A Study of the Water Requirement of the Eggplant Crop (Solanum melongena) Using the Techniques of Localized Drip Irrigation and its Comparison with the Traditional Surface Irrigation

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Abstract. The results showed that the total water consumptive use of the drip irrigation technique (irrigation line to planting line) was 5967 m$^3$ ha$^{-1}$, while the production approached 121.06 tons ha$^{-1}$. The total water use efficiency was 20.3 kg m$^{-3}$ ha$^{-1}$, and the percentage of irrigation water savings compared to the control was 42.6%. The increase in production over the control was 20%, and the yield per square meter was 12.1 kg, while the total water consumption of the drip irrigation technology (irrigation line for two cultivation lines) was 6679 m$^2$ ha$^{-1}$ with a yield of 110.78 tons ha$^{-1}$. The total water use efficiency was 16.6 kg m$^{-3}$ ha$^{-1}$ and the percentage of irrigation water savings compared to the control was 35.4%, the increase in production compared to the control was 9%, and the yield per square meter was 11.1 kg, while the total water consumption of the (traditional surface irrigation) technology reached 10,965 m$^3$ ha$^{-1}$ with a yield of 101.22 tons ha$^{-1}$. The total water use efficiency was 9.2 kg m$^{-3}$ ha$^{-1}$ and the yield per square meter was 10.1 kg. It was found that the drip irrigation technique (an irrigation line for a planting line) gave the highest production with the least amount of irrigation water compared to other methods, taking into account that the drip irrigation technique (a hazardous for two planting lines) was better in terms of saving in the cost of the lines.

1. Introduction

Iraq is considered one of the countries with limited water resources compared to the arable areas, hence, the irrigated crops do not exceed 27% of the total arable land due to lack of water, large losses in irrigation canals and the use of traditional irrigation methods. Due to the losses which reach 60%, the development of irrigation methods and techniques and rationalization of water use is an urgent necessity that must be taken as one of the main priorities in developing irrigated agriculture and improving its production. The losses in irrigation water by 50-40% of (GR) dripping, the horizontal expansion of the irrigated areas and the increase of production in terms of quantity and quality all require keen investigation.

For instance, [1] carried a study to determine the effect of deficient irrigation on Solanum melongena Crop in the station of Yenisehir Vocational School of Uludag University in Bursa, Turkey, during the 2007 planting season. The irrigation system used was full irrigation (1.00 K1cp), and three deficit
irrigation treatments (K2cp, K3cp, and K4cp corresponding to 0.75, 0.50, and 0.25 of cumulative evaporation). The non-quenching treatment (K5cp) was also designed for the purpose of control. The applied irrigation water volumes were changed between 85 and 464 mm, and water consumption was varying from 170 to 472 mm. The eggplant yield, length, diameter, weight and dry matter were significantly affected by the level of irrigation water. The highest yield was obtained with an average of 62 tons hectares K1cp. The crop yield response factor (KY) for eggplant was found to be 1.14. Water Use Efficiency (WUE) and the irrigation water use efficiency (IWUE) for K2cp treatment were calculated to be 13.16 and 10.63 kg m\(^{-3}\). These were the highest WUE and IWUE values. K2cp (75%) can be recommended as the most effective irrigation level for drip-irrigated eggplant under the condition of few water resources.

Also, [2] studied the effect of different drip line depths on water use for eggplant under semi-arid climate in Tunisia, and confirmed that the interaction between climate, soil and crop production presents an arrangement that requires scientific knowledge to improve productivity. The aim of the study was to evaluate and compare the effect of drip and subsurface irrigation in semi-arid regions on soil water content, yield and water use efficiency. The results showed that the drip buried at a height of 0.20 m allowed to improve the yield by about 14% compared to conventional drip irrigation. Hence, it was concluded that water use efficiency (WUE) differed little compared with drip line depth, whereas IWUE resulted in more sensitivity to drip line depth. In general, it was demonstrated that when the depth of lateral drip increased, the IWUE increased.

