# The impact of irrigation distribution uniformity and mulching soil on vegetative growth and yield of sweet fennel and squash plants

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Water shortage in agriculture is one of the adverse impacts of climate change which negatively affects global food production. Improving irrigation efficiency with mulching soil may optimize the condition by satisfing the water demand of food crops. Two experiments of the study were conducted at Dokki - Giza governorate, Egypt during winter and spring seasons of 2016/2017 and 2017/2018 under open field conditions. The study aimed to investigate the use of different number of PE laterals per growing bed (one irrigation line (OIL) and two irrigation line (TIL)) with different distances between the inline drippers (30 and 50 cm) on sweet fennel and squash to get the harmony distribution of irrigation in clay soil combined with mulching or with bare soil as the control. The field trails was performed using split plot design. The vegetative growth characteristics, yield parameters and N, P and K contents of sweet fennel and squash leaves were measured.

The obtained results indicated, that increasing number of laterals from 1 to 2 laterals /bed while decreasing the distance between drippers from 50 to 30 cm led to an increase in the vegetative characteristics, yield parameters and N, P, K contents of sweet fennel and squash plants as a results of enhancing the soil moisture availability and nutrient uptake. The treatment TIL 30 followed by TIL 50 recorded the highest results of sweet fennel and squash. Applying a black PE mulch into the soil led to an increase in soil temperature during winter and spring seasons and enhanced the vegetative growth, yield parameters and N, P, K contents of sweet fennel and squash plants compared to bare soil. Mulching soil lead to increase yield of sweet fennel and squash by 35 % compared to yield of bare soil. Results of the study conclude that applying two laterals per growing bed and mulching increase the yield of fennel and squash and it is a better option to mitigate adverse impacts of climate change.

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## 1. Introduction

Soil mulching around plants is a common agricultural practice which effectively increases the yield of butter lettuce and sweet fennel . The causes of yield increase of butter lettuce and sweet fennel cultivated under mulching were already discussed in the earlier study (Siwek et al., 2007). For decades, a common practice among the vegetable growers in Central Spain was the use of non-degradable plastic mulches in open fields, mainly for spring-summer season vegetable crops such as tomato, pepper, melon and watermelon for a variety of reasons (Green et al., 2003). Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss (Liakatas et al., 1986), resulting in more uniform soil moisture and a reduction in the amount of irrigation water, which is very important for summer crops. The plastic mulch application became a standard practice for most vegetable farmers who benefit from reduced evaporation, weed control, reduced fertilizer leaching and soil compaction, as well as elevated soil temperatures that promote earlier plant maturity. Hanada (1991) reported that mulching with appropriate materials had a number of effects, such as increased soil temperature, conserved soil moisture, controlled weeds, pests and diseases.

Efficient use of available fresh water by irrigation is becoming more important. Agronomic measures, such as varying tillage practices, mulching and anti-transparency can reduce the demand for irrigation water and improve irrigation water use efficiency (Farag et al., 2010). The mulch determines its energy-radiating behavior and its influence on the microclimate around the plant. Today, black and white mulches are common in the commercial production of vegetable crops around the world (Abdrabbo et al., 2010). Black PE mulch promote a relatively higher temperature at the soil surface, increase soil heat flux and, as a consequence, the minimum and maximum soil temperature are increased in comparison tobare soil treatments (Abdrabbo et al., 2009;EI-Dolify et al., 2016).

Christen et al., (2006) reported that drip irrigation is a method for applying water frequently and uniformly in small rates directly to the all plant root zones. Drip irrigation may not always be suitable for a particular agricultural system, regarding soil physical properties, establishment difficulties and cost considerations. In order to maximize plant production and minimize environmental impacts, good irrigation scheduling and management methods should be applied. Potential for improving water use efficiency depends on many factors related to the crop and soil system, water supply, the flexibility and efficiency of irrigation management system and the sensitivity of yield. By applying drip irrigation, severalplant stress, for example, water stress and aeration stress can be avoided.

Uniformity is a measure of how well water is distributed to the plants in a given field and is often expressed as a measure of variability (Howell, 2001). Mizyed and Kruse (2008) mentioned that irrigation uniformity is an important irrigation management factor of how evenly water is distributed across the field. No uniform distribution of irrigation water may create zones of over and/or under-irrigation, which can lead to yield reduction resulting from excessive nutrient leaching or plant water stress. Drip irrigation systems are very efficient in terms of water distribution and reduction of water losses. The uniformity is directly related to the pressure variation within the entire system and the variability of the emissions of each individual emitter. Several factors contribute to reduce the uniformity of water application such as excessive length of laterals, excessive pressure losses resulting from changes in elevation along the laterals, emitter clogging, and soil characteristics. Specifically, for drip irrigation in which the number of point sources of water (emitters) is limited, the uniformity of application can be compromised by the soil characteristics, leading to very intense water percolation during long irrigation events. Reduction in emitter spacing and also the use of double drip tapes placed closer to the crop rows may improve the uniformity of water and nutrient distribution along the beds while reducing the amount of water required. However, there is a lack of information about the effectiveness of this system for double-row crops (Zotarelli et al., 2009). Perennial crops may require one to five emitter laterals per plant row to adequately supply water needs depending on soil types, water emission device, size of plants and climate. Widely spaced planting establishments, like that of pecan trees, should have at least two lines, 2 to 3 m on either side of the row. More closely spaced perennial crops and vegetables, such as asparagus, grapes, sweet fennel and hops, may need only one lateral per row or bed (Lamm and Camp, 2007).


