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# Response of Growth, Yield and Essential Oil of Geranium Plants to Surface Irrigation and Humic Acid Treatments

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author KAH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SSSA and TN managed the analyses of the study. Author TN managed the literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

Water is among the most important factors affected growth, yield and quality of medicinal and aromatic plants since its deficiency may cause serious growth harms and yield losses. Egypt suffers from a scarcity of water, so each drop should be preserved. Therefore, the objective of the present study was to determine the suitable irrigation treatment (120, 100 and 80% ETo (evapotranspiration) and humic acid amounts (control), 1.0, 1.5 and 2.0 cm/L) that attain the highest growth, yield and essential oil of geranium (*Pelargonium graveolens* L. Herit Aiton) under surface irrigation in clay soil at El Kanater El Khairiya. Results showed that humic acid alleviated the deteriorative effect of water deficiency, where plants irrigated with 120% ETo and treated with 2.0 cm/L humic acid improved the growth characters in terms of plant height, number of branches, fresh, dry weights and volatile oil yield. While, the highest volatile oil percentage and proline content were recorded at 80% ETo with humic acid at 2.0 cm/L treatment during the two growing seasons.

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Results also showed that the applied irrigation water under 120% ETo treatment was 7192 $m^3$/fed averaged over the two growing seasons attained the highest yield. The highest values of water use efficiency and water productivity were 14.1 and 10.0 averaged over the two growing seasons attained under 80% ETo and application of 2.0 cm/L humic acid. Thus, it can be concluded that the required irrigation water for geranium is under 120% ETo. However, under water deficiency, 80% ETo and 2.0 cm/L humic acid could be applied, which increase geranium yield by 24%, compared to the 120% ETo treatment averaged over the two growing seasons.

*Keywords: Geranium (Pelargonium graveolens L. Herit Aiton); surface irrigation; humic acid; water productivity; yield; essential oil and chemical composition.*

## 1. INTRODUCTION

Geranium (*Pelargonium graveolens* L. Herit Aiton) is an important essential oil plant belongs to the *Geraneacea* family. It is used in chemical, pharmaceutical, food flavorings and industrial purposes. Large quantities of rose geranium oil are exported to international industries for flavor and fragrance, cosmetics and personal health care, aromatherapy as well as food manufacturers [1].The major natural components of its essential oil are citronellol, geraniol, linalool, citronellyl format and Menthone. Commercial geranium essential oils are characterized by a high concentration of citronellol and lower amounts of geraniol and linalool [2].

Humic acid is one of the major components of humic substances, which are dark brown and major constituents of soil organic matter humus that contributes to soil chemical and physical quality. Humic substances consist of heterogeneous mixtures of transformed biomolecules exhibiting a supramolecular structure that can be separated in their small molecular components by sequential chemical fractionation, which has a high effect on plants growth and quality [3]. It is demonstrated that humic acid usually enhance plant yields, seed germination, physic chemical characteristics and directly or indirectly stimulate absorption by roots [4]. Previous researches have shown positive effect of humic substances on fruits [5,6] vegetables [7], cereals [8] and *Lolium perenne* [9]. This was followed by reduction in the incidence of plant disease [10]. In addition to the notable changes on nutrient uptake and plant primary metabolism, secondary metabolism may also be strongly affected by humic substances [11]. Hendawy et al. [12] show that there were clear significantly positive trend in increasing growth characters by spraying of humic acid of *Mentha piperita* var. *citrata*. The highest values of plant height, herb fresh and dry weight, as well as oil yield were produced from spraying humic acid using 5.0 g/L at the two cuts. Farzad et al. [13] found that humic acid had positive effects on vegetative growth characters, essential oil content/plant and chemical composition gave the highest values of essential oil. Jamali et al. [14] showed that the effects of humic acid at 10 and 20 mg/kg of soil were significant on plant height, number of lateral branches and shoot dry weight of basil plants. Amir and Abbas [15] indicated that humic acid increased biological yield, chlorophyll a, chlorophyll b and total chlorophyll, essential oil percentage, essential oil yield, carotenoid, and free sugar of *Dracocephalum moldavica* L. plant. The highest positive effect was observed under springing with 400 mg/L humic acid.

Limited water and soil resources are exist in Egypt, in addition to high population rate. Irrigation water management has become very important task to be implemented in Egypt due to the prevailing conditions of water scarcity and to increase water the efficiency of the applied water in agriculture [16].However, shortage of the applied irrigation water to plants reduces cell volume, cell division, cell wall-making, overall size and of fresh consequently reduced growth and development of cells, especially in stems and leaves (Hsiao, 1973). Nevertheless, based on the experiment performed on marjoram (*Origanumm ajorana*) plant, it was reported that water shortage increases the amount essential oil [17]. Accordingly, AbdEl-Kafee et al. [18] stated that irrigation application to geranium (*Pelargonium graveolens* L.Herit Aiton) three times/week gave the highest values of all vegetative growth parameters, essential oil contents followed by application of two irrigations per week. However, there was no research in Egypt to determine the amount of required irrigation water to geranium under the weather conditions of Egypt.

Irrigation and plant nutrition management is one of the major issues in the production of aromatic crops. In this context, Said-Al Ahl et al. [19]

mentioned that, potassium-humate and/or irrigation intervals affected plant fresh weight, essential oil production and oil yield/plant of oregano in both cuts of both seasons. Putievsky et al. [20] stated that the green yield and essential oil yield decrease as the irrigation intervals increase for geranium *(Pelargonium graveolens* L.Herit Aiton) plants. Sami et al. [21] indicated that plant growth of geranium i.e. plant height, number of branches and shoot fresh weight decreased with irrigating plants after depletion of more or less 50% of field capacity. Farzad et al. [13] showed that increasing irrigation intervals to oregano (*Origanum vulgare* L.) reduced values of all morphological traits except for proportion of stems. They also added that irrigation every week and every two weeks without using cattle manure produce the lowest essential oil content. Siavash and Mohamad [22] showed that limited irrigation had significant effects on seed yield. With application of humic acid, seed yield was increased and essential oil percentage. Farshad [23] showed that increasing irrigation intervals significantly increased total phenol, antioxidant activity, proline and soluble sugars. Irrigation interval at highest level (once every nine days) compared to control increased proline, phenolic compounds, antioxidant activity, soluble sugars, essential oil and thymol. However, there was no research done in Egypt on the response of geranium (*Pelargonium graveolens*, L. Herit Aiton) yield and its attributes, as well as essential oil contents to irrigation amounts and spring with humic acid.

