Estimation of evapotranspiration of maize under climatic conditions of Wasit governorate Iraq


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A field experiment was carried to study the effect of irrigation methods, soil mulching and polymer on water consumption and water use efficiency of maize in the karama area, Kut district, Wasit Governorate. The experiment consist of three irrigation methods, basin (B), furrow (F) and drip (D), while three treatment soil mulching and polymer in addition to control treatment, no mulch: M0,: mulch with wheat stubble: M1, Polymer granules: M2 and Soil mulching + polymer granules: (M3) were laid in a randomized complete block design with split plot arrangements and three replications. The results of study showed that not significant effect on grain yield between irrigation methods, while evapotranspiration and water use efficiency, had significant influence, the lowest average of actual evapotranspiration (ETa) of maize was (330.4 mm) with using drip irrigation method (D). The highest average of WUE was (3.88 kg. m⁻³) with drip irrigation. While soil mulching and polymer significantly affected on the grain yield, evapotranspiration and water use efficiency were obtained from M1, the lowest average of actual evapotranspiration (497.0 mm) with mulch wheat stubble and polymer granules (M3). The highest average of grain yield was (13.41 t.ha⁻¹) with mulch wheat stubble (M1). The results indicated that the kc of (M0 and M2) treatments higher than kc of (M1 and M3) treatments.

Keywords: Irrigation methods, soil mulching, polymer and evapotranspiration of maize.

INTRODUCTION

Water is one of the most important factors affecting crop production and its movement through the soil-plant atmosphere Al-Taey (2018). The efficient use of water by modern irrigation systems is becoming increasingly important in arid and semi-arid regions with limited water resources Bozkurt et al., (2011). The irrigation studies have made great achievements on improving the efficiency of water and ensuring food security, but still has great potential for improving water use efficiency in many field crops Bozkurt et al., (2011). Al-Taey et al., (2018), AL-Taey et al., (2018) ].The pressure of using water in agriculture sector is increasing to create ways to improve water use efficiency and taking a full advantage of available water. Adoption of modern irrigation techniques is needed to be emphasized to increase water use efficiency. Drip irrigation is the most effective way to convey directly water and nutrients to plants and not only save water but also increases yields of vegetable crops Douh, b. and Boujelben, A. (2011).The practice of spreading plant residue or any other material like straw on the soil surface to reduce water evaporation losses is called mulching. Mulch practices are used to conserve soil moisture and increase the yield of crops. Crop residues at the soil surface act as shade; serve as a vapor barrier against moisture losses from the
soil, causing slow surface runoff. Pervaiz et al., (2009). Mulch helps to improve the soil environment for optimum crop growth and yield. Mulches are either organic (derived from plant and animal materials) or in organic (plastic film). The most frequently used organic materials include plant residues such as straw, hay, peanut hull, compost; wood products such as saw dust, wood chips/shavings and animal wastes. Ndubuisi, M.C. (2009).

In arid and semi-arid regions of the world, intensive research on water management is being carried out and use of super-absorbent polymers (SAPs) may effectively increase water use efficiency in crops. Applying superabsorbent polymers in agriculture has significant role in increase of soil capacity of holding and absorbing water to resist drought conditions and reduction of bad effects of drought. Rafiei et al., (2013).Crop water use information can be used to schedule irrigation systems. Crop water use is directly related to evapotranspiration (ET). The ET information must be adjusted to correspond to the crop and climate. The crop coefficient (Kc) uses for account the actual evapotranspiration (ETa) by multiplying with reference evapotranspiration (ETO). There may be several crop coefficients used for a single crop throughout an irrigation season depending on the crop’s stage of development. Crop coefficients may also vary depending on how the evapotranspiration data has been calculated or obtained. World population is increasing day by day, which is likely serious threat to food security. This can be overcome by enhancing production of major crops. Maize is the third most important cereal crop in the world after wheat and rice with respect to area and productivity. Pervaiz et al., (2009).

