid |
|----|----|------|------|------|------|-----------------------|
| H0 | S0 | 144.67 | 147.22 | 152.10 | 152.60 | 149.15                |
|    | H1 | 151.32 | 160.57 | 164.85 | 165.15 | 160.47                |
|    | H2 | 157.22 | 165.37 | 169.30 | 174.42 | 166.58                |
| Average of Silicon | S0 | 151.07 | 157.72 | 162.08 | 164.05 | 164.05                |

| L.S.D ≤ 0.05) (P | Humic acid | Silicon | Interaction |
|-----------------|------------|---------|-------------|
|                 | 1.60       | 1.85    | 3.21        |

These results are consistent with his findings by some studies (Rohanipoor et al., 2013; Salim, 2014; Shedeed, 2018).

Plant height (cm)

The results of table (4) indicated that plant height was significantly affected by treated plants with HA, the H2 level which gave the highest plant high 166.58 cm, with an increase of 11.69% as compared to control treatment (H0), which gave the lowest value (149.15 cm). The reason is that HA increases the permeability of cellular membranes, accelerates cellular division, and develops the root system (Khaled & Fawy, 2011). These results are agreement with the results of Ragheb (2016). The results of table (4) demonstrated that spraying of plants by silicon had a significant effect on plant height. The S3 treatment gave the highest value of plant height reached to 164.05 cm with an increase of 8.59% compared to the control treatment, which gave the lowest value of this character (151.07 cm). This increase in plant height is attributed to the role of Silicon in increasing the absorption of water and nutrients such as P and K, increasing rate of chlorophyll biosynthesis and efficiency of photosynthesis, as well as reducing oxidative harm in stressful plants (Xie et al., 2014; Cooke & Leishman, 2016).
Interaction between spraying of HA and silicon had a significant effect in plant height. The highest plant height was 174.42 cm have been obtain by the combination of S_3 × H_2 with an increase 20.56% compared to the combination (S_0 × H_0) which gave 144.67 cm (Table 4).

**Stem diameter (mm)**

The results in table (5) displayed an increase in stem diameter with increase HA concentration. The H_2 level gave the highest plant diameter 27.11 mm with an increase by 5.65% and 4.15% compared to H_0 and H_1 respectively. The spraying of plants with HA provided important nutrients for plant growth by increasing the absorption of monocular ions such as Nitrogen and potassium by accelerating the active absorption of plant roots, which increases the efficiency of photosynthesis, cell division and development. Increase the number of vascular bundles and their size and thus increase stem diameter (Shahryari et al., 2011). Our results are in agreement with findings of Eldardiry et al. (2012). The results of table (5) showed that foliar application of 3 mM silicon l^1 (S_3) significantly affected and exceeded the stem diameter. Silicon S_3 was significantly exceeded the stem diameter, giving the highest mean of this character of 26.88 mm, with an increase of 3.90% compared to S_0, which gave the lowest value (25.87mm). This increase in stem diameter can be attribute to role of silicon accumulating in cell walls, which is intertwine with cellulose and pectin, thus enhancing tissue mechanics. The spraying of silicon results in its deposition in cell membrane where silica becomes gel, resulting in hardening of the wall and increasing its thickness (Gao et al., 2006; Sahebi et al., 2015). These results are similar with that in Shedeed (2018). There is no interaction between humic concentration and silicon.

**Table (5) Effect of concentrations of humic acid and silicon in Stem diameter (mm)**

| HA | Si   | S_0     | S_1     | S_2     | S_3     | Average of Humic acid |
|----|------|---------|---------|---------|---------|-----------------------|
| H_0| S_0  | 25.24   | 25.19   | 25.77   | 26.45   | 25.66                 |
| H_1| S_1  | 25.66   | 25.73   | 26.16   | 26.58   | 26.03                 |
| H_2| S_2  | 26.73   | 26.70   | 27.39   | 27.61   | 27.11                 |
| Average of Silicon | S_3  | 25.87   | 25.88   | 26.44   | 26.88   |

| L.S.D (P ≤ 0.05) | Humic acid | Silicon | Interaction |
|------------------|------------|---------|-------------|
|                  | 0.24       | 0.27    | N.S.        |