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The current study aimed to enhance the agricultural practices for increasing the yield production of vegetables during different climate season conditions (winter and spring) and plant types (leafy and fruity) via investigations of the effect of irrigation distribution uniformity and mulching soil on sweet fennel and squash growth and yield.

## 2. Material and methods

Two field experiments were conducted in the experimental farm at the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Dokki - Giza governorate, Egypt, during winter and summer seasons of 2016/2017 and 2017/2018. The soil of the experimental field is clay with pH 8.2, EC 2.4 dS m-1, organic matter 1.45%, CaCO3 13 % and total N of 20 meq / l.

### Plant material

Sweet fennel (Apium graveolens var. rapeceum F1 hybrid) seeds were sown in polystyrene trays in the last week of October of both seasons while seedlings (after the fourth true leaf stage) were transplanted into soil on 20th and 22nd of November of the 2016 and 2017 seasons, respectively. Sweet fennel seedlings were cultivated in two rows (40 cm among rows) for each raised bed (80 cm wide) and the distance between the plants in-row was 30 cm.

Squash (Cucurbita pepo var Iskandrani) seeds were directly sown into the soil on 5th and 8th March of 2017 and 2018 after sweet fennel harvesting without soil preparation. Squash were placed in double rows. The final plant spacing was 50 cm in the row, 40 cm between the rows and 70 cm in between the beds.

### Experimental Design and Treatments

Two factors combined under the study were investigated. The first factor was the impact of mulching: black polyethylene plastic mulch (BP Mulch) and bare soil (control). The second factor was four irrigation distribution patterns via different No. of emitters per bed (I and 2) with different distance between the drippers (30 and 50 cm) were used as followed to performed the treatments of the study.

1- One irrigation line per bed with 30 cm drippers distance (OIL30)
2- One irrigation line per bed with 50 cm drippers distance (OIL50)
3- Two irrigation line per bed with 30 cm drippers distance (TIL30)
4- Two irrigation line per bed with 50 cm drippers distance (TIL50)

The black plastic-film (120 cm in width and 125 µ thickness) was used to cover the experimental beds before planting the plants under study (sweet fennel and squash). The water requirements of both sweet fennel and squash during the cultivated seasons were calculated by CLAC and depended on measured Eto data while the water requirements were even for all irrigation distribution uniformity treatments. The experiments were laid out in Split Plot Design (SPD) in triplicates.

### The vegetative and yield measurements

three fennel and Squash plants for each treatment were taken at the end of growing seasons for measurements. The sweet fennel measurements were Fresh weight of Bulb (g/plant), Bulb length (cm), Bulb width (cm), Total fresh of leaves (g/plant), Total dry weight of leaves (g/plant), Leaf number/ plant and Plant length (cm).

The Squash measurements were Leaves numbers, Plant fresh weight (g), Plant dry weight (g), Total leaf area (m2), Yield (g/plant) and Fruit numbers.

### Soil temperature and chemical analysis

Average soil temperature (oC) of different treatments were measured during the two cultivated seasons of both sweet fennel and squash by using a digital soil thermometer.

Mineral analyses of sweet fennel and squash leaves (N, P and K) were estimated at the harvest stage. Five samples of plant leaves from each treatment were dried at 70 oC in air forced oven for 48 h. Dried leaves were digested in H2SO4 according to the method described by A.O.A.C (2000). Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1982) while P and K contents were estimated in the acid digested solution by colorimetric method (ammonium molybdate) using spectrophotometer and flame photometer as described by Chapman and Pratt (1961).

**Statistical Analysis**

Data were statistically analysed using statistical analysis system (SAS) program (SAS, 2000). The differences among means for all traits were tested for significance at 0.05 alpha level according to Duncan tast.

## 3. Results

### 3.1. Effect of soil mulching on average soil temperature

The results given in Fig. (1) indicate that the mulching caused higher average soil temperature compared to bare soil treatment during winter and summer of sweet fennel and squash, respectively. The mulching of soil increased soil temperature in different rates regarding to air temperature .During the coldest days of January and First half of February in both seasons of sweet fennel and squash (2017 and 2018), the soil mulching recorded average soil temperature rates 0.4 oC higher than bare soil in winter season. The impact of increasing soil temperatures led to many advantages: enhancing the plant root growth, water and nutrients uptake due to better vegetative growth and