The objectives of this study are to clear the effect of irrigation method, mulching soil on actual evapotranspiration of maize that planted under climate conditions of middle of Iraq and calculate the Kc of maize and its water use efficiency.

**MATERIALS AND METHODS**

A field experiment was conducted during the 2016 autumn season for maize growing in private farm of Karama area, Kut district, Wasit Governorate, the site has latitude of 33.260 N, longitude 45.910 E, of 19 m above mean sea level. The soil was clay loam and classified under a typic Torrifluvent. The site was planted with sorghum in the previous season. The field was prepared by ploughing for twice by using moldboard plow, and the direction of the second plough was adverse the first, at depth of 20-30 cm followed by smoothing and leveling, soil sampling was done at 0-10, 10-20, 20-30 and 30 - 40 cm depth, using a composite sampling method before tillage. The soil samples were processed by air drying and passing through a 2 mm sieve, some physical and chemical properties were determined by using standard procedures. Page et al., (1982).

The field experiment was conducted by using a randomized complete block design with split plot arrangements and three replications, each experimental plot area was 3.5m x 3m, the experiment included the following factors:

First- Irrigation methods include three treatments, which were randomly assigned to the main plot:
- Basin irrigation (B)
- Furrow irrigation (F)
- Drip irrigation (D)

A/FKRS’ – Soil mulching and polymer include three treatments in addition to the control treatment, were randomly assigned to the sub plot:
- Control (M0) without soil mulching.
- Soil mulching (M1) with wheat stubble (15 t. ha⁻¹).
- Adding polymer granules (M2) by mixing 1 gm of polymer with soil to 10 cm depth in the location of the seed.
- Soil mulching with wheat stubble + polymer granules (M3).

The drip irrigation system has a typical control unit consisted of a pump, fertilizer tank, centrifugal sand separator, disc filters, control valves, pressure gauges and a flow meter. Each plot had one valve to control water application. Main supply pipe of 50 mm diameter and length 12 m to deliver the desired discharge, and lateral pipes of 16 mm diameter with length 4 m connected to main pipe, discharge of dripper GR was 8 L. h⁻¹ at 0.75 bar operating pressure distances between crop rows was 0.75 m. Laterals pipes were placed at adjacent crop rows in experimental plots.

Monarch maize hybrid (F1) seeds its imported from Netherland by Nahar al-award Company and registered in ministry of agriculture under Euphrates name was planted at July 25 in 2016, received the same amount of fertilizer application at rates of 30 gm DAP (Di Amino Phosphate, 18:46:0) per m² and incorporated into the soil at planting, all plots received 40 gm per m² in form of urea (46% N), which was applied in banding along the rows on two doses, first when six leaves appears and second after 30 days of the first one. Weed and pest control was carried out as needed and was harvest at 9 November in 2016 after the completely maturity. Irrigation scheduling conducted at depletion of (50 %) from available water in soil depth 0 – 30 cm at different growth
The wetted zone under every dripper was measured by selected many sites to calculate wetted zone percent (Pw) of the total area that occupied by plant using the following equation (5):

\[ Pw = \frac{Sw}{Sr} \times 100 \]  

where: Pw = wetted zone percentage (%), Sw = Maximum diameter of wetted zone (m), Sr = Distance between plants rows (m).

The actual evapotranspiration (ETa) of individual plots of maize for the entire growing season was estimated by the standard water balance equation (18):

\[ ET = \pm \Delta S + (P + I + C) - (RO + DP) \]  

where: \( \Delta S \) is the change in soil water storage before sowing and after harvest measured in the profile (mm), P is the precipitation (mm), I is the irrigation (mm), C is upward flow into the soil profile (mm), RO is the surface runoff from each plot (mm), DP is the deep percolation out of the soil profile (mm). ΔS, P, C, RO and DP were assumed to be negligible in the study, because the soil water storage before sowing: irrigation after harvest, no precipitation during the growing season, the ground water table remained at a depth of about 3 m below the surface, as irrigation water was protected by 40 cm high bunds, as irrigation water was added at field capacity limits, respectively.