In addition, [3] conducted field experiments at a pilot station for Northwest A&F University and the Soil Institute and Rationalization of water consumption in China. The experiment included the cultivation of eggplant by three irrigation methods, namely, the traditional irrigation, constant irrigation and alternative irrigation. The study demonstrated the effect of the different irrigation methods on the growth of eggplant in the different stages of growth. The activity of eggplant roots in the flowering stage was the largest, followed by the seedling stage. In three stages of growth, root activity in alternate irrigation was the greatest in all treatments, the early and late yield of alternate irrigation was greater than the conventional irrigation and constant irrigation. The early yield of eggplant with constant irrigation was greater compared with the traditional irrigation, and the late yield was smaller than the traditional irrigation. The alternative irrigation in eggplant was the highest in all treatments, for 66.59 kg, which was higher than the conventional irrigation. Constant irrigation was 14.11% and 27.16% for water use efficiency and eggplant yield. The alternate irrigation was 37.16 kg cm\(^{-2}\) mm\(^{-1}\) and 29.81 kg cm m\(^{-2}\) mm\(^{-1}\), which is higher than the constant irrigation and conventional irrigation which was 99. The research aims at:

1. Determining the net and total water needs using drip irrigation methods according to the different growth stages and within one water treatment (depletion 10% of field capacity).
2. Determining the irrigation interval between irrigations.
3. Studying the relationship between the yield and irrigation water used.
4. Calculation of the crop coefficient, (Kc), depending on the mathematical relationships used in estimating the reference evapotranspiration (ET\(_{0}\)) [4], [5] evaporation from the evaporation pan A-class and Ivanov equation)
2. Materials and Methods

2.1. Study site

The study was conducted at the feed research station in Haditha City, west of Iraq during 2021. The area of the experimental unit was 1736 m², located at a longitude 34°30.41′30″N and latitude 42°34.08′30″E). The area is characterized as hot and dry, and relatively cold in winters and hot, dry in summers.

The prevailing soil was a silt loam texture with 428 mg kg⁻¹ sand, 528 mg kg⁻¹ silt and 44 mg kg⁻¹ clay. The soil was classified as typic turifluvents. The soil bulk density is 1.31 gm cm⁻³, with a porosity of 0.55, the available water is within the limits of 0.14, the soil pH=8.7. It is considered from the non-saline soils as the average electrical conductivity of the saturated soil paste extraction = 0.6 dSm⁻¹, and the content of both available phosphorous and total nitrogen is low and poor in organic matter (0.5 Mg kg⁻¹).

![Figure 1. The location of the study area, Source: [6]](image)

2.2. Experiment design

The lay out of the experiment was Randomized Complete Block Design with three replications and the treatments were allocated as follows:

1. The first treatment: an irrigation line for a planting line.
2. The second treatment: an irrigation line for two cultivation lines.
3. The third treatment: a conventional surface irrigation method.
Each treatment consists of three replicates, and each replicate (experimental plot) consists of four agricultural lines with a length of 40 m, and the distance between the lines was 70 cm and between the plants on one line it was 50 cm.

The first and second treatments were irrigated by using the drip irrigation network type (GR). The distance between the drippers was 0.40 m, with a discharge of 4 liters hour$^{-1}$, and the operation pressure 100 Kpa was used.

The third treatment was irrigated using the traditional surface irrigation with a polyethylene tube, and the depth of irrigation water applied was estimated by using a counting meter.

2.3. Description of the drip irrigation system

The drip irrigation system used consists of two main components (a) a control unit and (b) network lines. The control unit consists of a pump, disk filters, control valves and a water flow meter. The system is also provided with a fertigation equipment of a venture injector (25.4 mm in-diameter) and fertilizer tank. Distribution lines network consists of polyethylene (PE) pipe manifolds (display and discharge) for each plot. Irrigation laterals of 16 mm in-diameter and 40m in length had in-line emitters spaced 0.4m apart, each delivering (manufacturing discharge = 4 L/h) at pressure of 1 bar. Drip irrigation lines were spaced 0.8 m apart. Thirty six emitters from six lateral lines were evaluated before cultivation, 6 emitters per each chosen lateral line. The first emitter is located in the front of the lateral and the others spaced by 15 emitters. The first lateral line is near from the valve and the others spaced by 15 lateral lines.

