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## Water requirements, growth and yield for sunflower *Helianthus annuus* L. and yellow corn *Zea mays* L. using the CROPWAT Program

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### Abstract:

A field experiment was conducted on 3/12/2023 in one of the agricultural fields affiliated with the College of Agricultural Engineering Sciences at the University of Baghdad / Al-Jadriya, with the aim of determining the budget, water needs, and yield coefficient of sunflower and yellow corn plants under field conditions. The experiment was carried out at a rate of 6 \* 6 m<sup>2</sup> for each crop, and the moisture was based on the two methods of gravity and the use of sensors. The depth of irrigation and the change in storage were calculated, and the optimal time period for irrigation was calculated. Daily evapotranspiration. The amount of actual evapotranspiration was also calculated, thus finding the crop coefficient K<sub>c</sub>. It was found from the results of the result of the plant height and disc area for the sunflower plant that the highest height was 237 cm, while the lowest height was recorded at 180 cm. This was for the sunflower plant. As for the yellow corn plant, the highest plant height was recorded at 238 cm and the lowest height was 189 cm. As well as the results of water use, it was found that adopting the water budget method has good results in monitoring the crop's water needs.

**Keywords:** CROPWAT program, Water requirements, Yield coefficient.

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تحديد الموازنة والاحتياجات المائية ومعامل المحصول لزهرة الشمس *Helianthus annuus* L. والذرة الصفراء *Zea mays* L. باستخدام برنامج CROPWAT.

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#### الخلاصة:

أجريت تجربة حقلية بتاريخ 2023/3/12 في إحدى الحقول الزراعية التابعة الى كلية علوم الهندسة الزراعية في جامعة بغداد /الجادرية بهدف تحديد الموازنة والاحتياجات المائية ومعامل المحصول لنباتي زهرة الشمس والذرة الصفراء تحت الظروف الحقلية. أذ تم تنفيذ التجربة بواقع 6\*6 م<sup>2</sup> لكل محصول وتم اعتماد الرطوبة على طريقتي الوزنية واستخدام المتحسسات وتم حساب كل من عمق الري والتغير في خزن وحساب المدة الزمنية المثلى للري التبخّر - نتح اليومي، كما تم حساب مقدار التبخّر نتح الفعلي وبالتالي إيجاد معامل المحصول Kc أذ وجد من خلال النتائج للحاصل المتمثل بارتفاع النبات ومساحة القرص لنبات زهرة الشمس بلغ اعلى ارتفاع 237 سم في حين سجل اقل ارتفاع 180 سم هذا بالنسبة لنبات زهرة الشمس أما بالنسبة لنبات الذرة الصفراء فقد سجل أعلى ارتفاع للنبات 238 سم واقل ارتفاع 189 سم. كذلك نتائج استخدام المياه فقد وجد ان اعتماد اسلوب الموازنة المائية ذات مردود جيد في متابعة احتياجات المحصول المائية.

**الكلمات المفتاحية:** برنامج CROPWAT، متطلبات المياه، زهرة الشمس.

#### Introduction

Arora and Marler (2004), Verplanke et al., (1985) defined water needs as the amount of water that a crop needs to grow naturally, regardless of the source of this water, for a certain period of time and under certain field conditions. Broner et al., (2003) stated that knowing the water needs of seasonal crops is extremely important for the purpose of planning the agricultural cycle, especially in dry seasons, although sufficient data on the water needs of irrigation water for most crops is not available in third world countries. The importance of knowing the water needs of the crop lies in estimating the exact amount of irrigation water needed for the crop, based on which the period between irrigations, the time of each irrigation, and the amount of water added to each irrigation are determined. When the actual water needs of the crop are estimated, water resources can be better controlled and their use rationalized. Accordingly, daily, monthly or seasonal water consumption can be known (Hillel, 1971) and the crop coefficient can also be changed after estimating evaporation and transpiration from climate data (Meteorological Network).