Regarding the information mentioned above, Eq (7) reduces to the following form

\[ ET = I \]  

Where: ET = actual evapotranspiration (mm), I = irrigation (mm).

The reference evapotranspiration (ET0) of maize through growing season was calculated from climatic meteorological date of kut meteorological station for growing season by using the following empirical equations:

1-Evaporation pan (class – A) equation (9):

\[ ET0 = kp \times Epan \]  

ET0: reference evapotranspiration (mm)

Kp: pan coefficient that depend on relative humidity and wind speed. Epan: pan evaporation (mm).

2-Kharrufa equation (19):

\[ ET_0 = CPT^{1.3} \]  

ET0 : Reference evapotranspiration (mm)

C: regional coefficient that calculated by using of climatic date for June, July and August months of kut meteorological station for last 20 year.

P: Percent of daylight hours at month relatively to its number in year.TC: monthly mean air temperature (C0)

3-Blaney and criddle equation (blaney and criddle, 1950):

\[ ET0 = C \left( 0.46 TC + 8.13 \right) \]  

E = (0.0311 TC + 0.24) \]  

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\[ ET = \pm \Delta S + (P + I + C) - (RO + DP) \]  

where: \( \Delta S \) is the change in soil water storage before sowing and after harvest measured in the profile (mm), P is the precipitation (mm), I is the irrigation (mm), C is upward flow into the soil profile (mm), RO is the surface runoff from each plot (mm), DP is the deep percolation out of the soil profile (mm). ΔS, P, C, RO and DP were assumed to be negligible in the study, because the soil water storage before sowing: irrigation after harvest, no precipitation during the growing season, the ground water table remained at a depth of about 3 m below the surface, as irrigation water was protected by 40 cm high bunds, as irrigation water was added at field capacity limits, respectively.

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ET0 : Reference evapotranspiration (mm)

C: regional coefficient that calculated by using of climatic date for June, July and August months of kut meteorological station for last 20 year.

P: Percent of daylight hours at month relatively to its number in year.TC: monthly mean air temperature (C0)
C = Corrected factor

The grain yield was estimated at the final harvest stage, the ears from each plot were separated, cleaned dried and weight separately, grain yield of each treatment was recorded with Kg. ha\(^{-1}\) individually and adjusted at 15.5 moisture. The water use efficiency was determined by dividing grain yield by evapotranspiration as following (7):

\[
WUE = \frac{GY}{ET} \quad \text{(13)}
\]

\(UE\) = water use efficiency (Kg. m\(^{-3}\)) \(GY\) = grain yield (Kg. ha\(^{-1}\))
\(ET\) = total water consumption of maize at growing season (m\(^3\). ha\(^{-1}\))

**Statistical analysis:**

Analysis of variance (ANOVA) was used to analyze the effects of the different treatments. ANOVA was performed at a 0.05 level of significance to determine whether the treatments were different. Multiple comparisons were made between the significant effects using the least significant difference (LSD) test at \(\alpha = 0.05\).

**RESULTS**

Table (1) illustrates that the lowest average of actual evapotranspiration (ET\(_a\)) of maize was (330.4 mm) with using drip irrigation method (D), while Basin and Furrow irrigation methods gave the highest average (651.8 and 652.3 mm) respectively. The results in Table 1 and Fig. (1) showed that actual evapotranspiration (ET\(_a\)) of maize was significantly affected (\(p \leq 0.05\)) by irrigation methods, soil mulching, polymer and interactions. The results illustrate that the lowest value of (ET\(_a\)) was (300.2 mm) of drip irrigation method (D) with mulching soil by wheat stubble and polymer granules (M3), while basin and furrow irrigation method (B, F) gave the highest value of ET\(_a\) (714.0, 713.9 mm) respectively, at without soil mulching (M0).