2.4. The relationships used to study the results

2.4.1. Calculation of reference evapotranspiration (ET$_o$)

Reference evapotranspiration is defined as the maximum evaporation rate possible from a free water surface or a completely covered green surface. The purpose of determining its value in one of the experimental and theoretical relationships is to find an equation by which the water consumption rate of a crop can be calculated in specific climatic conditions.

Using the values of the experimental yield coefficient ($k_c$), this is obtained through field experiments

$$ET_a = ET_o \times k_c... (1)$$

Whereas

$ET_a$ = water requirement of the crop (for the monthly or annual growing season) expressed as (mm or m$^3$ ha$^{-1}$)

$ET_o$ = maximum possible evaporation rate calculated by one of the experimental or theoretical relationships (mm or m$^3$ ha$^{-1}$)

$K_c$ = the crop coefficient of the monthly or annual yield or the average during the growing period. The following relationships were used to calculate (ET$_a$):

1. Penman relationship:
\[ ET_o = [W \cdot R_n + (18 - W) \cdot F(U) \cdot (e_a - e_d)] \] \quad \text{(2)}

Whereas:

\( ET_o \) = Previously defined

\( W \) = weight factor which expresses the effect of radiation on \( ET_o \) and is related to altitude and temperature

\( R_n \) = net radiance equivalent to \( ET_o \), which is the difference between incoming and reflected radiation at the surface of the soil or water \( \text{mm day}^{-1} \)

\( F(U) \) = wind factor and is estimated by the relationship

\[ F(U) = 0.27 \left(1 + \frac{U}{100}\right) F(U) = 0.27 \left(1 + \frac{U}{100}\right) \] \quad \text{...... (3)}

Where the wind speed is calculated at a height of 2 m \( \text{km/day} \)

\( (e_a - e_d)(e_a - e_d) \) = The difference between the saturated water vapor pressure at average temperature and the real mean water vapor pressure in millibars

\( C \) = correction factor and correlates with maximum relative humidity, wind speed and solar radiation.

2.4.2. BLANEY-CRIDDLE FORMULA

It is an empirical relationship that depends in determining the value of \( ET_o \) on the average daily temperature and true brightness.

\[ ET_o = C \cdot P(0.46t + B) \] \quad \text{...... (4)}

\( (n/N - Rh_{min})(n/N - Rh_{min}) \)

Whereas:

\( ET_o \) =Reference evapotranspiration (mm day\(^{-1}\))

\( T \) = daily average temperature.

\( P \) = Percentage of daily brightness hours.

\( C \) = correction factor for minimum relative humidity, theoretical and actual brightness, and wind speed.

2.4.3. Ivanovo’s equation

\[ ET_o = 0.0018 \times (25 + T)^2 \times (100 - a) \times K_o \] \quad \text{...... (5)}

Whereas:
3rd Scientific & 1st International Conference of Desert Studies-2021 (ICDS-2021) IOP Publishing
IOP Conf. Series: Earth and Environmental Science 904 (2021) 012045 doi:10.1088/1755-1315/904/1/012045

where:

\( E_{\text{o}} \) = Reference evapotranspiration (mm day\(^{-1}\))

\( T \) = daily average temperature (\( ^{\circ} \text{C} \))

\( a \) = mean relative humidity (%)

\( K_e \) = climate coefficient, shows the change of weather factors under the influence of irrigation, and it ranges between (0.75-1).