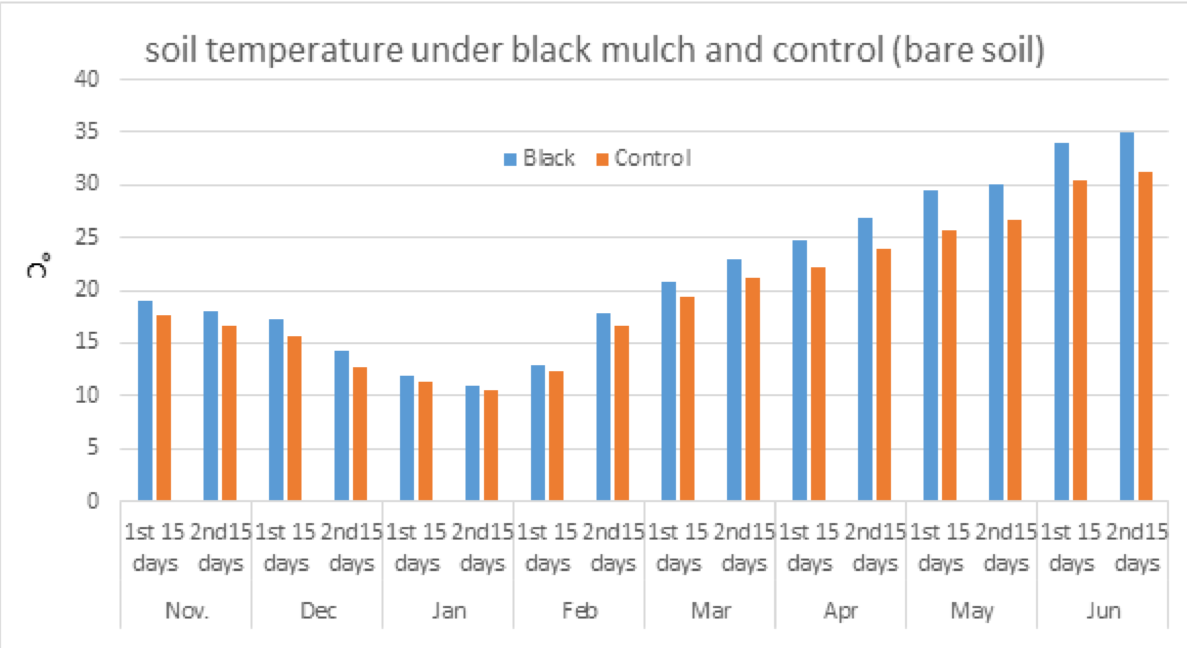


**Fig 1.** The effect of soil mulching on average soil temperature during the sweet fennel and squash seasons

yield. These results agreed with Abdrabbo et al. (2009) and Abdrabbo et al. (2013) who mentioned that soil temperature in control (bare soil) was the lowest soil temperature compared to black polyethylene mulch.

### 3.2. Effect of irrigation distribution uniformity and mulching soil on sweet fennel

#### 3.2.1. Vegetative characteristics

The number of lateral treatments and distance between emitters had significant impacts on total fresh weight and dry weight (g/plant) of sweet fennel leaves while these impacts were absent in case of No. of leaves and plant height (cm) of sweet fennel as presented in Table (1). TIL 30 recorded the highest values of total fresh weight and dry weight of sweet fennel leaves followed by TIL 50, with significant difference, butno significant differences on No. of leaves as well as plant height. Conversely, the lowest vegetative characteristics of sweet fennel (total fresh weight and dry weight of leaves, No. of leaves and plant height) resulted from the OIL 30 treatment.

Regarding the mulch application, the obtained results of Table (1) indicated that the mulching application


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had a superior effect on total fresh weight and dry weight of leaves, and plant height but not on No. of leaves of sweet fennel. Overall, the mulching application presented higher results compared to the bare soil treatment.

Table (1) illustrated number of laterals per bed, distance between emitters and mulching on vegetative characteristics of sweet fennel during the cultivated seasons. The interaction treatment TIL 30 combined

**Table 1.** Effect of irrigation distribution and mulching on vegetative characteristics of sweet fennel during the cultivated seasons.