Thus, the aim of this work was to determine the suitable irrigation water and humic acid amounts that attain the highest growth, yield and essential oil of geranium under surface irrigation in clay soil of El Kanater El Khairiya.

## 2. MATERIALS AND METHODS

A field experiment was carried out at the Experimental Farm of Medicinal and Aromatic Plants Research Department in El Kanater El Khairiya, HRI, ARC in Egypt, during the two successive seasons of 2017/2018 and 2018/2019.The effect of irrigation treatments with foliar applications of humic acid on geranium growth, yield, essential oil and its active constituents were studied in split plot design with three replicates. The soil physical and chemical characteristics of the experimental field were determined according to [24] and are shown in Table 1.

Soil moisture constants in the experimental site are presented in Table 2 according to [25].

The monthly averages of meteorological data of the experimental site were calculated for three year from 2017 to 2019 and averaged over these three years and presented in Table 3.

The experiment included 12 treatments composed of three irrigation amounts and four foliar applications of humic acid as followed:

**Irrigation treatments (main plots):**

Irr1: Application of 120% ETo (control)
Irr2: Application of 100% ETo
Irr3: Application of 80% ETo

**Humic acid treatments (sub-plots):**

H1: Without application of humic acid (control)
H2: Foliar applications of 1.0 cm/L humic acid
H3: Foliar applications of 1.5 cm/L humic acid
H4: Foliar applications of 2.0 cm/L humic acid

Geranium was planted on 4$^{th}$of November in both seasons. Each plot included 3 rows with distance of 60 cm between rows and 25 cm between plants within the rows. The plot area was 1.80 X 2.5 $m^2$, included 27 plant/plot. Cattle manure (15 $m^3$/fed) and calcium super phosphate (15.5% $P_2O_5$) at 250 kg/fed were added during land preparation two weeks before planting. While ammonium sulphate (20.5% N) at 400 kg/fed, and potassium sulphate (48% $K_2O$) at 100 kg/fed were added in three equal doses. The first dose was applied 45 day after planting, the second dose applied after one month from the first dose and the third dose after the first cut.

Two applications of humic acid were done three times, 15 days between applications. These application times were at fifteen days after planting, one month after planting and one month after the second application. Geranium plants were harvested twice by cutting the vegetative parts, 10-15 cm above the soil surface. The first and second cuts were done on 20$^{th}$ May and 5$^{th}$ October at the first season, respectively in the second season, the first and second cuts were done on15$^{th}$ May and 10$^{th}$ October, respectively.

### 2.1 The Recorded Data were as Followed

- Vegetative growth parameters were recorded as plant height (cm), branches

number/plant, herb fresh and dry weights per plant (g).
- Essential oil percentage was determined in fresh plants of the two cuts according to the method described by British Pharmacopoeia [26]. In addition, essential oil samples of the 2nd cut during the 2nd season were subjected to gas liquid chromatography (GLC) according to the methods of Hoftman [27] and Bunzen et al. [28].
- Chemical analysis of proline content in dry leaves was determined according to Bates et al. [29]
- Chemical analysis of the essential oil:

The volatile oil analyzed using DsChrom 6200 Gas Chromatograph equipped with a flame ionization detector for separation of volatile oil constituents. The analysis conditions were as follow:

- The chromatograph apparatus was fitted with capillary column DB-WAX 122-7032 Polysillphenelene-siloxane 30 mx0.25 mm IDx0.25 µm film.
- Temperature program ramp increase with a rate of 13°C/m from 60°C to 220°C.
- Flow rates of gases were nitrogen at 1 ml/min., hydrogen at 30 ml/min and 330 ml/min for air.
- Detector and injector temperatures were 280°C and 250°C, respectively.

The obtained chromatogram and report at GC analysis for each sample were analyzed to calculate the percentage of main components of volatile oil.

## 2.2 Water Relations

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to 60 cm. Soil samples were collected just before each irrigation, 48 hours after irrigation and at harvest time.

### 2.2.1 Amount of applied irrigation water (AIW)

Submerged flow orifice with fixed dimension was used to measure the amount of water applied, according to [30] as follows:

$$Q = CA\sqrt{2gh}$$

Where:

Q = discharge through orifice, (1/sec).
C = coefficient of discharge, (0.61).
A = cross-sectional area of the orifice, $cm^2$.
G = acceleration due to gravity, (981 $cm/sec.^2$).
H = pressure head, causing discharge through the orifice, (cm).

### 2.2.2 Water consumptive use (WCU)

Water consumptive use or actual evapotranspiration values were calculated for each irrigation using the following formula [31].

$$WCU = \sum_{i=1}^{i=4} \frac{(\theta_2 - \theta_1)}{100} X\ Bd\ X\ D$$

Where:

WCU = seasonal water consumptive use (cm),
$\Theta_2$ = soil moisture content after irrigation (on mass basis,%),
$\Theta_1$ = soil moisture content before irrigation (on mass basis, %),
Bd = soil bulk density ($g/cm^3$),
D = depth of soil layer (15cm each), and
i = number of soil layer.

### 2.2.3 Water use efficiency (WUE)

It is used to describe the relationship between production and the amount of water used. It was determined according to the following equation [32]:

$$WUE = \frac{\text{Yield (kg/fed)}}{\text{Seasonal ETc (m}^3\text{ water consumed/fed)}}$$

### 2.2.4 Crop water productivity (WP)

WP is defined as crop yield per unit of applied irrigation water, which determines the efficient use of applied irrigation water [33] and is given as follows:

$$WP = \frac{\text{Yield (kg)/fed.}}{\text{Seasonal AIW (m}^3\text{ water applied/fed)}}$$

## 2.3 Statistical Analysis

Recorded data were subjected to statistical analysis and means separation was performed using the Least Signification Difference (L.S.D.) test at 5% level as described by [34].