2.4.4. Evaporation through Pan Class-A

It is a circular basin with a diameter of (121) cm and a depth of (25.5) cm. It is made of zinc-coated iron, with a thickness of 0.8 cm. It is installed on a wooden base in a horizontal position. It is filled with water to a height of (20) cm. The water level should not be more than (7) cm from the upper edge. For the pan, the water is renewed regularly to get rid of turbidity and other suspended matter, and it is painted annually with aluminum paint if it is not zinc-coated.

\[ E_{\text{T}} = K_p \times E_{\text{pan}} \] ........ (6)

Whereas:

\( E_{\text{o}} \) = crop coefficient

\( E_{\text{pan}} \) = the amount of water evaporating from the surface of the water

\( K_p \) = correction factor related to relative humidity, wind speed, and environment surrounding the device (planted - barren).

2.4.5. Relationships used in calculating the water requirement and the irrigation system

Water consumption): The total water requirement is expressed by the amount of water consumptive by the plant during the useful period (growing season, ten days, daily). It is implemented according to the stages of growth, and is determined by the following relationship:

\[ ET = M + 10P + (W_1 - W_2) \] ........ (7)

Whereas:

\( ET \) = water consumption (water requirement) and it is equal to evapotranspiration and total evaporation from the soil surface for the period (day, month, ten days, growing season) (mm day\(^{-1}\), mm month\(^{-1}\), m\(^3\) ha\(^{-1}\) day\(^{-1}\), m\(^3\) ha\(^{-1}\) month\(^{-1}\), m\(^3\) hectare\(^{-1}\) ten days\(^{-1}\)).

\( P \) = Rainfall rate, mm, for a given guarantee probability during the calculation period.

\( W_1-W_2 \) = Average humidity available at the start and end of the period, mm, m\(^3\) ha\(^{-1}\)

\( M \) = net irrigation rate, m\(^3\) ha\(^{-1}\), for the entire growing season and equal to the total irrigations provided of the plant.


\[ M = ET - 10 \times \sigma \times P - (W_1 - W_2) = m \ldots(8) \]

Whereas:

\[ m = 10 \times H \times \alpha \times (B_1 - B_2)\ldots(9) \]

10= conversion factor for calculating the irrigation rate per hectare (m3 hectare-1)

H = the effective depth of the roots and varies according to the stages of growth

\[ \alpha = \text{soil bulk density (mg m}^3\text{)} \]

B1 = soil field capacity (%).

B2 = the minimum moisture suitable for the crop and it changes from one plant to another.

2.4.6. Calculation of the crop coefficient of the plant \( (K_c) \).

The daily, for 10 days, and monthly water consumption is calculated for the entire growing season based on the water balance equation (equation7) after determining the soil moisture content by gravimetric method and using the different above mentioned methods after determining the ET value for the period. The crop coefficient is calculated for the entire different growth stages by using equation (10).

\[ K_c = \frac{ET}{ET_o} \ldots(10) \]

\( K_c \) = crop coefficient

\( ET_o \) = reference evapotranspiration.

3. Results and discussion

The first water treatment: irrigation line for one planting line. It is clear from the analysis of the water consumption schedule according to the phonological stages, (Table 1) that in the planting and vegetative growth stage, the net water consumption reached 35 m\(^3\) ha\(^{-1}\), which formed 0.67% of the total net water consumption during the continuation of this stage, which is 14 days with a daily net consumption rate of 2.51 m\(^3\) ha\(^{-1}\).

Table 1. Water consumptive use based on the phonological stages of the eggplant crop, the first water treatment (irrigation line for one planting line)

| water consumption | phonological stages | average |
|--------------------|---------------------|---------|
|                    | stage of seedling and vegetative growth | vegetative growth stage | The stage of flowers, knots and picking |

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The net water consumption in relation to the reduction coefficient (m³ h⁻¹)

| Stage Continuity (day) | Stage |
|------------------------|-------|
| 20/5-2/6               | 3/6-23/6 | 24/6-10/11 |
| 14                     | 21      | 139       |
| 142                    | 2.69    | 96.65     |
| 5291                   | 100     | 174       |