The water balance equation is one of the ways to measure the moisture content of the soil, as understanding the water balance of the soil is necessary to estimate the role of

different management strategies in reducing losses and maximizing the use of water, which is the factor that most limits crop production in semi-arid areas. There are several factors on which the water needs of the crop depend, including:

- The prevailing climatic conditions
- The nature of the crop and variety
- Soil type and soil capacity to hold water
- Other soil hydraulic properties (Hillel, 1971).

Researchers in calculated the water needs and scheduled irrigation for the corn crop based on climate, crop and soil data and chose the best method they also found irrigation scheduling in conditions of water scarcity in India based on computer programs (Bhat et al.,2023).The abundance of technology is considered very advanced mechanisms for determining the water content of the soil. One of the most important of these mechanisms is Data Acquisition Technology, that is, the mechanism for obtaining (possessing data) through a system that includes soil moisture sensors and a Data Logger to record (save) the sensor data or the station and send the sensor data. The system also senses, saves and sends data. These systems are characterized by a high storage period of up to 40,000 readings in selected time periods ranging from one minute to 24 hours between one reading and another. This system was employed to study these data, as an accurate record of the variable moisture content in the soil depth as a function of depth and time.

Smith et al.,(1991) and Smith (1992) and FAO (1992) apointed out that the CROPWAT program is a practical tool to help agricultural meteorologists, agronomists and irrigation engineers to carry out evaporation-transpiration calculations and study the efficiency of water use by the crop, and more specifically In the design and management of irrigation projects because it allows developing recommendations to improve irrigation methods, planning irrigation scheduling under different conditions for water preparation, and evaluating production under rainy conditions or deficient irrigation.

### Materials and Methods

A field experiment was carried out to grow yellow corn, variety 5018, and the second to grow sunflower, variety Aqmar, during the spring season 12/3/2023. The planting was carried out in the research fields of the College of Agricultural Engineering Sciences/University of Baghdad in Al-Jadriyah, at latitude 32° 16' 06" north, and longitude 2.2 "23' 44° east and at an altitude of 34 meters above sea level, the field's soil was classified as having a clay loam texture ,strong fine, Typic, Towifuvents (Soil survey staff 2012).

Soil samples were taken from the field from 0-0.30 m, the samples were mixed, a composite sample was extracted from them, air-dried, ground, and passed through a sieve with holes diameter of 2 mm, for the purpose of estimating the physical and chemical properties before planting. As shown in the following tables.

**Table 1.**Shows some chemical properties of the soil before planting.

| Property | Ec                 | pH   | Ca                   | Mg   | Na    | K    | SO4  | Cl    | Hco3 | No2  | P    | SAR                                    |
|----------|--------------------|------|----------------------|------|-------|------|------|-------|------|------|------|----------------------------------------|
| Unit     | ds.m <sup>-1</sup> | ---  | Meq/ L <sup>-1</sup> |      |       |      |      |       |      |      |      | (Mmol.L <sup>-1</sup> ) <sup>1/2</sup> |
| Valur    | 1.13               | 7.41 | 9.66                 | 6.29 | 10.80 | 0.09 | 8.28 | 10.69 | 2.80 | 0.19 | 0.02 | 2.30                                   |

**Table 2.**Shows some physical properties of the soil before planting.

| Property     | Bulk density       | Particals density | Porosity | Sand                      | Clay | Silt |
|--------------|--------------------|-------------------|----------|---------------------------|------|------|
| Unit         | Meg.M <sup>3</sup> |                   | ----     | gm.Kgm soil <sup>-1</sup> |      |      |
| Valur        | 2.62               | 1.48              | 0.44     | 378                       | 222  | 400  |
| Soil Texture |                    |                   |          | Clay Loam                 |      |      |

The water balance equation is used to calculate the water consumption of plants in a specific area that may be small, and it is also used in large areas such as river valleys. The general water balance equation is written in the following form (Allen et al.,1998).

$$Cu = (I + P + C) + (Gs - Ge) - (R + D) \quad (1)$$

That:

Cu = plant water consumption during the season for a certain area (mm).

I = the amount of irrigation water added to the field during the season (mm).