<table>
<thead>
<tr>
<th>Irrigation methods</th>
<th>Soil mulching and polymer</th>
<th>Average of irrigation methods (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin (B)</td>
<td></td>
<td>M0</td>
</tr>
<tr>
<td>Furrow (F)</td>
<td></td>
<td>714.0</td>
</tr>
<tr>
<td>Drip (D)</td>
<td></td>
<td>367.0</td>
</tr>
<tr>
<td>Average of mulching treatment (M)</td>
<td></td>
<td>598.3</td>
</tr>
</tbody>
</table>

LSD (0.05)

<table>
<thead>
<tr>
<th></th>
<th>0.6476</th>
<th>0.5049</th>
<th>0.8950</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>= I</td>
<td>= M</td>
<td>= I × M</td>
</tr>
</tbody>
</table>

**Figure (1)** Actual evapotranspiration (ET\(_a\)) of the study treatments and reference evapotranspiration (ET\(_0\)) calculated by kharrufa eq., Blaney-criddle eq., Epan eq. and evaporation values Epan. measured from evaporation pan.
The reason of this return to the increasing of amount of irrigation water that depleted and evaporated from the treatments that irrigated by basin and furrow methods comparatively with drip irrigation method (Table 2). The results showed that drip irrigation gave less seasonal actual evapotranspiration (ETa) which decreased by (49.31 and 49.35 %) compared with basin and furrow irrigation respectively. These results are similar to that obtained by Suleiman, W.M .(2014). Xiukang et al., (2014).

they added that drip irrigation gave the lowest mean of water consumption. Because the amount of irrigation water which added by drip irrigation method was the lowest in comparison with other irrigation methods (table.2), as that drip irrigation method works on adding water to soil slowly and maintain a constant proportion of moisture in root zone, that reduce evaporation and side losses including leaching Suleiman, W.M .(2014).

Table (1) indicates that the lowest average of actual evapotranspiration (497.0 mm) with mulch wheat stubble and polymer granules (M3), while control treatment (M0) gave the highest average (598.3 mm). Actual evapotranspiration (ETa) was reduced by 16.55%, 2.27% and 16.93% at mulching soil surface with wheat stubble (M1), polymer granules (M2) and wheat stubble+ polymer granules (M3) respectively in comparison with control (M0). The reason of this return to preserve moisture, improve soil, pleasant soil temperature and decrease moisture evaporation Zamir et al., (2013).

Moreover, mulches improve macro-porosity and structure of soil furthermore reducing runoff and evaporation losses Yaseen  et al., (2014) . These results are similar with Al-hadithi, (2002).

who explained that soil surface mulch with wheat straw gave the lowest evapotranspiration of maize plant. The date in (fig 1,2,3,4) and (Table.3) showed the actual evapotranspiration (ETa) through the different growth stages of maize crop (Germination, vegetative growth, flowering and maturity) and number of days for every growth stage which (7,44,18 and 39 days) respectively after the germination irrigation.

![Figure (2) Actual evapotranspiration (ETa) through stage of flowering of the study treatments](image-url)
Table 2. Effect of irrigation methods, soil mulching, polymer and interaction on average grain yield (t.ha⁻¹), average amount of irrigation water (m³.ha⁻¹) and water use efficiency (kg.m⁻³) during the autumn season 2016.