The net water consumption in relation to the reduction factor (%)

| Stage Continuity (day) | Stage |
|------------------------|-------|
| 20/5-2/6               | 3/6-23/6 | 24/6-10/11 |
| 0.67                   | 2.69    | 96.65     |
| 100                    | 174     | 15        |

The net daily consumption in relation to the reduction factor (m³ h⁻¹)

| Stage Continuity (day) | Stage |
|------------------------|-------|
| 20/5-2/6               | 3/6-23/6 | 24/6-10/11 |
| 2.51                   | 6.78    | 36.79     |
| 15                     | 114     | 15        |

The average rate of irrigation in relation to Reduction coefficient (m³ ha⁻¹)

| Stage Continuity (day) | Stage |
|------------------------|-------|
| 20/5-2/6               | 3/6-23/6 | 24/6-10/11 |
| 50                     | 71      | 227       |
| 114                    | 15      | 25        |

Table 2 showed the water consumptive use according to the phonological stages, seedling and vegetative growth stages, the net water consumptive use during this stage approached to 35 m³ ha⁻¹, which formed 0.60% of the total net water consumptive use during the continuity of this stage, which took 14 days with 2.53 m³ ha⁻¹ of daily net consumptive use average. On the other hand, the net water consumptive use during the vegetative growth stage was 122 m³ ha⁻¹, which formed 2.06% of the total net water consumptive use during the continuity of this stage which took 21 days with 5.81 m³ ha⁻¹ of daily net consumptive use average. However, the water consumptive use approached to 5761 m³ ha⁻¹ during the flowering, boot and harvesting stage, which took 139 days with 41.44 m³ ha⁻¹ daily net consumptive use average. The number of irrigations for this treatment was 25 irrigation, while the net water consumptive use approached to 5291 m³ ha⁻¹ during the entire season, however the yield was 121,060 tons ha⁻¹.

3.1. The second water treatment is an irrigation line for two cultivation lines

Table 2 showed the water consumptive use based on the phonological stages of the eggplant crop, the third water treatment (irrigation line for two cultivation lines)

| phonological stages         | water consumption |
|-----------------------------|-------------------|
| stage seedling and vegetative growth | 20/5-2/6 | 3/6-23/6 | 24/6-10/11 |
| stage flowers, knots and picking | 5761   | 5918     |
| The net water consumption in relation to the reduction coefficient | 35     | 122      | 121,060 |
3.2. The third water treatment (traditional surface)

Table 3 showed the water consumptive use according to the phonotypical stages of eggplant crop. The net water consumptive use in the seedling and vegetative growth stage was 35 m³ ha⁻¹, which formed 0.61% of the total net water consumption during the entire of this stage, which took 14 days with 2.53 m³ ha⁻¹ daily net consumptive use average. On the other hand, the net water consumption during the vegetative growth stage was 120 m³ ha⁻¹, which formed 2.08% of the total net water consumption during the entire of this stage as well, which took 21 days, with 5.72 m³ ha⁻¹ daily net consumptive use average.

Table 3. Water consumptive use based on the phonological stages of the eggplant crop, the third water treatment (surface- traditional)

| phonological stages | seedling and vegetative growth stages 20/5-2/6 | vegetative growth stage 3/6-23/6 | flowering, boot and harvesting stages 24/6-10/11 | average (
m³ ha⁻¹) |
|---------------------|-----------------------------------------------|---------------------------------|-----------------------------------------------|------------------|
| The net water consumptive use in relation to the reduction coefficient (m³ ha⁻¹) | 35 | 120 | 5627 | 5783 |
| The net water consumption in relation to the reduction factor (%) | 0.61 | 2.08 | 97.31 | 100 |
| Stage Continuity (day) | 14 | 21 | 139 | 174 |
| The net daily consumption in relation to the reduction coefficient (m³ ha⁻¹) | 2.53 | 5.72 | 41.48 | 16 |
| The average rate of irrigation in relation to the reduction coefficient (m³ ha⁻¹) | 50 | 69 | 239 | 119 |
| number of irrigations | 2 | 2 | 23 | 27 |

The net water consumptive use during the flowering, boot and harvest stage approached to 5627 m³ ha⁻¹, which formed 97.31% of the total net water consumptive use during the entire of this stage, which took 139 days with 40.48 m³ ha⁻¹ daily net consumptive use average. On the other hand, the net water consumption reached 5783 m³ ha⁻¹ during the entire season. The average yield was 101.22 tons ha⁻¹, while the number of irrigations reached 27.