P = amount of rain during the season (mm).

Gs = amount of water stored in the root zone at the beginning of the season (mm).

Ge = amount of water stored in the root zone at the end of the season (mm).

R = Runoff of water during the season (mm).

D = The amount of water extracted (out of the root zone) during the season (mm).

C = Ground water contribution (mm).

#### *Surface Irrigation System*

The surface irrigation process was carried out by selecting a tube for each experimental panel, and the system was operated for twenty minutes under a discharge of 20 m<sup>3</sup>/min. The irrigation discharge depends on the operating pressure of the network as well as the diameter of the pipe opening.

#### *Sensor ET5*

The ET5 sensor manufactured by the American company Decagon Devices was used during the season for both plates for yellow corn and sunflower crops, at two different depths. The ET5 sensor is the latest type of device and is characterized by more accurate sensitivity to soil electrical conductivity readings and greater resistance. Operating the sensor requires the use of data storage devices known as data loggers. Logger and install a special program that the calculator can download this data: ECH2O Utility (Version 1.70\2006-2013) and Decagon Devices' Data Trac3 program to record, save and deal with the data. There is a special UBS (Stereo Plug) cable that connects the ET5 sensor to the calculator. The data logger features a high memory for storing data, with a capacity of 40,000 readings in a time period ranging from one minute to 24 hours between one reading and another. It is connected to a very small power device, as the ET5 sensor senses changes that occur in both the moisture content and electrical conductivity in the soil through an electromagnetic field to measure the dielectric constant of the material in the surrounding area. So, it is equipped with a wave frequency of 70 MHz to the prongs. To calibrate the sensor, its reading in air is 1 cm<sup>3</sup> cm<sup>-3</sup> and in water is 80 cm<sup>3</sup> cm<sup>-3</sup>, with an accuracy ranging between ±1(Decagon Devices 2013).

### *Mechanism for Placing the Sensor in the Soil*

The ET5 sensor is placed in the soil during the agricultural season at two depths of 0.15 and 0.30 m from the soil surface for the two agricultural panels, as shown in Figure1. Calibration and adjustment of the devices were also performed to store and save data over a period of every four hours between reading and using the ECH2OUtility program.



**Figure 1.** Mechanism for placing sensors in the soil.

### *The Agricultural Process*

Seeds of yellow corn, *Zea mays* L., variety 5018, and sunflower *Helianthus Annuus* L. were planted during the spring season on 3/12/2023 in a hollow in the form of lines. The crop was harvested on 15/7/2023 for the Baghdad site, as the distance between one hollow and another was 0.30 m. The distance between one planting line and another on the same terrace is 0.75 metres. The thinning process was carried out after germination and the emergence of seedlings in order to obtain one plant per shoot. The process of controlling corn stalk borers was carried out with the granular pesticide diazinon, 10% concentration, by spraying the pesticide in a ring around the plant. Weeds and weeds were also controlled using the pesticide arazine.

### *Irrigation Process*

The irrigation basin was supplied with Tigris water during the season to the Baghdad site successively. It has an electrical conductivity of  $0.91 \text{ dS.m}^{-1}$ , and irrigation is done based on the ET5 sensor reading the moisture content within the field capacity limits, and using subsurface drip irrigation during the agricultural season. Irrigation is carried out until 50% of the ready water is exhausted, then it is added by adding the depth of water necessary to reach the moisture content at the field capacity of the field soil.