<table>
<thead>
<tr>
<th>Irrigation methods</th>
<th>Soil mulching and polymer</th>
<th>Average grain yield (t.ha⁻¹)</th>
<th>Average amount of irrigation water (m³.ha⁻¹)</th>
<th>water use efficiency (kg.m⁻³)</th>
<th>Average irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M0 M1 M2 M3 Average (I)</td>
<td>M0 M1 M2 M3 Average (I)</td>
<td>M0 M1 M2 M3 Average (I)</td>
<td></td>
</tr>
<tr>
<td>Basin (B)</td>
<td></td>
<td>11.39 13.09 11.81 13.01 12.32</td>
<td>7140 5988 6985 5959 6518</td>
<td>1.60 2.19 1.69 2.18 2.18</td>
<td>1.91</td>
</tr>
<tr>
<td>Furrow (F)</td>
<td></td>
<td>11.80 13.53 12.14 12.66 12.53</td>
<td>7139 5974 7030 5949 6523</td>
<td>1.65 2.27 1.73 2.13 2.13</td>
<td>1.94</td>
</tr>
<tr>
<td>Drip (D)</td>
<td></td>
<td>12.48 13.60 12.41 12.26 12.69</td>
<td>367 3016 3527 3002 3304</td>
<td>3.40 4.51 3.52 4.08 3.88</td>
<td></td>
</tr>
<tr>
<td>Average of mulching treatment (M)</td>
<td></td>
<td>11.89 13.41 12.12 12.64</td>
<td>2.22 2.99 2.31 2.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>N.S</td>
<td>I</td>
<td>0.175</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.782</td>
<td>M</td>
<td>0.171</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N.S</td>
<td>M × I</td>
<td>N.S</td>
<td>M × I</td>
</tr>
</tbody>
</table>

Table 3. Actual evapotranspiration (ETa) (mm) for study treatments, No of irrigations through growth stages of maize for the autumn season 2016.

<table>
<thead>
<tr>
<th>Irrigation methods</th>
<th>Soil mulching treatments</th>
<th>Crop growth stages</th>
<th>Germination</th>
<th>Vegetative growth</th>
<th>Flowering</th>
<th>Maturity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin</td>
<td>M0</td>
<td>417.0</td>
<td>149.0</td>
<td>148.0</td>
<td>714.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M1</td>
<td>395.1</td>
<td>123.1</td>
<td>116.2</td>
<td>598.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>408.5</td>
<td>148.0</td>
<td>142.0</td>
<td>698.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>357.1</td>
<td>123.0</td>
<td>115.8</td>
<td>595.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of stage days</td>
<td>7</td>
<td>44</td>
<td>18</td>
<td>39</td>
<td>108</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of irrigations</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furrow</td>
<td>M0</td>
<td>419.0</td>
<td>149.0</td>
<td>145.9</td>
<td>713.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M1</td>
<td>358.1</td>
<td>123.1</td>
<td>116.2</td>
<td>597.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>410.0</td>
<td>148.0</td>
<td>145.0</td>
<td>703.0</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>356.1</td>
<td>123.0</td>
<td>115.8</td>
<td>594.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of stage days</td>
<td>7</td>
<td>44</td>
<td>18</td>
<td>39</td>
<td>108</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of irrigations</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drip</td>
<td>M0</td>
<td>216.5</td>
<td>89.50</td>
<td>61.00</td>
<td>367.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M1</td>
<td>178.8</td>
<td>72.90</td>
<td>49.90</td>
<td>301.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>213.6</td>
<td>82.00</td>
<td>57.10</td>
<td>352.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>178.4</td>
<td>72.60</td>
<td>49.20</td>
<td>300.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of stage days</td>
<td>7</td>
<td>44</td>
<td>18</td>
<td>39</td>
<td>108</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of irrigations</td>
<td>2</td>
<td>9</td>
<td>4</td>
<td>3</td>
<td>18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure (3) Actual evapotranspiration (ETa) through stage of vegetative growth of the study treatments.

Figure (4) Actual evapotranspiration (ETa) through stage of maturity of the study treatments.
Table 4. Climate data of the season 2016 for the study location

<table>
<thead>
<tr>
<th>Month</th>
<th>Avg Temperature (°C)</th>
<th>Avg Relative Humidity (RH) %</th>
<th>Avg Wind Speed (m.sec(^{-1}))</th>
<th>Epan (mm)</th>
<th>Mean daylight hours (P%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug</td>
<td>37.41</td>
<td>21.73</td>
<td>1.90</td>
<td>320.71</td>
<td>9.2</td>
</tr>
<tr>
<td>Sep</td>
<td>33.03</td>
<td>22.27</td>
<td>2.00</td>
<td>324.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Oct</td>
<td>26.99</td>
<td>28.96</td>
<td>1.55</td>
<td>211.14</td>
<td>7.7</td>
</tr>
<tr>
<td>Nov</td>
<td>16.64</td>
<td>39.98</td>
<td>1.52</td>
<td>46.0</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Table 5. Crop coefficient (Kc) calculated based on the equations Blaney-Criddle, Kharrufa and Epan through growth stages of maize for the autumn season 2016