3.3. Crop coefficient (k<sub>c</sub>)

Crop coefficients are properties of plants used in predicting evapotranspiration. Table 4 and Figure 2 showed that the value of the crop coefficient is low in the seedling and vegetative growth stages, while
the value was increased in all relationships in the vegetative, flowering, boot and yield growth stages, and then decreased until the end of the stages. The lowest value of the crop coefficient was noted in the seedling and growth stages. It has been noted that the values of the crop coefficient were converging in this stage. The data also showed that the value of the average of crop coefficient according to the relationships was 0.69, 0.51, 0.61 and 0.65 for the Penman, Blaney Criddle, Ivanov and Class-A pan, respectively.

3.4. **Phonological stages**

Water consumptive use during seedling, vegetative, flowering, boot and yield growth stages for the period 4/6 to 10/11, 3/6 to 23/6 and 20/5 to 2/6 was 5627, 120, 35 m³ ha⁻¹ while the net water consumptive use in relation to the reduction factor (%) approached to 97.31, 2.08, 0.61 m³ ha⁻¹. On the other hand, the continuity of the stages was 139, 21, and 14 days. Net daily consumption in relation to the reduction factor was 40.48, 5.72, 2.53783 m³ ha⁻¹ and the number of irrigations was 23, 2 and 2 as average of the irrigation rate and the consumptive use was 239, 69 and 50 m³ ha⁻¹ in relation reduction factor.

Table 4. Comparison of the crop coefficient (Kc) according to the relations used for the treatment of a planting line irrigation line

| Months  | Penman | Blaney Criddle | Ivanov | evaporation pan-class-A |
|---------|--------|----------------|--------|-------------------------|
| May     | 0.27   | 0.20           | 0.28   | 0.30                    |
| June    | 0.34   | 0.27           | 0.33   | 0.34                    |
| July    | 0.69   | 0.54           | 0.71   | 0.53                    |
| August  | 0.73   | 0.58           | 0.78   | 0.74                    |
| September | 0.99  | 0.74           | 0.92   | 0.81                    |
| October | 1.09   | 0.81           | 0.81   | 0.95                    |
| November| 0.73   | 0.44           | 0.42   | 0.85                    |
| Kc      | 0.69   | 0.51           | 0.61   | 0.65                    |
3.5. Crop coefficient \( (K_c) \)

It was noted that the value of the crop coefficient is low in the stage of seedling and vegetative growth. The value increases in all relationships in the stage of vegetative growth, and during the flowering, boot and fruiting stage, and then decreases until the end of all stages. According to the relationships, they were 0.67, 0.72, 0.54 and 0.65 for each of Penman's equation, Blaney Criddle, Ivanov and Class-A evaporation pan, respectively (Table 5 and Figure 3). It was also observed that the value of the crop coefficient decreases in the seedling and vegetative growth stages, then the value of the crop coefficient increases in all relationships in the vegetative growth stage, then during the flowering, boot and fruiting stages, and then decreases until the end of the stages (Table 6 and Figure 3). It was found that the lowest value of the crop coefficient was observed in the seedling and vegetative growth stage, and the values of the crop coefficient converge in this stage.

These data also show that the average value of the crop coefficient according to the relationships are 0.70, 0.74, 0.55 and 0.66, for each of the Penman equation, Blaney Criddle, Ivanov, and evaporation pan class-A, respectively.

