The Effect of Drip Irrigation, Plant Spacing and Chemical Fertilizers on Some Characteristics of Eggplant Solanum melongena L. Grown inside A greenhouse

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Abstract

The experiment was conducted at the College of Agriculture - University of Kirkuk during the growing season 2016-2017 on the hybrid eggplant (Solanum melongena L.) category Balcan F1, to study the effect of distances of plants and the concentrations of chemical fertilization and interaction between some of the growth and yield using drip irrigation system grown under greenhouse conditions. The experiment included 18 treatments of a consensus between three planting distances (20.30, 40 cm) with three concentrations of fertilizer trio (16.6, 20.8, 25 g plant\(^{-1}\)) given in two batches. The experiment carried out according to the design of randomized complete sectors (R.C.B.D.) as Split- Split plot method and three replicates and tested the differences between the averages, according to the least significant difference test L.S.D. The results showed significant influence at the level of p< 0.01 and p< 0.05 for the treatment of interactions between the interlayer distance and concentrations of fertilizer D\(_1C_1\) (20 cm and 16.8 g plant\(^{-1}\)) highest averages for most of the traits (plant height, branches, early yield of plant, total yield of plant) of (62.577 cm plant\(^{-1}\), 6.56 branch plant\(^{-1}\), and 2.098 kg plant\(^{-1}\) and 4.69 kg plant\(^{-1}\)), respectively. However, the treatments D\(_1C_2\) and D\(_2C_1\) gave a highest value of chlorophyll ratio in the plant and the total number of leaves reached (54.26 % and 93.78 leaves plant\(^{-1}\)), respectively.

Keywords: Cultivation distances, Drip Irrigation, Eggplant, Fertilizers, Plant Spacing, and Yield.

1. Introduction

The area planted with eggplants in the world reaches 1.6 million hectares with a yield of 124 tons h\(^{-1}\), and the most important of which is China and India. As for Iraq, the cultivated area for the year 2006 amounted to about 23,665 hectares and the yield reached 51.7 tons h\(^{-1}\), and therefore this is a clear indication of the low level of productivity per unit area compared to the global productivity rate, and the reason may be due to the deterioration of service operations and the lack of use of modern methods and means cultivation of this crop [1].

Eggplant (Solanum melongena L.) is one of the main vegetable crops in Iraq and in the tropical regions. It belongs to the eggplant family and its original homeland is India and central and southern China [2]. The eggplants are grown in Iraq in open fields and also in protected agricultural facilities. Its importance comes from the use of fruits that are eaten after cooking, and it is also used in making pickles and preserved frozen or canned for the purpose of export [3]. The crops are cultivated under conditions of sheltered cultivation in winter in plastic and glass houses, in addition to early cultivation at the end of winter in low-lying tunnels. And it is considered one of the stressful crops of the soil, therefore it needs organic fertilizers as well as chemical fertilizers in more quantities than other crops, especially in protected cultivations, and these fertilizers are added directly to the soil as solid fertilizers [4].

Given the importance of vegetable crops, it is necessary to increase the cultivated areas to increase their productivity, and this requires providing sufficient water for watering these crops, and one of the most important modern technologies is drip irrigation, which provides the plants with water and fertilizer requirements with little loss in them, as well as soil, climate factors and new agricultural methods [5, 6].
Occupied area by the plants affects the growth of the plants and the amount of yield, by increasing the exposure of the vegetative part to sunlight and reducing competition in obtaining water and nutrients from the soil, which may encourage the plant to grow well and the length of the plant increases as the planting distance decreases [7]. In addition to that when planting potatoes over a narrow distance has led to an increase in the number of tubers and the average weight of the tuber.

The results showed the effect of nitrogen fertilizer, phosphate and potassium fertilization and the intensity of the watermelon plants that leaving two plants in one hole had a significant effect in increasing the yield of the plant while it had no effect on the rest of the studied characteristics. [8].

Fertilization is one of the most important processes of the crop and production service for its important role in regulating the physiological processes of the plant. It is important to add the appropriate quantities of fertilizers that are soluble and absorbed by plants for the purpose of increasing production and improving the quality and preserving the soil from deterioration and maintaining its fertility, including potassium fertilizers. Moreover, the provision of the nutrients the plant needs is a necessary condition [9].