| | **2017** | | | **2018** | | |
|---|---|---|---|---|---|---|
| | **Soil mulch** | | | | | |
| **Irrigation** | **Total fresh weight of leaves (g/plant)** | | | | | |
| | **Control** | **Mulch** | **Mean** | **Control** | **Mulch** | **Mean** |
| OIL 30 | 251.5 cd | 323.5 ab | 287.5 AB | 235.4 cde | 303.0 b | 269.2 B |
| TIL 30 | 261.3 cd | 359.0 a | 310.1 A | 246.3 cd | 330.8 a | 288.5 A |
| OIL 50 | 241.8 d | 292.0 bc | 266.9 B | 217.3 e | 261.0 c | 239.1 C |
| TIL 50 | 258.8 cd | 342.5 a | 300.6 A | 233.8 de | 327.0 ab | 280.4 AB |
| Mean | 253.3 **B** | 329.3 **A** | | 233.2 **B** | 305.4 **A** | |
| | **Total dry weight of leaves (g/plant)** | | | | | |
| OIL 30 | 34.4 b | 46.1 a | 40.2 B | 34.9 c | 48.9 a | 41.9 B |
| TIL 30 | 38.8 b | 49.5 a | 44.2 A | 41.3 b | 52.5 a | 46.9 A |
| OIL 50 | 35.7 b | 39.6 b | 37.6 B | 36.1 bc | 41.0 bc | 38.6 B |
| TIL 50 | 35.5 b | 45.1 a | 40.3 B | 36.3 bc | 48.6 a | 42.5 B |
| Mean | 36.1 **B** | 45.1 **A** | | 37.1 **B** | 47.7 **A** | |
| | No. of leaves / plant | | | | | |
| OIL 30 | 10.0 a | 10.8 a | 10.4 A | 10.3 a | 11.8 a | 11.0 A |
| TIL 30 | 10.5 a | 11.0 a | 10.8 A | 11.5 a | 12.5 a | 12.0 A |
| OIL 50 | 10.0 a | 10.5 a | 10.3 A | 10.3 a | 11.8 a | 11.0 A |
| TIL 50 | 10.3 a | 10.5 a | 10.4 A | 11.0 a | 11.3 a | 11.1 A |
| Mean | 10.2 **A** | 10.7 **A** | | 10.8 **B** | 11.8 **A** | |
| | **Plant height (cm)** | | | | | |
| OIL 30 | 86.8 a | 91.3 a | 89.0 A | 91.0 a | 95.0 a | 93.0 A |
| TIL 30 | 88.5 a | 92.3 a | 90.4 A | 93.6 a | 96.7 a | 95.1 A |
| OIL 50 | 86.5 a | 90.3 a | 88.4 A | 90.5 a | 94.0 a | 92.2 A |
| TIL 50 | 88.5 a | 92.3 a | 90.4 A | 94.2 a | 95.1 a | 94.6 A |
| Mean | 87.6 **B** | 91.5 **A** | | 92.3 **B** | 95.2 **A** | |

* Similar letters indicate non-significant at 0.05 levels.
** Capital letters indicate the significant difference of each factor (P<0.05)
*** Small letters indicate the significant difference of interaction (P<0.05)

with mulching soil gave the highest records of total fresh weight and dry weight of sweet fennel leaves while OIL 50 produced the lowest results. There were no significant differences among the different interaction treatments on No. of leaves and plant height of sweet fennel.

### 3.2.2. Yield parameters

Table (2) observed number of laterals per bed, distance between emitters and mulching on yield parameters of sweet fennel during the cultivated seasons. Referring to the number of laterals per bed and the distance between emitters effect, the treatment of TIL 30 yielded the highest records of fresh weight of bulb (g/ plant) and bulb width (cm) of sweet fennel while the highest result of bulb length (cm) was recorded with the use of OIL 30.

The mulching application had the highest values for fresh weight of bulb and bulb width while bare soil illustrated the highest bulb length of sweet fennel. These results could be explained by less competition between sweet fennel and weeds. Mulching soil minimized weed growth and offered better soil moisture and temperature conditions that encouraged more horizontal growth, while competition between the plant and weed encouraged more vertical growth Table (2) results indicated.

The interaction effects among the different treatments are illustrated in Table (2). The obtained results

**Table 2.** Effect of irrigation distribution and mulching on yield parameters of sweet fennel during the cultivated seasons.

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Soil mulch | | | | | |
| Irrigation | Fresh weight of Bulb (g/plant) | | | | | |
| | Control | Mulch | Mean | Control | Mulch | Mean |
| OIL 30 | 134.5 $^{c}$ | 218.0 $^{b}$ | 176.3 B | 128.5 $^{e}$ | 217.1 $^{b}$ | 172.8 C |
| TIL 30 | 160.1 $^{c}$ | 327.5 $^{a}$ | 243.8 A | 152.4 $^{cd}$ | 312.3 $^{a}$ | 232.3 A |
| OIL 50 | 151.0 $^{c}$ | 217.8 $^{b}$ | 184.4 B | 139.9 $^{de}$ | 205.5 $^{b}$ | 172.7 C |
| TIL 50 | 188.0 $^{bc}$ | 225.0 $^{b}$ | 206.5 B | 174.5 $^{c}$ | 207.5 $^{b}$ | 191.0 B |
| Mean | 158.4 **B** | 247.1 **A** | | 148.8 **B** | 235.6 **A** | |
| | Bulb length (cm) | | | | | |
| OIL 30 | 11.3 a | 10.9 a | 11.1 A | 10.9 a | 10.7 a | 10.8 A |
| TIL 30 | 11.0 a | 10.1 a | 10.6 AB | 10.5 a | 10.0 a | 10.2 B |
| OIL 50 | 11.0 a | 10.5 a | 10.8 AB | 10.4 a | 10.3 a | 10.3 AB |
| TIL 50 | 10.8 a | 10.1 a | 10.4 B | 10.3 a | 9.8 a | 10.0 B |
| Mean | 11.0 **A** | 10.4 **B** | | 10.5 **A** | 10.2 **A** | |
| | Bulb width (cm) | | | | | |
| OIL 30 | 10.3 $^{b}$ | 11.6 $^{b}$ | 10.9 B | 9.6 $^{c}$ | 10.9 $^{bc}$ | 10.2 B |
| TIL 30 | 11.0 $^{b}$ | 13.3 $^{a}$ | 12.1 A | 10.4 $^{bc}$ | 12.2 $^{a}$ | 11.3 A |
| OIL 50 | 10.5 $^{b}$ | 11.8 $^{ab}$ | 11.1 B | 9.6 $^{c}$ | 10.6 $^{bc}$ | 10.1 B |
| TIL 50 | 11.3 $^{b}$ | 11.8 $^{ab}$ | 11.5 AB | 10.2 $^{bc}$ | 11.0 $^{ab}$ | 10.6 AB |