**Table 1. Soil properties of the experimental farm of medicinal and aromatic plants research department, El-Kanater El-Khairiya**

| Soil properties | 2017/2018 | 2018/2019 |
|---|---|---|
| | **Physical properties** | |
| Clay % | 49.30 | 51.52 |
| Silt % | 21.03 | 22.82 |
| Sand % | 23.32 | 23.37 |
| Texture | Clay | Clay |
| | **Chemical properties** | |
| E.C. (mmhos/cm) | 0.55 | 0.71 |
| pH | 7.2 | 7.5 |
| Organic matter (%) | 1.34 | 1.51 |
| Available N (ppm) | 34.21 | 37.34 |
| Available P (ppm) | 27.51 | 27.81 |
| Available K(ppm) | 0.91 | 0.94 |

**Table 2. Soil-moisture parameters and bulk density of the soil at the experimental site**

| | Water parameters and bulk density | | | | | | |
|---|---|---|---|---|---|---|---|
| Depth | Field capacity (FC) | | Wilting point (WP) | | Available water (AW) | | Bulk density (BD) $Mg/m^3$ |
| | % weight | Cm | % weight | cm | % weight | cm | |
| 0-15 | 38.9 | 6.94 | 18.2 | 3.25 | 20.7 | 3.69 | 1.19 |
| 15-30 | 36.5 | 6.57 | 17.1 | 3.11 | 19.4 | 3.49 | 1.20 |
| 30-45 | 33.9 | 6.46 | 16.5 | 3.14 | 17.4 | 3.31 | 1.27 |
| 45-60 | 32.8 | 6.84 | 16.4 | 3.42 | 16.4 | 3.42 | 1.39 |
| Total | | 26.81 | | 12.92 | | 13.91 | |

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of Irrigation and Humic Acid on Growth, Yield and Essential Oil

#### 3.1.1 Effect of irrigation and humic acid on growth

*3.1.1.1 Plant height and number of branches/plant*

Results of growth parameters for the two cuts in both growing seasons of geranium plant are shown in Tables 4 and 5.The results indicated that, irrigation with (120%, 100% and 80%) of ETo, significantly affected plant height and number of branches/plant for the two cuts in both growing seasons. The superiority mean values of plant height (91.97and 85.46) cm and (91.06 and 87.42) cm were recorded under 120% of ETo in the first and second growing seasons, respectively and (17.11 and 21.53) cm and (17.20 and 20.78) branches/plant for number of branches/plant in the two cuts in both growing seasons. These results are in close agreement with the findings [20].

Concerning the effect of humic acid treatments, data in Tables 4 and 5 showed that humic acid significantly increased vegetative growth plants of geranium plant. The highest values of plant height (98.72 and 93.80 cm) and (98.67 and 95.01 cm)were obtained in plants supplied with 2 cm/L, in the two cuts in the first and second growing seasons, respectively, while the highest values of number of branches/plant (18.07 and 22.52) and (18.66 and 22.22)branches/plant were obtained from the same treatment. Similar increases in plant height and number of branches/plant as a result of humic acid treatments have been reported by [12] on *Mentha piperita* var. *citrata*. These results may be explained depending on the positive effect of humic acid as an effective soil enhancer, a plant growth bio-stimulant, a chelating agent and a disease suppressant; in order to it has high in auxins, minerals, vitamins, etc. It can increases soil microbial and mycorrhizal activity, promote nutrient uptake, increase crop yields and aid in reducing frost damage [35].

Data presented in Tables 4 and 5 showed that the interaction between irrigation and humic acid levels had a significant effects on plant height and number of plants/plant in both cuts in both growing seasons. Combination of irrigation at 120% of ETo and humic acid at 2.0 cm/L resulted

**Table 3. Average of meteorological data from 2017 to 2019**

| Months | TMAX (°C) | TMIN (°C) | Td (°C) | WS (m/sec) | Pcp (mm) | SRAD ($MJ/m^2/day$) | ETo (mm/day) |
|---|---|---|---|---|---|---|---|
| Jan. | 18.6 | 6.6 | 4.3 | 2.6 | 0.4 | 12.0 | 2.6 |
| Feb. | 21.4 | 8.1 | 5.3 | 2.2 | 0.2 | 13.3 | 3.0 |
| March | 25.8 | 10.4 | 5.8 | 2.7 | 0.1 | 19.2 | 4.8 |
| April | 29.3 | 13.0 | 7.1 | 2.9 | 0.7 | 22.8 | 6.1 |
| May | 35.7 | 18.1 | 8.9 | 3.2 | 0.0 | 25.8 | 8.4 |
| June | 38.0 | 21.0 | 12.7 | 3.2 | 0.1 | 28.4 | 9.2 |
| July | 39.5 | 22.5 | 14.9 | 3.0 | 0.1 | 28.6 | 9.1 |
| August | 38.7 | 22.7 | 15.9 | 2.8 | 0.0 | 26.5 | 8.3 |
| Sep. | 36.2 | 20.5 | 15.2 | 2.8 | 0.0 | 21.5 | 7.0 |
| Oct. | 31.5 | 17.8 | 13.3 | 2.7 | 0.4 | 18.2 | 5.3 |
| Nov. | 25.9 | 13.6 | 10.3 | 2.1 | 0.8 | 11.2 | 3.3 |
| Dec. | 20.7 | 9.9 | 7.9 | 2.4 | 0.2 | 10.7 | 2.5 |

*Where: TMAX, TMINandTd: maximum, minimum and dew temperatures; WS: wind speed; Pcp: precipitation (mm); SRAD: solar radiation; ETo: evapotranspiration*

in the tallest plants and the highest number of branches/plant in both cuts during the two experimental seasons. Similar results were reported by Zaghloul et al. [36] where they indicated that spraying *Thuja orientalis* plants with humic acid increased growth, compared to control plants due to the direct effect of humic acid on solubilization and transport of nutrients. The above results are also in accordance with those obtained by Norman et al*.* [37] on marigolds.

### 3.1.2 Effect of irrigation and humic acid on plant fresh and dry weights

Results presented in Tables 6 and 7 revealed that, the abundant irrigation rate 120%of ETo gave the highest mean values of fresh and dry weight [(894.02and 1050.36) g/plant and (959.39and 1107.0)] g/plant and [(180.08 and 215.56) g/plant and (193.52 and 213.590] g/plant in the two cuts in both growing seasons, respectively followed by those irrigated with 100% of ETo. Whereas, the lowest values were obtained from irrigation with 80% of ETo. These findings are in agreement with the results of Farzad et al. [13] on oregano (Origanum vulgare L.).

It is cleared that in both cuts at the first season, the highest mean values of fresh weight being of (980.48 and1098.01 g/plant) while dry weight gave (183.37 and 212.37 g/ plant ) were obtained under the treatment of humic acid at (2.0 cm/L), while the second season had the same trend (Tables 6 and 7).