Therefore, this experiment was conducted to show the effect of cultivation distances, chemical fertilizing concentrations and their interaction on some of the characteristics of the eggplant plants using the drip irrigation system to improve plant growth and increase the yield quantity and quality.

2. Materials and methods

The experiment was carried out in a greenhouse belonging to the Faculty of Agriculture, University of Kirkuk. On 9/9/2016 hybrid eggplant seeds, Balcan F1, were grown in cork dishes, containing sandy soil and peat. On 1/11/2016 the seedlings were transported to a plastic house when the height of them were 12-16 cm and the number of real leaves was 3-4, after having been done three terraces with a width of 1 m for each plot with rows between them. It is dotted by 75 cm and laying drip irrigation pipes in the form of two lines for a plot with a distance of (50 cm) between them and three distances between plants (20, 30, 40 cm). The experiment was carried out using the Split-Plot Design method according to the Randomized Complete Block Design (RCBD) with three replicates and in each replicate were 18 treatments with two factors the first, the distances between plants with three distances (20, 30, 40 cm), which was put in main plots and NPK fertilizer at three levels (16.6, 20.8, 25 g Plant⁻¹) and in two batches amounted to (8.3, 10.4, 12.5 g plant⁻¹), which was placed in the sub-plots and symbolized by (C₈, C₁₀, C₁₂). The second batch of the remaining and supplemented fertilizer from NPK fertilizer (20:20:20) was added. On 31/5/2017 the plants were harvested and transported to the laboratory, where they weighed. The experimental unit was 3 m in length and 1 m in width. The differences between the averages tested according to the Least Significant Difference Test (L.S.D.) [10]. At the end of the experiment, the following characteristics were calculated as an average of four plants randomly taken:

2.1 Studied traits.

Four plants were randomly taken from each experimental unit for each replicate. The following characteristics were measured:

2.1.1 The characteristics of vegetative growth:

1. The height of the plant (cm plant⁻¹): It was measured from where the plant was contacted with the soil to the highest developing part of the plant.
2. The leaf area (cm² plant⁻¹): The foliar area was measured by taking samples of the leaves of plants from each experimental unit and for each treatment. It was measured by the sensitive scale and then cut from it with a known diameter (with an area of 4 cm²) and then weighed with the scale and by using the following formula, the area was measured:

   \[ \text{Area of one leaf} = \frac{\text{area of harvested part of plant leaves} \times \text{area of full leaf weight}}{\text{Weight of the section cut}} \]

3. Percentage chlorophyll in the plant: The percentage of chlorophyll in eggplant leaves was estimated by a Chlorophyll meter, type SPAD-502, that were taken randomly for each replicate, then averaged [11] and were measured in SPAD unit.
4. Total number of leaves (leaf plant⁻¹): The total number of leaves was calculated in each plant for each experimental unit.
5. Average number of branches (branch plant⁻¹): The number of main branches for each plant was calculated at the end of the season, and then the average was calculated for a plant.
2.1.2 Characteristics of the yield and its components

6. Weight of a Single Fruit (g fruit⁻¹): This attribute was calculated at the end of the season by dividing the yield of the experimental unit by the number of harvested fruits.

7. Single plant yield (kg plant⁻¹): It was calculated by multiplying the number of fruits by the average weight of the fruit per experimental unit.

8. Early yield (kg plant⁻¹): It is calculated based on the first three collections [1, 12].

9. Total yield of a plant (kg plant⁻¹): It was calculated based on the yield of the experimental unit by collecting all the collections [13].

10. Greenhouse Productivity (kg m⁻²): The productivity of the greenhouse was calculated at the end of the season by dividing the productivity of one experimental unit by the number of its plants, and then multiplied by the total number of plants in the greenhouse.

3. Results and discussion

3.1 The characteristics of vegetative growth

Table 1. shows that there are differences in the effect of cultivation distances, chemical fertilizing concentrations, and the interaction between them in some characteristics of the vegetative growth of the eggplant plant.