* Similar letters indicate non-significant at 0.05 levels.
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showed that TIL 30 combined with mulching soil gave the highest results of fresh weight of bulb and bulb width while the lowest values came from OIL 50 combined with control (bare soil). There were no significant differences among the different interaction treatments regarding bulb length of sweet fennel.

### 3.2.3. N, P and K contents

The number of laterals per bed and distance between emitter treatments had a significant impact on N, P and K (%) contents of sweet fennel plants. The treatment TIL 30 presented the highest records of N, P and K contents of sweet fennel plants. Increasing the number of laterals, as well as shorter distance between emitters (30 cm) led to an increase in soil moisture uniformity and enhanced the nutrient uptake (Abdrabbo et al., 2005).

Table (3) illustrated the mulching soil impacts on N, P and K contents of sweet fennel; applying soil mulching led to improved N, P and K contents of sweet fennel resulting from enhanced soil moisture content, less competition and better soil temperature that encouragedw the N, P and K uptake. Mulching soil observed the highest N, P and K contents of sweet fennel compared to control.

Regarding the interaction effects among the number

**Table 3.** Effect of irrigation distribution and mulching on N, P and K (%) contents of sweet fennel plant during the cultivated seasons.

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Soil mulch | | | | | |
| Irrigation | N (%) | | | | | |
| | Control | Mulch | Mean | Control | Mulch | Mean |
| OIL 30 | 1.90 c | 1.82 d | 1.86 B | 1.89 b | 1.80 c | 1.85 B |
| TIL 30 | 1.83 d | 2.01 a | 1.92 A | 1.84 bc | 2.01 a | 1.93 A |
| OIL 50 | 1.80 d | 1.98 b | 1.89 B | 1.80 c | 1.96 ab | 1.88 AB |
| TIL 50 | 1. 82 d | 1.82 d | 1.82 C | 1.82 bc | 1.83 bc | 1.83 B |
| Mean | 1.84 **B** | 1.91 **A** | | 1.84 B | 1.90 A | |
| | P (%) | | | | | |
| OIL 30 | 0.370 cd | 0.423 ab | 0.397 A | 0.403 a | 0.740 a | 0.437 A |
| TIL 30 | 0.363 cd | 0.443 a | 0.403 A | 0.427 a | 0.480 a | 0.453 A |
| OIL 580 | 0.377 bcd | 0.410 abc | 0.393 A | 0.403 a | 0.493 a | 0.448 A |
| TIL 50 | 0.347 d | 0.440 a | 0.433 A | 0.380 a | 0.493 a | 0.435 A |
| Mean | 0.364 **B** | 0.429 **A** | | 0.403 **B** | 0.483 **A** | |
| | K (%) | | | | | |
| OIL 30 | 2.67 bc | 3.52 ab | 3.10 AB | 2.75 bc | 3.67 ab | 3.21 B |
| TIL 30 | 3.06 bc | 3.98 a | 3.52 A | 3.06 bc | 4.21 a | 3.63 A |
| OIL 50 | 2.60 c | 3.06 bc | 2.83 B | 2.67 c | 3.21 bc | 2.94 B |
| TIL 50 | 2.52 c | 3.36 abc | 2.94 B | 2.67 c | 3.52 abc | 3.10 B |
| Mean | 2.71 **B** | 3.48 **A** | | 2.79 **B** | 3.65 **A** | |

* Similar letters indicate non-significant at 0.05 levels.
** Capital letters indicate the significant difference of each factor (P<0.05)
*** Small letters indicate the significant difference of interaction (P<0.05)

of laterals per bed, distance between emitters and mulching soil as shown in Table (3), the interaction treatment TIL 30 combined with mulch had the highest values of N, P and K contents of sweet fennel while the lowest results were recorded by OIL50 treatment combined with control.

### 3.3. Effect of irrigation distribution uniformity and mulching soil on squash

#### 3.3.1. Vegetative characteristics

Table (4) present the effects of irrigation distribution and mulching on vegetative characteristics of squash during the cultivated seasons. The irrigation distribution uniformity had strong significant impacts on the vegetative characteristics of squash, while TIL 30 treatment gave the highest results of No. of leaves / plant, plant fresh weight (g), plant dry weight (g) and total leaf area (m2). The lowest vegetative characteristics were illustrated by OIL 50.Also, mulching had significant encouragement impacts on vegetative characteristics of squash compared to the control (bare soil). Mulching application recorded higher results of vege-

**Table 4.** Effect of irrigation distribution and mulching on vegetative characteristics of squash during the cultivated seasons.