**Leaf area (cm^2)**

The results in table (6) indicated that leaf area increased progressively irrespective of the treatment over control for both factors. Regarding to HA, the highest value was recorded by H_2 level (7022.83 cm^2), with an increase 24.89 % compared to H_0 which gave 5623.25 cm^2. this may be due to the positive role of this added acid and then increase the amount of macro and micro-nutrients availability for absorption, which led to the
development of vegetative growth and increase photosynthesis and then increase the leaf area of the plant (Pettit, 2004; Vaccaro et al., 2015). Corresponding to silicon, the same table showed that S3 gave the highest value for leaf area reached to 6779.05 cm²; differ significantly from the other levels, with an increase by 16.41% compared to control (S0) which recorded 5823.62 cm². This may be due to the positive effect of silicon when sprayed on plant vegetation by increasing the efficiency of enzymatic activity. The accumulated silicon in cuticle cells also affects the angle of leaf’s inclination to make it more efficient, that receive more sunlight and more it increases reception of light. Moreover, silicon increases chlorophyll a, chlorophyll b and total chlorophyll, thereby enhancing photosynthesis, inhibiting transpiration and increasing water use efficiency (Barbosa et al., 2015; Liang et al., 2015). These outcomes are agreement with Rohanipoor et al. (2013) and Shedeed (2018). With respect to results in table (6), it is clearly indicated a significant effect due to interaction between the two factors. The highest value was obtained by using 4 gm. l⁻¹ from humic acid with 3 mM silicon (H₂S₃), which recorded 7390.65 cm² and an increase of 40.19% compared to combination (H₀×S₀), which recorded the lowest value (5271.98 cm²).

### Table (6) Effect of concentrations of humic acid and silicon in leaf area (cm²).

| HA  | Si | S₀   | S₁   | S₂   | S₃   | Average of Humic acid |
|-----|----|------|------|------|------|-----------------------|
| H₀  |    | 5271.98 | 5635.05 | 5827.77 | 5758.22 | 5623.25 |
| H₁  |    | 5718.82 | 6626.63 | 6972.21 | 7188.28 | 6626.48 |
| H₂  |    | 6480.07 | 7091.72 | 7128.90 | 7390.65 | 7022.83 |
| Average of Silicon | 5823.62 | 6451.13 | 6642.96 | 6779.05 |

**L.S.D (P ≤ 0.05)**

| Humic acid | Silicon | Interaction |
|------------|---------|-------------|
| 75.38      | 87.05   | 150.77      |

**Ear length (cm)**

The results of table (7) presented that spraying of humic acid has a significant effect on ear length. H₂ and H₁ levels gave the highest value reached to 17.48 and 17.45 cm with an increase by 3.49% and 3.32% respectively as compared with the treatment without spray, which gave the lowest value (16.89 cm). This is due to the important role of humic acid in increasing plant height and leaf area (Tables 4 & 6), which reflected positively on photosynthesis proses and then on increasing ear length. These results are in agreement with Ragheb (2016). The results of table (7) also showed that silicon spray has a significant effect. The S₃ and S₂ levels gave the highest values of ear length (17.64 and 17.61 cm) with an increase of 6.01% and 5.83% as compared with treatment without spray, which gave the lowest value of 16.64 cm. This may be due to the role of silicon in
Table (7) Effect of concentrations of humic acid and silicon in Ear length (cm).

| HA | Si | S₀ | S₁ | S₂ | S₃ | Average of Humic acid |
|----|----|----|----|----|----|-----------------------|
| H₀ |    | 15.72 | 17.03 | 17.41 | 14.40 | 16.89 |
| H₁ |    | 16.96 | 17.38 | 17.46 | 18.00 | 17.45 |
| H₂ |    | 17.23 | 17.18 | 17.96 | 17.53 | 17.48 |
| **Average of Silicon** |    | 16.64 | 17.20 | 17.61 | 17.64 | |

| L.S.D (≤ 0.05) (P) | Humic acid | Silicon | Interaction |
|--------------------|------------|---------|-------------|
|                    | 0.12 | 0.14 | 0.24 | 

increasing of water use efficiency, maintaining the balance of nutrients within plant and it is increasing the production of dry matter (Janislampi, 2012). For the effect of interaction, the (H₁ × S₃) and (S₂ × H₂) combination recorded the highest values of ear length (18.00 and 17.96 cm) with an increase by 25% and 24.72% compared to combination (S₃ × H₀) which gave the lowest value of 14.40 cm.

**Conclusion**

Based on the obtained results, it could be concluded that under the condition of this work when foliar application Humic Acid and silicon play an important role in plant growth. Spraying by Humic Acid and silicon gave the best results of plant height, stem diameter, and ear length. Humic acid sprayed at rate 4 gm L⁻¹ with silicon at level of 3Mml⁻¹ were extremely effective in increasing plant height, leaf area and ear length.

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