Table 1. ANOVA analysis of the effect of cultivation distances, chemical fertilization concentrations and their interaction on the vegetative growth characteristics of eggplant.

| S.O.V     | d.f | MS.                         |
|-----------|-----|-----------------------------|
| Blocks    | 2   | 134.8829**                  |
| Treat.    | 8   | 4537.029**                  |
| D         | 2   | 150.5603**                  |
| C         | 2   | 41.48174                   |
| DxC       | 4   | 65.17844                   |
| Error     | 16  | 42.36932                   |
| Total     | 26  | 57.93056                   |

ns not significant; * significant at p < 0.05; ** significant at p < 0.01.

It is clear from Table No. (2) that there were significant effects of cultivation distances on the characteristics of vegetative growth, plant height and total number of leaves, as the distances between plants D₁ and D₂ had the highest averages for those characteristics, that were (55.185 cm leaf⁻¹ and 78.815 leaves plant⁻¹), respectively. The distance D₃ had the lowest mean of the two vegetative growth traits (48.469 cm plant⁻¹ and 66.259 leaves plant⁻¹), respectively. While the differences of the rest of the traits were not significant. The reason may be that the high plant density increases the height of the plant as a result of competition for light and the hormonal effect (oxines) that leads to the elongation of the cells in the stem, while the plant height decreases relative to the low plant density because there is no competition for light and breakdown of oxins [14]. This is consistent with the findings of [7].

Table 2. indicates that there is a significant effect at p < 0.01 of the chemical fertilizer concentrations on the characteristics of plant height, foliar area, total number of leaves and number of branches, so treatment C₁ gave the highest values for the characteristics of the vegetative growth, which reached (56.761 cm plant⁻¹, 117.195 cm² plant⁻¹, 82.519 leaves plant⁻¹ and 5.481 branches plant⁻¹), respectively. The treatment C₂ gave the lowest values for the characteristics of the vegetative growth, the height of the plant and the leaf area reached (48.625 cm plant⁻¹ and 74.653 cm² plant⁻¹) and the treatment C₃ gave the lowest values for the vegetative growth characteristics, the total number of leaves and the number of branches that reached (67.519 leaves plant⁻¹ and 4.296 branches plant⁻¹). The percentage of chlorophyll in the plant was not significantly affected.
Table 2. Effect of cultivation distances, chemical fertilization concentrations and their interaction on the characteristics of vegetative growth of eggplant.

| Treatments | Plant height (cm plant⁻¹) | Foliar area (cm² plant⁻¹) | % Chlorophyll in leaves | Number of leaves (leaf plant⁻¹) | Number of branches (Branch plant⁻¹) |
|------------|---------------------------|---------------------------|-------------------------|-------------------------------|-----------------------------------|
| **Distances** |                           |                           |                         |                               |                                   |
| D1         | 55.185                    | 103.861                   | 47.274                  | 75.037                        | 4.852                             |
| D2         | 55.163                    | 95.493                    | 46.599                  | 78.815                        | 4.926                             |
| D3         | 48.469                    | 100.867                   | 43.264                  | 66.259                        | 4.444                             |
| **L.S.D. 0.01** | 19.35412                 | ns                        | ns                      | 43.28419                      | Ns                                |
| **Fertilizer concentrations** |                           |                           |                         |                               |                                   |
| C1         |                           |                           |                         |                               |                                   |
| D1         | 56.761                    | 117.195                   | 43.769                  | 82.519                        | 5.481                             |
| D2         | 53.430                    | 108.372                   | 44.584                  | 67.519                        | 4.296                             |
| D3         | 48.625                    | 74.653                    | 48.784                  | 70.074                        | 4.444                             |
| **L.S.D. 0.01** | 19.35412                 | ns                        | ns                      | 43.28419                      | Ns                                |
| **Distances X Fertilizer concentration** |                           |                           |                         |                               |                                   |
| D1         |                           |                           |                         |                               |                                   |
| C1         |                           |                           |                         |                               |                                   |
| D1         | 62.577                    | 113.033                   | 39.430                  | 91.444                        | 6.556                             |
| C2         | 57.752                    | 110.778                   | 54.259                  | 66.556                        | 4.000                             |
| C3         | 45.225                    | 87.773                    | 48.133                  | 67.111                        | 4.000                             |
| D1         | 58.678                    | 124.067                   | 50.793                  | 93.778                        | 5.111                             |
| C2         | 53.161                    | 108.311                   | 42.719                  | 74.889                        | 4.222                             |
| C3         | 53.650                    | 54.100                    | 46.285                  | 67.778                        | 4.444                             |
| D2         | 49.028                    | 114.486                   | 41.085                  | 62.333                        | 4.778                             |
| C2         | 49.378                    | 106.028                   | 36.774                  | 61.111                        | 4.667                             |
| D3         | 47.000                    | 82.086                    | 51.933                  | 75.333                        | 3.889                             |
| **L.S.D. 0.01, 0.005, 0.00** | 0.01=7.17756              | ns                        | 9                       | 0.01=16.05213                 | 0.00=1.08738                      |
| ns not significant; * significant at p <0.05; ** significant at p <0.01. |