<table>
<thead>
<tr>
<th>Irrigation methods</th>
<th>Soil Mulching treatment</th>
<th>Vegetative growth</th>
<th>Crop growth stages</th>
<th>maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Kharrufa eq.</td>
<td>B.C.eq</td>
<td>Evaporation pan.eq</td>
</tr>
<tr>
<td>Basin</td>
<td>M0</td>
<td>1.11</td>
<td>1.34</td>
<td>1.25</td>
</tr>
<tr>
<td></td>
<td>M1</td>
<td>0.96</td>
<td>1.15</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>1.09</td>
<td>1.31</td>
<td>1.22</td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>0.95</td>
<td>1.15</td>
<td>1.07</td>
</tr>
<tr>
<td>Furrow</td>
<td>M0</td>
<td>1.12</td>
<td>1.34</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>M1</td>
<td>0.95</td>
<td>1.15</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>1.09</td>
<td>1.32</td>
<td>1.23</td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>0.95</td>
<td>1.14</td>
<td>1.07</td>
</tr>
<tr>
<td>Drip</td>
<td>M0</td>
<td>0.58</td>
<td>0.69</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>M1</td>
<td>0.48</td>
<td>0.57</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>0.57</td>
<td>0.69</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>M3</td>
<td>0.48</td>
<td>0.57</td>
<td>0.53</td>
</tr>
</tbody>
</table>
The values of ETa for studied treatments calculated by using water balance equation for the autumn season 2016. The highest ETa for basin irrigation method ranged between (357.1 - 417.0 mm) in vegetative growth stage and reached (123.0 - 149.0 mm) in flowering stage, while the maturity stage was (115.8 - 148.0 mm). The highest total ETa of maize showed at control treatment (M0) was (714.0 mm), whereas the lowest total ETa was (595.9 mm) at soil mulching with wheat stubble + polymer granules (M3). The highest ETa for furrow irrigation method ranged between (356.1 - 419.0 mm) in vegetative growth stage and reached (123.0 - 149.0 mm) in flowering stage, while the maturity stage was (115.8 - 145.9 mm). The highest total ETa of maize showed at control treatment (M0) was (713.9 mm), whereas the lowest total ETa was (594.9 mm) at soil mulching with wheat stubble + polymer granules (M3). The highest ETa for drip irrigation method ranged between (178.4 - 216.5 mm) in vegetative growth stage and reached (72.6 - 89.5 mm) in flowering stage, while the maturity stage was (49.2 - 61.0 mm). The highest total ETa of maize showed at control treatment (M0) was (367.0 mm), whereas the lowest total ETa was (300.2 mm) at soil mulching with wheat stubble + polymer granules(M3).

DISCUSSION

The above results showed that the highest value of ETa indicated in vegetative growth stage and decreased with progressing of growing season of maize for all treatments. The reason of that return to dependence of ETa on climatic conditions through months of study (table 4) and plant density of crop, that the temperature is the main factor affecting on ETa and coincide with low relative humidity, high percent of light hours (P %) especially in vegetative growth stage (44 days) consequently increase plant requirements for water supply during this stage Al-Maeini ( 2004).

The decrease of ETa of plant in the last stages return to complete the composition of his tissues and cells and dry the high proportion of its parts Al-Janabi (2012).