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Soil mulch | | | | | |
| Irrigation | No. of leaves / plant | | | | | |
| | Control | Mulch | Mean | Control | Mulch | Mean |
| OIL 30 | 14.0 $^{bc}$ | 16.7 $^{ab}$ | 15.3 A | 15.3 $^{bc}$ | 18.7 $^{ab}$ | 17.0 AB |
| TIL 30 | 12.7 $^{c}$ | 17.7 $^{a}$ | 15.2 A | 16.0 $^{bc}$ | 20.7 $^{a}$ | 18.3 A |
| OIL 50 | 12.3 $^{c}$ | 14.0 $^{bc}$ | 13.2 C | 15.0 $^{bc}$ | 16.3 $^{bc}$ | 15.7 B |
| TIL 50 | 11.0 $^{c}$ | 16.3 $^{ab}$ | 13.7 B | 12.7 $^{c}$ | 18.7 $^{ab}$ | 15.7 B |
| Mean | 12.5 **B** | 16.2 **A** | | 14.8 **B** | 18.6 **A** | |
| | Plant fresh weight(g) | | | | | |
| OIL 30 | 537.7 $^{cd}$ | 1035.3 $^{ab}$ | 786.5 B | 501.2 $^{cd}$ | 998.8 $^{a}$ | 750.0 B |
| TIL 30 | 680.0 $^{c}$ | 1225.0 $^{a}$ | 952.5 A | 644.0 $^{bc}$ | 1127.7 $^{a}$ | 885.9 A |
| OIL 50 | 392.3 $^{d}$ | 672.0 $^{c}$ | 532.2 C | 359.6 $^{d}$ | 644.0 $^{bc}$ | 501.8 C |
| TIL 50 | 667.3 $^{c}$ | 900.3 $^{b}$ | 783.8 B | 618.1 $^{c}$ | 786.6 $^{b}$ | 702.4 B |
| Mean | 569.3 **B** | 958.2 **A** | | 530.7 **B** | 889.3 **A** | |
| | Plant dry weight (g) | | | | | |
| OIL 30 | 40.6 $^{e}$ | 68.4 $^{b}$ | 54.5 B | 42.3 $^{bc}$ | 71.6 $^{a}$ | 56.9 B |
| TIL 30 | 54.0 $^{cd}$ | 79.5 $^{a}$ | 66.8 A | 55.1 $^{b}$ | 85.7 $^{a}$ | 70.4 A |
| OIL 50 | 28.6 $^{f}$ | 44.9 $^{de}$ | 36.8 C | 31.5 $^{c}$ | 46.5 $^{bc}$ | 39.0 C |
| TIL 50 | 52.7 $^{cd}$ | 55.9 $^{c}$ | 54.3 B | 54.4 $^{b}$ | 53.6 $^{b}$ | 54.0 B |
| Mean | 44.0 **B** | 62.2 **A** | | 45.8 **B** | 64.3 **A** | |
| | Total leaf area ($m^2$) | | | | | |
| OIL 30 | 2.61 $^{c}$ | 3.73 $^{b}$ | 3.17 B | 2.59 $^{c}$ | 3.72 $^{b}$ | 3.16 B |
| TIL 30 | 2.95 $^{c}$ | 4.67 $^{a}$ | 3.81 A | 2.97 $^{c}$ | 4.86 $^{a}$ | 3.92 A |
| OIL 50 | 1.49 $^{d}$ | 2.72 $^{c}$ | 2.10 D | 1.52 $^{d}$ | 2.85 $^{c}$ | 2.18 D |
| TIL 50 | 2.33 $^{c}$ | 2.96 $^{c}$ | 2.64 C | 2.38 $^{c}$ | 3.00 $^{c}$ | 2.69 C |
| Mean | 2.34 **B** | 3.52 **A** | | 2.37 **B** | 3.61 **A** | |

* Similar letters indicate non-significant at 0.05 levels.
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tative characteristics compared to control as presented in Table (4).

Referring to the interaction effects on vegetative characteristics of squash, the obtained results of Table (4) indicated that the interaction treatment TIL 30 combined with mulching soil recorded the highest values of No. of leaves / plant, plant fresh weight (g), plant dry weight (g) and total leaf area (m2) while the lowest results of vegetative characteristics of squash were presented by OIL 50 combined with bare soil (control).

Table (4) shows the effects of irrigation distribution and mulching on vegetative characteristics of squash during the cultivated seasons. The irrigation distribution uniformity had a strong significant impact on the vegetative characteristics of squash while TIL 30 treatment gave the highest results of No. of leaves / plant, plant fresh weight (g), plant dry weight (g) and total leaf area (m2). The lowest vegetative characteristics were illustrated by OIL 50.