3.2. Characteristics of the yield and its components

Table No. 3 shows that there are differences in the effect of cultivation distances, chemical fertilizing concentrations, and the interference between them in the characteristics of the yield and its components for the eggplant plant, some of which were affected significantly, while others were not significantly affected.

Table 3. ANOVA analysis of the effect of cultivation distances, chemical fertilizer concentrations and their interaction on yield characteristics and components of eggplant..

| S.O.V             | d.f | A single fruit weight | A single plant yield | Early yield | Total yield of a plant | Productivity of glass house |
|-------------------|-----|-----------------------|----------------------|------------|------------------------|-----------------------------|
| Blocks            | 2   | ns                    | ns                   | Ns         | Ns                     | Ns                          |
| Treat.            | 8   | ns                    | ns                   | Ns         | Ns                     | Ns                          |
| D                  | 2   | 323.697ns             | 9.000053 ns          | 0.73087*   | 3.17261**              | 0.99667**                   |
| C                  | 2   | 51.737ns              | 0.000058 ns          | 0.18176ns  | 1.04898ns              | 0.01659 ns                  |
| DxC                | 4   | 481.065ns             | 0.000083 ns          | 0.73864*   | 2.27780*               | 0.04816 ns                  |
| Error             | 16  | 343.095               | 0.00030              | 0.15737    | 0.48296                | 0.03287                     |
| Total             | 26  | ns                    | ns                   | Ns         | Ns                     | Ns                          |

ns not significant; * significant at p <0.05; ** significant at p <0.01.
reached (62.577 cm plant$^{-1}$ and 6.56 branches plant$^{-1}$) and the treatment of D$_1$C$_2$ and D$_2$C$_1$ at a significant level $p<0.05$ in the two characteristics of chlorophyll in the plant reached (54.26%) and the total number of leaves (93.78 leaves plant$^{-1}$), respectively, and the number of branches in D$_3$C$_3$ treatment was (3.89 branches plant$^{-1}$).

Likewise, the interference treatment D$_1$C$_1$ had a significant effect at a significant level $p<0.05$ on giving the highest values characteristics.

Also, it did not show any significant effects of the compound chemical fertilizer concentrations in all the studied consistent with the findings of [7].

The increase in the yield of the plant may be due to the formation of a good vegetable group and as a result, new sugars will accumulate to help increase the speed of cell division and thus increase the size of the vegetative group [15] and this in turn led to an increase in the amount of carbohydrates manufactured in the source and transfer to sink storage sites produce an increase in the number of fruits in a plant and then an increase in the weight of the fruit [16], all of which led to an increase in