This manner leads us that maize crop need greater a mounts of water in vegetative growth stage comparatively with other stages. Soil mulching reduce the evaporation values from soil surface, as a result of changing climatic conditions surrounding the plant as well as improves water properties of the soil surface and the ratio of covering land Blaney and Criddle, (1950). The results in (Tables 1, 2, 3) showed that the amount of water added by drip irrigation must be less than water added by basin and furrow methods because the wetted diameter of surface soil was limited 40 cm diameter around plant), that means the addition of water did not include all cultivate area, for that the water losses via runoff, deep percolation will be reduced, furthermore the evaporation from soil surface will decrease also. These results confirmed thought the seasonal water consumption was (330.4 mm) for drip irrigation compared with basin and furrow irrigation (651.8 and 652.3 mm) respectively Suleiman, W.M .(2014).

Table [2] indicates that the highest average of grain yield was (13.41 t. ha⁻¹) with mulch wheat stubble (M1) followed by treatment (M3) with non-significant differences between them, compared with control treatment (M0) which gave the lowest average (11.89 t. ha⁻¹), but the results showed that there are significant differences between (M1) treatment and other mulching treatments (M0, M2), the reason of this return to explained previously.This result are similar with those found Khurshid et al., (2006) Pervaiz et al., (2009) Yaseen et al., (2014).

They reported that the grain yield of maize was increased by using mulch with wheat stubble. The grain yield was not affected by irrigation methods and their interaction with soil mulching and polymer (M0, M1, M2 and M3). Grain yield increased by drip irrigation method with non-significant difference in spite of the quantity water added in this method was less than basin and furrow irrigation by (49.31% and 49.35%) respectively. This was due to that drip irrigation which played role to maintain available soil moisture of rhizosphere, through the slow application of water in the form of discrete, continuous drops through emitters, all this merit will be enhance good plant growth and limited weed growth Suleiman, W.M .(2014).

Table (2) indicates that water use efficiency for maize was significantly affected (p ≤ 0.0.5) by irrigation methods, soil mulching and polymer, whereas their interaction had non-significant effect. The highest average of WUE was (3.88 kg. m⁻³) with drip irrigation (D) in comparison to basin irrigation (1.92 kg. m⁻³) and furrow irrigation (1.95 kg. m⁻³),it was increased about (102.1 and 99%) compared with basin and furrow irrigation respectively. Mulch treatment (M1) gave the highest water use efficiency, it was (2.99 kg. m⁻³) in comparison with control treatment (2.22 kg. m⁻³), might be due to proper moisture availability and
frequent availability of nutrients. Furthermore, soil covering by mulch throughout the cropping seasons improves soil physical properties Zamir et al., (2013).

Moreover, mulches increased infiltration rate and water in the rhizosphere, improved macro - porosity and structure of soil along with reducing runoff and evaporation losses Yaseen et al., (2014) which compared with treatment non mulch, which confirms the high relationship between water use efficiency and grain yield Al-hadithi, (2002).

and improve shoot growth which reflected on high grain yield therefore we obtained high water use efficiency that reflect on water productivity when we used soil mulching with wheat stubble. The results in (Fig 1) showed the values of reference evapotranspiration (ET0) that calculated by three empirical equations (Blaney -criddle, kharrufa, Epan) through growing season of maize, the values of ET0 was (678.3, 840.1 and 615.1 mm) for the three previous equation respectively. The reason of increasing ET0 that calculated by kharrufa equation comparatively with ET0 calculated by Blaney –criddle and Epan equation return to the high value of local coefficient (c= 0.39) that used in kharrufa equation (2) because the climatic factors of study area. The value of Ep through growing season of maize reached (878.7 mm), this value is high comparatively with ET0 and ETa, the reason of this increasing return to happening of evaporation from Epan through day and night by losing of water at vapor form to atmosphere with existence of energy source furthermore act of wind in removing of saturated layer that near from free water surface for displacing air dry layer, moreover the turbulence of temperature and relative humidity and heat transfer through pan sides that affect energy balance, but reference evapotranspiration values (ET0) depend on climatic factors (air temperature ,relative humidity, number of hours sunshine in a day and wind speed) that represent the evapotranspiration from grass land covered earth surface without water shortage Allen et al., (1998).