Referring the interaction effects on vegetative characteristics of squash, the obtained results of Table (4) indicated that the interaction treatment TIL 30 combined with mulching soil recorded the highest values of No. of leaves / plant, plant fresh weight (g), plant dry weight (g) and total leaf area (m2) while the lowest results of vegetative characteristics of squash presented by OIL 50 combined with bare soil (control).

### 3.3.2. Yield parameters

The number of laterals per bed and distance between emitter treatments had a significant impact on N, P and K (%) contents of squash. The treatment TIL 30 presented the highest records of N, P and K contents of sweet fennel plants. Increasing the number of lateral as well as shorter distance between emitters (30 cm) led to an increase in soil moisture uniformity and enhance the nutrients uptake (Abdrabbo et al., 2005).

Table (5) illustrated the mulching soil impacts on N, P and K contents of sweet fennel, applying soil mulching led to improve the N, P and K contents of sweet fennel as a result of enhancing the soil moisture content, less competition and better soil temperature that led to encourage the N, P and K uptake. Mulching soil observed the highest N, P and K contents of sweet fennel compared to control.

**Table 5.** Irrigation distribution and mulching on yield parameters of squash during the cultivated seasons.

| | **2017** | | | **2018** | | |
|---|---|---|---|---|---|---|
| | **Soil mulch** | | | | | |
| **Irrigation** | **Total yield (g/plant)** | | | | | |
| | **Control** | **Mulch** | **Mean** | **Control** | **Mulch** | **Mean** |
| OIL 30 | 543 c | 1373 a | 958 B | 457 d | 1276 a | 867 B |
| TIL 30 | 1132 b | 1250 ab | 1191 A | 1053 bc | 1095 abc | 1074 A |
| OIL 50 | 472 c | 1250 ab | 861 B | 417 d | 1211 ab | 814 B |
| TIL 50 | 1123 b | 1164 b | 1144 A | 997 c | 1077 bc | 1037 A |
| Mean | 818 **B** | 1259 **A** | | 731 **B** | 1165 **A** | |
| | **No. of fruits / plant** | | | | | |
| OIL 30 | 14.3 c | 37.3 a | 25.8 B | 14.3 d | 35.3 a | 24.8 C |
| TIL 30 | 29.0 b | 31.3 b | 30.2 A | 28.7 c | 29.3 bc | 29.0 B |
| OIL 50 | 12.7 c | 32.3 b | 22.5 C | 13.0 d | 32.0 b | 22.5 D |
| TIL 50 | 31.0 b | 31.3 b | 31.2 A | 29.7 bc | 32.0 b | 30.8 A |
| Mean | 21.8 **B** | 33.1 **A** | | 21.4 **B** | 32.2 **A** | |

* Similar letters indicate non-significant at 0.05 levels.
** Capital letters indicate the significant difference of each factor ($P<0.05$)
*** Small letters indicate the significant difference of interaction ($P<0.05$)

Regarding the interaction effects among the number of laterals per bed, distance between emitters and mulching soil as shown in Table (5), the interaction treatment TIL 30 combined with mulch had the highest values of N, P and K contents of sweet fennel while the lowest results recoded by OIL50 combined with control.

### 3.3.3. N, P and K (%) contents

Table (6) presents number of laterals per bed, distance between emitters and mulching effects on N, P and K (%) contents of squash leaves during the cultivated seasons. Enhancing the distribution uniformity of irrigation water led to improved nutrient uptakes while increasing the N, P and K contents of squash leaves. The treatment TIL 30 had the highest results of N, P and K (%) contents of squash leaves while the lowest values were recorded by OIL 50 treatment.

Similar results were observed in N, P, K contents of leaves under mulching in both squash and fennel. Mulching treatment had a significant effect on N, P and K contents of squash leaves compared to control treatment as shown in Table (6).

The results of interaction treatments effects on N, P and K contents of squash leaves Table (6) indicated that TIL 30 combined with mulching presented the highest N, P and K (%) contents of squash leaves while the lowest value was recorded by OIL 50 combined with bare soil treatment (control).

## 4. Discussion

**Table 6.** Irrigation distribution and mulching on N, P and K (%) contents of squash leaves during the cultivated seasons.