Regard to the interaction between the irrigation and humic acid treatments, it is noticed that irrigation at 120% of ETo combined with 2.0 cm/L of humic acid produced the highest fresh and dry plant weight in both and seasons. While the irrigation rate of 80% of ET o combined with control gave the lowest values in both seasons. However, the results indicated that, promoting effect of humic acid treatment at 2.0 cm/L was recorded in the growth of geranium plants grown under 80% ETo, compared to those plants in the control irrigated with 100 or 120% ETo. This result is similar to the obtained results by Said-Al Ahl et al. [18] for oregano plants. According to Osman and Rady [38], humic acid significantly increased leaf area, shoot dry weight and grain yield. The increase in leaf, stem and total dry matter can be attributed to the improvement of soil structure, increasing of soil water holding capacity and good ventilation and drainage, which helped in expanding root growth, enhances the absorption of nutrients and may provide tolerance to drought stress. Cacco et al. [39] provided evidence on the promoting effect of humic acids on the molecular expression of proteins in the nitrate transport system.

### 3.1.3 Effect of irrigation and humic acid on essential oil

#### *3.1.3.1 Oil percentage and oil yield per plant (ml)*

Results in Tables (8 and 9) revealed that irrigation treatments had a significant effect on oil percentage and oil yield per plant in both cuts of geranium plants in the two growing seasons. Increasing the irrigation amount increased oil percentage. While the highest values from oil yield per plant were obtained from 120% of ETo. The greatest mean values of oil percentage due to irrigation treatments (0.29 and 0.31)% and (0.29 and 0.32)% were recorded with plants received the lowest water amount, namely 80% of ETo in both cuts and both growing seasons, respectively. The highest values of oil yield per plant (2.37 and 3.01) ml/plant and (2.52 and 3.10) ml/plant were obtained from plants received 120% of ETo in the two cuts and both growing seasons, respectively.

Regarding the effect of different levels from humic acid treatments, data in Tables (8 and 9) showed that humic acid fertilization significantly increased oil % and oil yield/plant, and the highest values were obtained from plants supplied with 2.0 cm/L. The highest values of oil percentage(0.33 and 0.36)% and (0.34 and 0.37)% were obtained for plants sprayed with 2.0 cm/L humic acid comparing to other treatments and irrigated with in the two cuts and both growing seasons. Whereas, the highest values of oil yield per plant (3.19 and 4.14) ml/plant and (3.32 and 4.50) ml/plant. These results are in close agreement with the findings of Abd El-Kafee et al. [17] on geranium. Massoud et al. [40] showed that spraying plants with humic acid 1% was effective in raising the productivity of essential oil percentage and constituents.

With regard to the interaction, it was clear that irrigation with 80% of ETo combined with the highest concentration from humic acid (2.0 cm/L) resulted in the highest oil percentage in both cuts and both growing seasons. While the highest values of oil yield per plant were obtained from plants irrigated with 80% of ETo and received 2.0 cm/L humic acid.

## 3.2 Effect of Irrigation and Humic acid on Chemical Composition

### 3.2.1 Chemical composition of the essential oil

To study the effect of irrigation levels and humic acid fertilization on the main constituents of the essential oil of geranium plant, the oil of each treatment was separately subjected to gas liquid chromatography and the main compounds and their relative percentages are shown in (Table 10).Eleven constituents were identified by GC in the control, representing 90.01, 78.96 and 87.62% from the separated compounds. The main components were found: ∝-Pinene, P-cymene, Iso-menthone, Linalool, Citronyl Formate, Geeranyl Formate, Citronellol, Geraniol, Geranyl butrate, Eugenol and β-Caryophyllen. It was clear that, Citronellol was the most abundant compound in all analyzed oils, followed by Geraniol. The highest percentage of Citronellol (34.79%) was obtained from using 120% of ETo + untreated plants (control), while the highest values from geraniol (29.43%) was obtained from plants received 120% of ETo + 1.0 cm/L humic acid.

### 3.2.2 Proline content

Results in Table 11 showed that the highest contents of proline in geranium tissues were recorded in plants irrigated with 80% of ETo (3.27 and 3.22 mg/100 g proline) in the first and second growing seasons, respectively. Whereas, the lowest values (2.38 and 2.45 g/100 g proline) were obtained in plants irrigated with the highest rate (120% of ETo) in both growing seasons. An increase in proline concentration under water deficiency stress has been observed in many plant species and has led to the hypothesis that it is not just a symptom of stress but part of the stress response, decreasing cell osmotic potential and thereby increasing cells turgor, while decreasing plant water potential [41].The present findings are confirmed with Bahreininejada et al. [42], where they found that water stress increased proline content of *Thymus daenensis*in plants Also, increasing proline under drought stress has been reported by [43] in lima bean, where the increase in proline concentration under drought stress may indicate the potential role of this amino acid in osmotic regulation [44]. Munns [45] indicated that proline accumulates under water stress is found at high concentrations in plants adapted to dry soils.

With respect to the effect of humic acid fertilization treatments, the results in Table 11 showed that application of 2.0 cm/L was the most effective treatments in increasing the proline content, compared to all other treatments in both seasons.

Concerning the combination between irrigation rates and humic acid levels, significant responses were found under full irrigation and drought stress conditions, application of 2.0 cm/L humic acid, which produced the highest proline values, however the increase was higher under water deficiency stress (80% ETo), as compared to the 100 or 120% of ETo irrigation application. This imply that the use of humic acid could moderate and reduce the effect of drought stress. These results are in agreement with Abbas and Esmaeil [46] on grain yield.