The decreasing of actual evapotranspiration (ETa) return to that transpiration contain evaporation of water that contained by plant tissues and removing the vapor to atmosphere. The crop loses water through stomas that water vapor pass from it or evaporation happen through leaf with limitation the cell pores. The exchange of vapor with atmosphere controlled by opening of stomas moreover soil factors, management, plant and climatic conditions The above results showed the ET0 increases as increase in the temperature especially in vegetative growth stage, moreover increasing of number of days stage Bhandari,( 2012).

Table (5) indicates that the high value of crop coefficient (kc) was 1.35 at basin and furrow irrigation method with no mulching (M0) and polymer granules (M2) treatments, whereas the lowest value of kc was 0.25 at drip irrigation with wheat stubble (M1) and wheat stubble + polymer granules (M3) treatments. The high values of kc showed at basin and furrow irrigation comparatively with drip irrigation, this return to increasing of ETa for this irrigation method comparatively with ET0 of drip irrigation (Table. 1, 3 and fig.1) thus increasing of kc for basin and furrow irrigation and decrease of kc for drip irrigation because the kc represents the ratio between ETa and ET0 (kc = ETa /ET0).

The results in (Table 5) indicated that the kc of (M0 and M2) treatments higher than kc of (M1 and M3) treatments, thus return to the role of wheat stubble in decreasing of ETa comparatively with other mulching treatments (table.1, 3 and fig.1) Zamir et al., (2013).

The results showed that values of kc was high in vegetative growth stage comparatively with other growing stages (flowering and maturity) for all treatments when we used the ET0 that calculated by kharrufa and Blaney – criddle equations in computing kc, the reason of this day) comparatively with other growing stages Bhandari, ( 2012).

The results of (Table 5) showed the sequence of kc values for growing stages as flowering > vegetative growth> maturity for all treatments when we used the ET0 that calculated by Epan equation in computing kc, the reason of this return to dependency of ET0 calculated by this equation on number of days for every growing stages which based on the measurement of evaporation from evaporation pan (Ep). The kc values for the vegetative growth, flowering and maturity stages were (0.48 -1.34, 0.27-1.35 and 0.25-0.97) respectively, while the values reported for maize by FAO are (0.3, 1.2, 0.35 - 0.6) for the initial, mid- season and late stage, respectively. The other researches carried out in mid Iraq showed that the kc of maize ranged between (0.45 to 0.85) Douh, b. and Boujelben, A. (2011).

The measured kc values for this study were different up to some extent from the FAO values, the reason might be that FAO kc values are generalized ones and recommended for a wide
range of climatic conditions Abedinpour, (2015).

The crop coefficient (kc) is affected by a number of factors, which include: the type of crop, stage of growth of the crop, climatic factors and cropping pattern Bhandari, (2012).

CONCLUSION

Results indicated that at the clay loam soil in Kut town, Wasit governorate, mid Iraq, reference evapotranspiration (ET0) that calculated by three empirical equations (Blaney-criddle, kharrufa, Epan) through growing season of maize were (678.3, 840.1 and 615.1mm) respectively. ETA values of irrigation methods (basin, furrow and drip) were (651.8,652.3 and 330.4 mm) respectively. Maximum value of Kc was 1.35 at flowering stage and the minimum value of Kc was 0.25 at maturity stage of maize. The low amount of irrigation water (m³:ha⁻¹) that used in drip irrigation was (3304 m³:ha⁻¹) comparatively with (6518 and 6523 m³:ha⁻¹) that used in basin and furrow irrigation methods respectively. The high value for water use efficiency was (3.88 kg. m⁻³) that showed at drip irrigation method. The high value for grain yield was (13.6 t. ha⁻¹) for mulching soil with wheat stubble (M1). The estimation of Kc in different areas helps in irrigation management and precise water applications.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEDGEMENT

The study was interested to estimate of irrigation method, mulching soil on actual evapotranspiration of maize that planted under climate conditions of middle of Iraq and calculate the Kc of maize and its water use efficiency.

REFERENCES


and Antioxidant in Pepper. Plant Archive.18(1): 479-488