| Treatments | Weight of a fruit (g fruit$^{-1}$) | Yield of a plant (kg Plant$^{-1}$) | weight of early fruits (kg plant$^{-1}$) | weight of total fruits (kg plant$^{-1}$) | Plastic house productivity (kg m$^{-2}$) |
|------------|-----------------------------------|-----------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| Distans    |                                   |                                   |                                        |                                        |                                        |
| D$_1$      | 118.365                           | 0.131                             | 1.537                                  | 3.378                                  | 1.348                                  |
| D$_2$      | 115.388                           | 0.145                             | 1.327                                  | 2.663                                  | 0.851                                  |
| D$_3$      | 106.814                           | 0.143                             | 0.973                                  | 2.200                                  | 0.716                                  |
| L.S.D. 0.05, 0.01 | ns | ns | 0.05=0.945809 | 0.01=3.952143 | 0.01=1.0310207 |
| Fertilizer concentration |                                   |                                   |                                        |                                        |                                        |
| C$_1$      | 131.080                           | 0.142                             | 2.098                                  | 4.687                                  | 1.423                                  |
| C$_2$      | 116.891                           | 0.124                             | 1.748                                  | 3.371                                  | 1.410                                  |
| C$_3$      | 107.122                           | 0.126                             | 0.765                                  | 2.077                                  | 1.209                                  |
| C$_4$      | 120.816                           | 0.120                             | 1.324                                  | 2.757                                  | 0.681                                  |
| D$_1$      | 118.805                           | 0.155                             | 1.094                                  | 2.306                                  | 0.918                                  |
| C$_5$      | 121.559                           | 0.160                             | 1.562                                  | 2.924                                  | 0.954                                  |
| C$_6$      | 95.753                            | 0.129                             | 0.881                                  | 1.915                                  | 0.737                                  |
| D$_2$      | 122.587                           | 0.155                             | 0.899                                  | 2.332                                  | 0.734                                  |
| C$_7$      | 121.102                           | 0.145                             | 1.139                                  | 2.353                                  | 0.676                                  |
| L.S.D. 0.05 | ns | ns | 0.05=0.565542 | 0.05=0.990731 | ns |

The results showed in Table 4. indicate that there was no significant effect of cultivation distances on the characteristics of the yield and its components, the weight of a single fruit and the yield of a single plant, while the effect was significant in the rest of the studied characteristics, as the distance between plants exceeded (D$_1$ = 20 cm) in giving the highest averages for the attributes of the yield and its components, the early yield (at a significant level $p<0.05$) and the total yield of the plant and the productivity of the greenhouse at a significant level $p<0.01$ as it reached (1.537 kg plant$^{-1}$, 3.378 kg plant$^{-1}$ and 1.348 kg m$^{-2}$ ) respectively, while the distance between plants (D$_3$ = 40 cm) gave the lowest value to the mean of the yield characteristics and its components, the early yield and the total yield of the plant and the productivity of the greenhouse as they reached (0.973 kg plant$^{-1}$, 2.200 kg plant$^{-1}$ and 0.716 kg m$^{-2}$ ) respectively. The reason for increasing the total yield of the unit area may be due to an increase in the number of fruits per plant in the narrow distance compared to the wide distances. This is consistent with the findings of [7].

Also, it did not show any significant effects of the compound chemical fertilizer concentrations in all the studied characteristics.

Likewise, the interference treatment D$_1$C$_1$ had a significant effect at a significant level $p<0.05$ on giving the highest values of yield and its components, early fruit weight and total fruit weight reached (2.098 kg plant$^{-1}$ and 4.69 kg plant$^{-1}$), respectively. The interference factors D$_3$C$_3$ and D$_2$C$_1$ also had a significant effect on giving the lowest values for the early fruit weight and total fruit weight attributes (0.765 kg plant$^{-1}$ and 1.92 kg plant$^{-1}$), respectively.

The increase in the yield of the plant may be due to the formation of a good vegetable group and as a result, new sugars will accumulate to help increase the speed of cell division and thus increase the size of the vegetative group [15] and this in turn led to an increase in the amount of carbohydrates manufactured in the source and transfer to sink storage sites produce an increase in the number of fruits in a plant and then an increase in the weight of the fruit [16], all of which led to an increase in
the yield of a single plant and thus increased the total production of the greenhouse. These results are consistent with what other researchers found [17].

We conclude from this study that the studied growth characteristics were significantly affected by the interaction between the cultivation distances parameters and the added chemical fertilization concentrations, except for the characteristic of the leaf area, which was not significantly affected. Likewise, the interference treatment had a significant effect on giving the highest values of the yield characteristics and its components, the weight of the early fruits and the total weight of the fruits. The other characteristics studied were not significant.

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