**Table 4. Effect of irrigation and humic acid treatments and their interactions on height of geranium plant (cm)**

| Treatments | Plant height (cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | | | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| | First cut | | | | Second cut | | | |
| Control | 81.01 | 78.00 | 68.20 | 75.74 | 72.91 | 65.24 | 70.60 | 72.25 |
| Humic A.(1.0 cm/L) | 85.61 | 81.86 | 80.71 | 82.73 | 80.63 | 78.80 | 74.21 | 77.88 |
| Humic A.(1.5 cm/L) | 95.67 | 91.06 | 82.68 | 89.80 | 89.01 | 83.75 | 82.52 | 85.09 |
| Humic A.(2.0 cm/L) | 105.57 | 95.80 | 94.08 | 98.72 | 100.19 | 94.03 | 90.80 | 93.80 |
| Mean | 91.97 | 86.68 | 81.42 | | 85.46 | 80.46 | 79.53 | |
| LSD at 5 % | 5.44 | | | | 5.98 | | | |
| Humic(H) | 11.73 | | | | 13.95 | | | |
| Irr*H | 14.79 | | | | 16.34 | | | |
| **Treatments** | **Second growing season (2018/2019)** | | | | | | | |
| | **First cut** | | | | **Second cut** | | | |
| | **Irr1** | **Irr2** | **Irr3** | **Mean** | **Irr1** | **Irr2** | **Irr3** | **Mean** |
| Control | 93.00 | 81.00 | 75.00 | 83.00 | 72.00 | 61.67 | 62.67 | 65.45 |
| Humic A.(1.0 cm/L) | 96.33 | 95.33 | 91.00 | 94.22 | 85.00 | 79.67 | 69.33 | 78.00 |
| Humic A.(1.5 cm /L) | 99.00 | 96.00 | 92.67 | 95.89 | 91.00 | 81.67 | 74.33 | 82.33 |
| Humic A.(2.0 cm/L) | 102.23 | 98.67 | 95.00 | 98.67 | 101.67 | 86.67 | 84.00 | 95.01 |
| Mean | 91.06 | 92.75 | 88.42 | | 87.42 | 77.42 | 72.58 | |
| LSD at5 % | 4.00 | | | | 3.42 | | | |
| ggqHumic A (H) | 5.81 | | | | 5.72 | | | |
| Irr*H | 11.51 | | | | 7.24 | | | |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 5. Effect of irrigation and humic acid treatments and their interactions on number of branches of geranium plant**

| Treatments | Number of branches/ plant | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | | | | | |
| | First cut | | | | Second cut | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| Control | 13.67 | 12.60 | 11.30 | 12.52 | 18.17 | 14.97 | 13.83 | 15.66 |
| Humic A.(1.0 cm/L) | 15.97 | 12.93 | 12.63 | 13.84 | 20.53 | 15.83 | 15.03 | 17.13 |
| Humic A.(1.5 cm /L) | 18.83 | 15.50 | 14.67 | 16.33 | 22.33 | 19.50 | 17.33 | 19.72 |
| Humic A.(2.0 cm/L) | 19.97 | 17.93 | 16.30 | 18.07 | 25.10 | 21.67 | 20.80 | 22.52 |
| Mean | 17.11 | 14.74 | 13.73 | | 21.53 | 17.99 | 16.75 | |
| LSD at 5 % | | | | | | | | |
| Irrigation (I) | 0.51 | | | | 0.21 | | | |
| Humic (H) | 0.68 | | | | 0.40 | | | |
| I*H | 1.41 | | | | 0.70 | | | |
| **Treatments** | **Second growing season (2018/2019)** | | | | | | | |
| | **First cut** | | | | **Second cut** | | | |
| | **Irr1** | **Irr2** | **Irr3** | **Mean** | **Irr1** | **Irr2** | **Irr3** | **Mean** |
| Control | 15.43 | 13.27 | 12.17 | 13.62 | 16.50 | 17.50 | 14.50 | 15.50 |
| Humic A.(1.0 cm/L) | 16.00 | 13.67 | 12.93 | 14.20 | 19.63 | 17.20 | 16.17 | 17.67 |
| Humic A.(1.5 cm /L) | 18.00 | 17.80 | 14.50 | 16.77 | 20.50 | 18.50 | 18.87 | 19.29 |
| Humic A.(2.0 cm/L) | 19.37 | 18.93 | 17.67 | 18.66 | 26.47 | 20.70 | 19.50 | 22.22 |
| Mean | 17.20 | 15.92 | 14.32 | | 20.78 | 18.48 | 17.26 | |
| LSD at 5 % | | | | | | | | |
| Irrigation (I) | 0.41 | | | | 0.61 | | | |
| Humic (H) | 0.78 | | | | 1.12 | | | |
| I*H | 0.13 | | | | 1.55 | | | |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 6. Effect of irrigation and humic acid treatments and their interactions on fresh weight/plant (g) of geranium plant**

| Treatments | Fresh weight (g/plant) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First growing season 2017/2018 | | | | | | | |
| | First cut | | | | Second cut | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| Control | 680.09 | 679.12 | 650.02 | 675.74 | 800.20 | 750.13 | 714.28 | 754.87 |
| Humic A.(1.0 cm/L) | 880.05 | 680.26 | 650.72 | 737.01 | 1000.44 | 813.77 | 770.87 | 861.69 |
| Humic A.(1.5 cm /L) | 915.55 | 777.44 | 680.22 | 791.07 | 1105.54 | 905.01 | 785.40 | 931.98 |
| Humic A.(2.0 cm/L) | 1100.40 | 950.46 | 890.57 | 980.48 | 1295.25 | 1000.42 | 998.36 | 1098.01 |
| Mean | 894.02 | 771.82 | 717.88 | | 1050.36 | 876.33 | 817.23 | |
| LSD at 5 % | | | | | | | | |
| Irrigation(I) | 66.21 | | | | 75.41 | | | |
| Humic (H) | 148.8 | | | | 166.61 | | | |
| I*H | 198.07 | | | | 219.10 | | | |
| **Treatments** | **Second growing season 2018/2019** | | | | | | | |
| | First cut | | | | Second cut | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| Control | 712.67 | 690.67 | 642.02 | 681.79 | 785.33 | 730.33 | 725.00 | 746.89 |
| Humic A.(1.0 cm/L) | 939.67 | 743.33 | 701.33 | 794.78 | 1029.67 | 839.00 | 741.00 | 869.89 |
| Humic A.(1.5 cm /L) | 1039.67 | 841.33 | 796.24 | 892.41 | 1110.67 | 911.33 | 791.33 | 937.78 |
| Humic A.(2.0 cm/L) | 1145.55 | 922.33 | 935.67 | 1001.18 | 1500.67 | 1009.67 | 985.30 | 1165.21 |
| Mean | 959.39 | 799.42 | 768.82 | | 1107.0 | 872.58 | 810.66 | |
| LSD at 5 % | | | | | | | | |
| Irrigation (I) | 51.24 | | | | 82.67 | | | |
| Humic (H) | 135.07 | | | | 138.5 | | | |
| I*H | 177.25 | | | | 215.21 | | | |