| | 2017 | | | 2018 | | |
|---|---|---|---|---|---|---|
| | Soil mulch | | | | | |
| Irrigation | N (%) | | | | | |
| | Control | Mulch | Mean | Control | Mulch | Mean |
| OIL 30 | 3.69 c | 4.22 ab | 3.95 A | 3.52 c | 4.33 ab | 3.93 B |
| TIL 30 | 3.63 c | 4.43 a | 4.03 A | 3.90 bc | 4.58 a | 4.24 A |
| OIL 50 | 3.74 c | 4.07 b | 3.90 A | 3.71 c | 4.35 ab | 4.03 AB |
| TIL 50 | 3.48 c | 4.41 a | 3.95 A | 3.50 c | 4.19 b | 3.84 B |
| Mean | 3.64 B | 4.28 A | | 3.66 B | 4.36 A | |
| | P (%) | | | | | |
| OIL 30 | 0.32 c | 0.42 b | 0.37 B | 0.31 c | 0.40 ab | 0.36 B |
| TIL 30 | 0.35 c | 0.48 a | 0.42 A | 0.35 bc | 0.46 a | 0.40 A |
| OIL 50 | 0.31 c | 0.37 bc | 0.34 B | 0.30 c | 0.35 bc | 0.32 B |
| TIL 50 | 0.31 c | 0.40 bc | 0.36 B | 0.29 c | 0.39 b | 0.34 B |
| Mean | 0.32 B | 0.42 A | | 0.31 B | 0.40 A | |
| | K (%) | | | | | |
| OIL 30 | 2.64 c | 2.95 a | 2.70 AB | 2.56 b | 3.12 a | 2.84 AB |
| TIL 30 | 2.49 c | 2.96 a | 2.73 A | 2.99 ab | 3.12 a | 3.05 A |
| OIL 50 | 2.42 c | 2.71 b | 2.57 B | 2.55 b | 2.69 b | 2.62 B |
| TIL 50 | 2.33 c | 2.82 ab | 2.57 B | 2.41 b | 3.04 ab | 2.72 B |
| Mean | 2.43 B | 2.86 A | | 2.63 B | 2.99 A | |

* Similar letters indicate non-significant at 0.05 levels.
** Capital letters indicate the significant difference of each factor (P<0.05)
*** Small letters indicate the significant difference of interaction (P<0.05)


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The investigation on the effect of the number of laterals per bed and distance between emitters has less work than the assessment of water rationing, requirement of different crops and the development of modern irrigation methods. However it is important to regularize the optimal distribution of soil moisture at the same irrigation water amounts. In general, the proper number of laterals per bed and distance between emitters led to improvements in root and vegetative growth as a result of enhancing nutrient absorption (Abdrabbo et al., 2005). Improved vegetative growth resulted in increased quality of leafy vegetable crops while led to increase the yield of vegetable crops (Abdrabbo et al., 2005; Abdrabbo et al., 2015; Farag et al., 2016) .

The increase No. of laterals per bed from 1 to 2 with a decrease in the distances between drippers from 50 to 30 cm led to better moisture availability and improvements during the vegetative growth of sweet fennel and squash plants. TIL 30 followed by TIL 50 recorded the highest results of vegetative characteristics, yield parameters and N, P and K contents of both sweet fennel and squash. Sweet fennel and squash under TIL 30 gave a high yield and good quality.The results agreed to Mizyed and Kruse (2008) who reported that number of laterals per bed and distance between emitters are an important irrigation management factor, that determines how evenly water is distributed across the field. Improper number of laterals per bed and distance between emitters may create zones of over and/or under-irrigation, which can lead to yield reduction resulting from excessive nutrient leaching or plant water stress. Drip irrigation systems are very efficient in terms of water distribution and reduction of water losses. Christen et al., (2006) mentioned that to maximize plant production and minimize environmental impacts, good irrigation scheduling and management methods should be applied (Farag et al., 2016). Potentials for improving water use efficiency depends on many factors related to the crop and soil system, water supply, the flexibility and efficiency of irrigation management system and the sensitivity of yield. Sustained moisture supply by using proper water quantity with installed polyethylene mulch enhanced plant yield (Abdrabbo et al., 2014). The irrigation water supplied, irrespective of irrigation methods, was retained in the soil and efficiently distributed for crop growth (Farrag et al., 2016). The mulched soil causes indistinguishable irrigations levels by the crop .Higher water use efficiency is an integral part of mulch accompanied with drip irrigation (Abdrabbo et al., 2015)

The application of soil mulching required a lot attention in contrast to irrigation distribution uniformity. The positive effects of mulching cover many issues such as consistent soil moisture, conservation of irrigation water, soil temperature improvement, less weed competition, better nutrient uptake and better root and vegetative growth. Needless to mention many investigations assure the general positive impacts of soil mulching on the vegetable crops (Liakatas et al., 1986; Hanada 1991; Green et al., 2003; Hatami et al., 2012; Kumar and Lal, 2012).

Water resources and threats are specific to domestic conditions, as climate change consequences are manifested differently across local or regional levels. Development efforts for water resource management should involve proper analysis of dominating local conditions and concerns over development needs, and stakeholders should be involved in such progress (Chen and Davis, 2014).

Integrating both factors of number of laterals per growing bed as well as distance between emitters and mulching soil led to improved yields of sweet fennel and squash during different climate seasons conditions. The effect of both factors appeared during the coolest and warmest seasons for both of sweet fennel as leafy vegetable and squash as fruit vegetable crop.

## 5. Conclusion

Using two laterals per bed accompanied with 30 cm distance between emitters led to increased productivity of sweet fennel as well as squash during the two seasons. Moreover, using mulch led to improved productivity as well as water NPK percentages in both sweet fennel and squash leaves. The obtained results recommend the use two line emitters with 30 cm distance between emitters and black polyethylene mulch for producing both crops.

## Conflict of Interest

The authors declare that there is no conflict of interest.

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