Table 5. Comparison of the crop coefficient \( (K_c) \) according to the relationships used for the treatment of an irrigation line for two cultivation lines

| Months     | Penman | Blaney Criddle | Ivanov | evaporation basin-a |
|------------|--------|----------------|--------|--------------------|
| May        | 0.27   | 0.20           | 0.28   | 0.30               |
| June       | 0.41   | 0.34           | 0.40   | 0.42               |
| July       | 0.78   | 0.62           | 0.81   | 0.60               |
| August     | 0.90   | 0.72           | 0.96   | 0.92               |
| September  | 1.16   | 0.87           | 1.08   | 0.95               |
Figure 3. Comparison of the crop coefficient ($K_c$) according to the relationships used for the treatment of two irrigation lines for two cultivation lines

Table 5. Comparison of the crop coefficient ($K_c$) according to the relationships used for a conventional surface irrigation treatment

| Months    | Penman | Blaney Ciddle | Ivanov | evaporation pas class-A |
|-----------|--------|---------------|--------|-------------------------|
| May       | 0.27   | 0.20          | 0.28   | 0.30                    |
| June      | 0.41   | 0.33          | 0.40   | 0.41                    |
| July      | 0.71   | 0.56          | 0.73   | 0.54                    |
| August    | 0.88   | 0.71          | 0.94   | 0.90                    |
| September | 1.09   | 0.81          | 1.02   | 0.89                    |
| October   | 1.07   | 0.80          | 0.80   | 0.94                    |
| November  | 0.78   | 0.48          | 0.45   | 0.91                    |
| $K_c$     | 0.74   | 0.55          | 0.66   | 0.70                    |
Figure 4. Comparison of the crop coefficient ($K_c$) according to the relationships used for surface irrigation.
### Table 7. Yield and its relationship to water consumptive use of eggplant crop

| Treatment                       | Water consumptive use | Yield kg ha\(^{-1}\) | Residual moisture m\(^3\) ha\(^{-1}\) | number of irrigations | Irrigation rate m\(^3\) ha\(^{-1}\) | Uniformity coefficient % | Water use efficiency kg ha\(^{-1}\) | Yield production increase over comparison% | Water saving in comparison with control |
|---------------------------------|-----------------------|----------------------|--------------------------------------|-----------------------|------------------------------------|-------------------------------|---------------------------------|---------------------------------------------|---------------------------------------|
|                                 | Net                   | Total                | theoretical                           | effective rain        | effective depth                    | total residual moisture       | theoretical | effective | Net | total |                                    |                                    |                                      |
| Irrigation line for planting line | 5291                  | 5967                 | 121060                               | 6081                  | 6757                               | 0                             | 1005           | 7087          | 2470 | 23    | 264                             | 294                             | 90                                   | 22.9                      | 20.3                  | 20  | 42.6 |
| Irrigation line for two cultivation lines | 5918               | 6679                 | 110780                               | 6848                  | 7609                               | 0                             | 950             | 7798          | 2470 | 28    | 245                             | 212                             | 90                                   | 18.7                      | 16.6                  | 9   | 35.6 |
| Traditional superficial         | 5783                  | 10965                | 101120                               | 6596                  | 11776                              | 0                             | 1041           | 7636          | 2462 | 27    | 244                             | 436                             | 56                                   | 17.5                      | 9.2                   | -   | -   |
4. Conclusions:

1. The drip irrigation technique (irrigation line for planting line) saved a large amount of water amounting to 42.6% compared to the control treatment and gave an increase in the yield by 20% compared to the control treatment.

2. The drip irrigation technique (one irrigation line for two planting lines) saved a quantity of water that reached 35.4% compared to the control treatment; and gave an increase in the yield by 9% compared to the control treatment.

3. The drip irrigation method (an irrigation line for two cultivation lines) is the best in terms of saving irrigation water and increasing production, while the irrigation method (an irrigation line for two cultivation lines) was the best in terms of saving the cost of pipes.

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