*(Irr1:Irrigation 120%; Irr2:Irrigation 100%; Irr3:Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 7. Effect of irrigation and humic acid treatments and their interactions on dry weight/plant (g) of geranium plant**

| Treatments | Dry weight (g/plant) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | | | | | |
| | First cut | | | | Second cut | | | |
| | **Irr1** | **Irr2** | **Irr3** | **Mean** | **Irr1** | **Irr2** | **Irr3** | **Mean** |
| Control | 133.11 | 131.98 | 129.47 | 131.52 | 149.44 | 145.94 | 120.11 | 146.26 |
| Humic A. (1.0 cm/L) | 176.11 | 139.22 | 135.11 | 150.15 | 215.11 | 159.41 | 141.91 | 172.14 |
| Humic A.(1.5 cm /L) | 193.11 | 152.34 | 134.46 | 159.97 | 239.44 | 182.01 | 151.46 | 190.97 |
| Humic.A.(2.0 cm/L) | 219.11 | 169.71 | 161.28 | 183.37 | 258.24 | 199.49 | 179.37 | 212.37 |
| Mean | 180.36 | 148.31 | 140.08 | | 215.56 | 171.71 | 146.21 | |
| LSD at 5 % | | | | | | | | |
| Irrigation (I) | 11.25 | | | | 10.44 | | | |
| Humic A (H) | 22.11 | | | | 18.85 | | | |
| I*H | 29.06 | | | | 26.91 | | | |
| **Treatments** | **Second growing season (2018/2019)** | | | | | | | |
| | **First cut** | | | | **Second cut** | | | |
| | **Irr1** | **Irr2** | **Irr3** | **Mean** | **Irr1** | **Irr2** | **Irr3** | **Mean** |
| Control | 152.30 | 142.11 | 136.01 | 143.47 | 157.01 | 152.44 | 149.54 | 153.00 |
| Humic A. (1.0 cm/L) | 195.41 | 142.97 | 136.97 | 158.45 | 212.11 | 175.25 | 150.86 | 179.41 |
| Humic A.(1.5 cm /L) | 207.21 | 165.11 | 157.14 | 176.49 | 225.11 | 187.34 | 151.28 | 187.91 |
| Humic A.(2.0 cm/L) | 219.14 | 192.07 | 182.01 | 197.74 | 260.11 | 200.17 | 199.5 9 | 219.96 |
| Mean | 193.52 | 160.57 | 153.03 | | 213.59 | 178.80 | 162.82 | |
| LSD at 5 % | | | | | | | | |
| Irrigation ( I) | 11.00 | | | | 14.78 | | | |
| Humic (H) | 18.56 | | | | 32.52 | | | |
| I*H | 25.00 | | | | 41.97 | | | |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 8. Effect of irrigation and humic acid treatments and their interactions on essential oil percentage of geranium plant**

| Treatments | Essential oil (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | | | | | |
| | First cut | | | | Second cut | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| Control | 0.26 | 0.22 | 0.24 | 0.24 | 0.27 | 0.23 | 0.25 | 0.25 |
| Humic A.(1.0 cm/L) | 0.27 | 0.22 | 0.24 | 0.24 | 0.29 | 0.24 | 0.27 | 0.27 |
| Humic A.(1.5 cm /L) | 0.29 | 0.25 | 0.28 | 0.27 | 0.33 | 0.24 | 0.29 | 0.29 |
| Humic A.(2.0 cm/L) | 0.33 | 0.27 | 0.29 | 0.30 | 0.36 | 0.29 | 0.32 | 0.32 |
| Mean | 0.29 | 0.24 | 0.26 | | 0.31 | 0.25 | 0.28 | |
| LSD at 5 % | | | | | | | | |
| Irrigation (I) | 0.01 | | | | 0.02 | | | |
| Humic (H) | 0.02 | | | | 0.03 | | | |
| I*H | 0.03 | | | | 0.06 | | | |
| | Second growing season (2018/2019) | | | | | | | |
| | First cut | | | | Second cut | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| Control | 0.24 | 0.20 | 0.23 | 0.22 | 0.26 | 0.22 | 0.24 | 0.24 |
| Humic A.(1.0 cm/L) | 0.29 | 0.21 | 0.25 | 0.25 | 0.30 | 0.23 | 0.28 | 0.27 |
| Humic A.(1.5 cm /L) | 0.29 | 0.24 | 0.27 | 0.27 | 0.34 | 0.24 | 0.28 | 0.29 |
| Humic A.(2.0 cm/L) | 0.34 | 0.26 | 0.29 | 0.30 | 0.37 | 0.28 | 0.30 | 0.32 |
| Mean | 0.29 | 0.23 | 0.26 | | 0.32 | 0.24 | 0.28 | |
| LSD at 5 % | | | | | | | | |
| Irrigation (I) | 0.02 | | | | 0.03 | | | |
| Humic (H) | 0.04 | | | | 0.04 | | | |
| I*H | 0.05 | | | | 0.06 | | | |

*(Irr1: Irrigation 120%;Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 9. Effect of irrigation and humic acid treatments and their interactions on oil yield (ml/plant) of geranium plant**

| Treatments | Essential oil yield (ml/plant) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | | | | | |
| | First cut | | | | Second cut | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| Control | 1.63 | 1.49 | 1.69 | 1.60 | 1.98 | 1.84 | 1.93 | 1.92 |
| Humic A.(1.0 cm/L) | 2.11 | 1.50 | 1.76 | 1.77 | 2.70 | 1.95 | 2.24 | 2.33 |
| Humic A.(1.5 cm /L) | 2.56 | 1.94 | 1.97 | 2.14 | 3.21 | 2.17 | 2.59 | 2.70 |
| Humic A.(2.0 cm/L) | 3.19 | 2.57 | 2.94 | 2.90 | 4.14 | 2.90 | 3.59 | 3.54 |
| Mean | 2.37 | 1.85 | 2.09 | | 3.01 | 2.20 | 2.59 | |
| LSDat5% | | | | | | | | |
| Irrigation (I) %Irrigation (I) | 0.10 | | | | 0.15 | | | |
| Humic (H) | 0.14 | | | | 0.22 | | | |
| I*H | 0.21 | | | | 0.70 | | | |
| **Treatments** | **Essential oil yield of values second season 2018/2019** | | | | | | | |
| | **First cut** | | | | **Second cut** | | | |
| | **Irr1** | **Irr2** | **Irr3** | **Mean** | **Irr1** | **Irr2** | **Irr3** | **Mean** |
| Control | 1.59 | 1.43 | 1.54 | 1.52 | 1.91 | 1.73 | 1.89 | 1.84 |
| Humic A.(1.0 cm/L) | 2.35 | 1.56 | 2.03 | 1.99 | 2.88 | 1.93 | 2.22 | 2.35 |
| Humic A.(1.5 cm /L) | 2.81 | 2.02 | 2.31 | 2.41 | 3.11 | 2.19 | 2.69 | 2.72 |
| Humic A.(2.0 cm/L) | 3.32 | 2.40 | 3.18 | 2.97 | 4.50 | 2.83 | 3.65 | 3.66 |
| Mean | 2.52 | 1.85 | 2.27 | | 3.10 | 2.13 | 2.61 | |
| LSDat5% | | | | | | | | |
| Irrigation (I) %Irrigation (I) | 0.40 | | | | 0.23 | | | |
| Humic (H) | 0.74 | | | | 0.38 | | | |
| I*H | 1.59 | | | | 1.00 | | | |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 10. Effect of irrigation and humic acid treatments and their interactions on chemical composition of essential oil of geranium plant during two second growing seasons**

| NO. | Treatments | Compounds % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ∝-Pinene | P-cymene | Iso-menthone | Linalool | Citronyl Formate | Geerany lFormate | Citronel ol | Gerani ol | Geranyl butrate | Eugen ol | B-Caryophyllene | Total |
| 1 | Irr1 + control | 0.64 | 1.27 | 5.87 | 4.93 | 7.54 | 4.13 | 34.79 | 18.29 | 0.62 | 9.00 | 2.93 | 90.01 |
| 2 | Irr2 + control | 0.31 | 0.52 | 3.97 | 8.31 | 0.67 | 3.47 | 33.50 | 14.40 | 2.19 | 9.64 | 1.98 | 78.96 |
| 3 | Irr3 + control | 0.67 | 5.72 | 3.09 | 7.70 | 3.19 | 1.57 | 31.50 | 15.30 | 2.13 | 12.21 | 4.54 | 87.62 |
| 4 | Irr1+ Humic 1 cm/L | 1.40 | 4.72 | 5.61 | 7.52 | 4.28 | 3.44 | 32.62 | 29.43 | 1.03 | 6.34 | 1.99 | 93.26 |
| 5 | Irr2+Humic 1 cm/L | 0.41 | 1.01 | 4.31 | 7.34 | 0.86 | 3.06 | 27.50 | 12.20 | 2.52 | 13.25 | 3.95 | 81.53 |
| 6 | Irr3+Humic 1 cm/L | 0.32 | 1.30 | 4.27 | 4.21 | 7.75 | 5.50 | 22.78 | 21.44 | 1.87 | 12.73 | 4.14 | 86.31 |
| 7 | Irr1+Humic 1.5 cm/L | 0.55 | 0.37 | 5.76 | 0.10 | 6.28 | 0.06 | 33.75 | 25.47 | 2.64 | 11.38 | 2.61 | 73.09 |
| 8 | Irr2+Humic 1.5 cm/L | 0.31 | 1.00 | 4.63 | 3.42 | 8.31 | 3.53 | 25.74 | 14.17 | 2.65 | 10.97 | 2.02 | 84.76 |
| 9 | Irr3+Humic 1.5 cm/L | 0.49 | 1.36 | 6.58 | 6.22 | 10.34 | 8.41 | 17.87 | 23.24 | 1.60 | 1.50 | 5.99 | 91.47 |
| 10 | Irr1+Humic 2 cm/L | 0.33 | 6.00 | 8.35 | 0.54 | 4.30 | 1.63 | 33.11 | 19.67 | 2.61 | 7.53 | 1.40 | 85.22 |
| 11 | Irr2+Humic 2 cm/L | 0.28 | 4.76 | 2.37 | 7.34 | 0.31 | 3.10 | 32.86 | 10.88 | 2.89 | 12.99 | 4.01 | 82.04 |
| 12 | Irr3+Humic 2 cm/L | 0.51 | 1.50 | 5.84 | 5.50 | 7.71 | 5.56 | 25.17 | 23.10 | 1.75 | 10.25 | 1.39 | 88.28 |

*(Irr1: Irrigation 120%; Irr2:Irrigation 100%; Irr3:Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 11. Effect of irrigation and humic acid treatments and their interactions on proline content of geranium plant**

| Treatments | Proline content(mg/100 g) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | | Second growing season (2018/2019) | | | |
| | Irr1 | Irr2 | Irr3 | Mean | Irr1 | Irr2 | Irr3 | Mean |
| Control | 2.07 | 2.74 | 3.03 | 2.61 | 2.12 | 2.72 | 2.98 | 2.61 |
| Humic A.(1.0 cm/L) | 2.29 | 2.73 | 3.07 | 2.70 | 2.30 | 2.86 | 3.03 | 2.73 |
| Humic A.(1.5 cm /L) | 2.47 | 2.95 | 3.25 | 2.89 | 2.55 | 3.02 | 3.15 | 2.91 |
| Humic A.(2.0 cm/L) | 2.69 | 3.01 | 3.73 | 3.14 | 2.81 | 3.30 | 3.70 | 3.27 |
| Mean | 2.38 | 2.86 | 3.27 | | 2.45 | 2.98 | 3.22 | |
| LSD 5% | | | | | | | | |
| Irrigation (I) | 0.08 | | | | 0.10 | | | |
| Humic (H) | 0.11 | | | | 0.06 | | | |
| I*H | 0.19 | | | | 0.18 | | | |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 12. Applied irrigation water ($m^3$/fed) for geranium plant under different irrigation treatments in both growing seasons**

| Applied water ($m^3$/fed) | Irr1 | Irr2 | Irr3 | Irr1 | Irr2 | Irr3 |
|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | Second growing season (2018/2019) | | |
| Control | 7084 | 5903 | 4723 | 7299 | 6082 | 4866 |
| Humic A.(1.0 cm/L) | 7084 | 5903 | 4723 | 7299 | 6082 | 4866 |
| Humic A.(1.5 cm /L) | 7084 | 5903 | 4723 | 7299 | 6082 | 4866 |
| Humic A.(2.0 cm/L) | 7084 | 5903 | 4723 | 7299 | 6082 | 4866 |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 13. Water consumptive use ($m^3$/fed) for geranium plant under different irrigation treatments in both growing seasons**

| WCU ($m^3$/fed) | Irr1 | Irr2 | Irr3 | Irr1 | Irr2 | Irr3 |
|---|---|---|---|---|---|---|
| | First growing season (2017/2018) | | | Second growing season (2018/2019) | | |
| Control | 4898 | 4082 | 3266 | 5292 | 4410 | 3528 |
| Humic A.(1.0 cm/L) | 4898 | 4082 | 3266 | 5292 | 4410 | 3528 |
| Humic A.(1.5 cm /L) | 4898 | 4082 | 3266 | 5292 | 4410 | 3528 |
| Humic A.(2.0 cm/L) | 4898 | 4082 | 3266 | 5292 | 4410 | 3528 |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

## 3.3 Crop Water Relations

### 3.3.1 Applied irrigation water

The results in Table 12 indicated that the applied irrigation treatments for geranium were ranged between 7084 to 4723 $m^3$/fed in first growing season and 7299 to 4866 $m^3$/fed in second growing season, with the highest values applied were found under 120% of ETo and the lowest value for 80% of ETo. The results also indicated that water the values the applied irrigation water were higher in second season, compared to the first growing season, which can also be attributed to the differences in climatic parameters.

### 3.3.2 Water consumptive use (WCU)

Table 13 showed that water consumptive use values ranged between 4898 to 3266 $m^3$/fed in first growing season and 5292 to 3528 $m^3$/fed in second growing seasons. The results also showed that water consumptive use values were higher in second growing season, compared to the first growing season.

### 3.3.3 Water use Efficiency (WUE)

Table 14 showed that the highest value of WUE was attained under irrigation with 80% of ETo, namely 14.5 and 13.6 (kg/$m^3$) in both growing seasons under application humic 2.0 cm/L. Cantore et al. [47] reported that, under mild water stress, transpiration decreases more than photosynthesis during slight stomata closure and, consequently WUE increases. Miller and Martin [48] and Alva [49] indicated that sufficient water availability during most of the plant growing period is crucial for maintaining optimal crop

**Table 14. Water use efficiency (WUE) and Fresh weight (ton/fed) for geranium plant under different irrigation treatments in both growing seasons**

| Treatments | Irr1 | Irr2 | Irr3 | Irr1 | Irr2 | Irr3 |
|---|---|---|---|---|---|---|
| | Fresh weight (ton/fed) | | | WUE (kg/m$^3$) | | |
| 2017/2018 | | | | | | |
| Control | 35.8 | 37.0 | 34.1 | 7.3 | 9.1 | 10.4 |
| Humic A.(1.0 cm/L) | 47.0 | 37.4 | 35.5 | 9.6 | 9.2 | 10.9 |
| Humic A.(1.5 cm /L) | 50.5 | 42.1 | 36.6 | 10.3 | 10.3 | 11.2 |
| Humic A.(2.0 cm/L) | 59.9 | 48.8 | 47.2 | 12.2 | 11.9 | 14.5 |
| Second growing season (2018/2019) | | | | | | |
| Control | 35.5 | 37.5 | 34.2 | 6.7 | 8.5 | 9.7 |
| Humic A.(1.0 cm/L) | 49.2 | 39.6 | 36.1 | 9.3 | 9.0 | 10.2 |
| Humic A.(1.5 cm /L) | 53.8 | 43.8 | 39.7 | 10.2 | 9.9 | 11.2 |
| Humic A.(2.0 cm/L) | 66.2 | 48.3 | 48.0 | 12.5 | 11.0 | 13.6 |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

**Table 15. Water productivity (WP) and fresh weight (ton/fad) for geranium plant under different irrigation treatments in both growing seasons**

| Treatments | Irr1 | Irr2 | Irr3 | Irr1 | Irr2 | Irr3 |
|---|---|---|---|---|---|---|
| | Fresh weight (ton/fed) | | | WP (kg/fed) | | |
| First growing season (2017/2018) | | | | | | |
| Control | 35.8 | 37.0 | 34.1 | 5.0 | 6.3 | 7.2 |
| Humic A.(1.0 cm/L) | 47.0 | 37.4 | 35.5 | 6.6 | 6.3 | 7.5 |
| Humic A.(1.5 cm /L) | 50.5 | 42.1 | 36.6 | 7.1 | 7.1 | 7.8 |
| Humic A.(2.0 cm/L) | 59.9 | 48.8 | 47.2 | 8.5 | 8.3 | 10.0 |
| Second growing season (2018/2019) | | | | | | |
| Control | 35.5 | 37.5 | 34.2 | 4.9 | 6.2 | 7.0 |
| Humic A.(1.0 cm/L) | 49.2 | 39.6 | 36.1 | 6.7 | 6.5 | 7.4 |
| Humic A.(1.5 cm /L) | 53.8 | 43.8 | 39.7 | 7.4 | 7.2 | 8.2 |
| Humic A.(2.0 cm/L) | 66.2 | 48.3 | 48.0 | 9.1 | 7.9 | 9.9 |

*(Irr1: Irrigation 120%; Irr2: Irrigation 100%; Irr3: Irrigation 80 %;) of evapotranspiration (ETo)*

production in potato. Even short periods of water stress negatively affect tuber production. Humic acid application increased WUE compared with the control treatment. Similar results were obtained by Sadeghi-Shoae et al. [50] who found that the highest WUE in geranium was obtained via the application of humic acid along with irrigation. The role of humic acid in increasing WUE probably results from its role in advancing root development and penetration, which increases the ability of plants to absorb water from the soil [51].

### 3.3.4 Water productivity (WP)

Crop water productivity is a quantitative term used to define the relationship between crop produced and the amount of water involved in crop production. It is a useful indicator for quantifying the impact of irrigation scheduling decisions, with regard to water management [52]. Achieving greater water productivity became the primary challenge for scientists in agriculture. This should include the employment of techniques and practices that deliver more accurate supply of water to crops. The highest water productivity in both growing seasons were obtained with 80% of ETo under application of humic acid 2 cm/L, which gave 10.0 and 9.9 kg/m$^3$, respectively. Goswami and Sarkar [53] observed either decreased or non-significant change in water productivity at higher levels of irrigation. Regarding to the both growing season, irrigation with an amount of 80% of ETo gave the higher water productivity under humic acid 2 cm/L (Table 15).

## 4. CONCLUSION

It could be concluded that application of humic acid (2.0 cm/L) with applied 120% ETo improved the growth characters in terms of plant height, number of branches, fresh, dry weight and volatile oil yield. While, the highest volatile oil percentage and proline content were recorded at 80% ETo with humic acid at 2.0 cm/L treatment during the two growing seasons. The required irrigation water for geranium under the experimental weather condition was 7192 $m^3$/fed averaged over the two growing seasons. However, when a shortage of irrigation water occurs, 80% of ETo and application of 2.0 cm/L humic acid could be applied, which increase geranium yield by 24%, compared to the control treatment averaged over the two growing seasons.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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