The equation proposed by (2) was also used to calculate the depth of water that must be added to compensate for the depleted moisture, as follows:

$$d = (\theta_{fc} - \theta_I) \times D \dots\dots\dots (2)$$

Since

d: Depth of water added (mm)

$\theta_{fc}$ : Volumetric humidity at field capacity ( $\text{cm}^3 \text{cm}^{-3}$ )

$\theta_I$ : Volumetric humidity before irrigation ( $\text{cm}^3 \text{cm}^{-3}$ )

D: Root zone depth (mm)

## Results and Discussion

### *Water Balance and Crop Coefficient*

The table shows the values of the moisture content of the soil at different time periods. It also shows the depth of irrigation water added to the soil, the change in the soil, and the daily rate of evapotranspiration, given that the contribution of groundwater was zero. Evapotranspiration was also calculated from climate data based on the CROPWAT program. Calculating the yield coefficient. The results showed that the use of irrigation is of great benefit and is consistent with what was found by (Khudhair et al., 2015). An increase in the actual crop's water consumption was observed as the growing season progressed. The reason for this is due to the completion of the vegetation cover that covered the entire surface of the soil and The air temperature decreased, so the fermentation rate decreased during this stage (Gutierrez et al., 2019).

**Table 3.** Water budget for yellow maize crop.

| Day after planting | Water Content | DA/W <sub>mm</sub> | R <sub>mm</sub> | DS   | ET <sub>a</sub> | ET <sub>o</sub> | Kc   |
|--------------------|---------------|--------------------|-----------------|------|-----------------|-----------------|------|
| 0                  | 0.16          | 47                 | 35.9            | 2    | 63.18           | 80.9            | 0.78 |
| 26                 | 0.15          | 45                 | 21              | -2.7 | 33.6            | 68.7            | 0.49 |
| 12                 | 0.14          | 47.7               | 5.7             | 0.2  | 51.38           | 53.2            | 0.97 |
| 14                 | 0.14          | 47.5               | 5               | -2.5 | 41              | 55              | 0.75 |
| 10                 | 0.13          | 50                 | 0               | 3    | 48.5            | 47              | 1.03 |
| 10                 | 0.14          | 47                 | 0               | 0    | 0               | 0               | 0    |

**Table 4.** Water budget for sunflower crop.

| Day after planting | Water Content | DA/W <sub>mm</sub> | R <sub>mm</sub> | DS | ET <sub>a</sub> | ET <sub>o</sub> | Kc   |
|--------------------|---------------|--------------------|-----------------|----|-----------------|-----------------|------|
| 0                  | 0.13          | 50                 | 35.9            | 7  | 63.18           | 78.9            | 0.80 |
| 26                 | 0.16          | 43                 | 21              | 0  | 33.6            | 64              | 0.53 |
| 12                 | 0.16          | 43                 | 5.7             | -1 | 51.38           | 50.7            | 1.01 |
| 14                 | 0.15          | 45                 | 5               | 1  | 41              | 49              | 0.84 |
| 10                 | 0.15          | 44                 | 0               | -1 | 48.5            | 45              | 1.08 |
| 10                 | 0.15          | 45                 | 0               | 0  | 0               | 0               | 0    |

The yield coefficient values ranged between (0.4-1.03) for the yellow corn crop, while it reached (0.5-1.78) for the sunflower crop, as it increased as growth progressed, reaching its maximum value at flowering. It decreased when the yield was established. The results agreed with (Mahnna and Seglar 2002) as they attributed the reason to the occurrence of high water stress on the plant. The reason for the higher yield factor value for sunflower crop is also due to the higher actual water consumption values for this treatment during the growing season compared to yellow corn. This result agreed with what was found by (Erdem et al., 2001). The yield coefficient values also increased as growth progressed until it reached its maximum value at flowering and then began to decrease at the stage of yield formation and maturity. I agree with Mahnna and Seglar (2002) who found a decrease in yield coefficient when water stress occurred on the plant. The yield

coefficient ranges for plant growth salts are close, except for those subjected to water stress, due to the lower actual evaporation-transpiration of these coefficients (Pessarakli and Mohammad 1999).

#### *Plant Height of Both Crops (cm)*

One of the indicators that was taken into consideration in the study of determining the water budget was plant height. It was found that there was a good and noticeable increase in plant heights, and this indicates the waterfall method and the adoption of appropriate timing for irrigation and giving the appropriate amount. After 70 days from the planting date, the highest height reached 237 and 238 cm for both crops, respectively, while the lowest height reached 189 and 185, respectively. After 44 days of planting, the highest average plant height reached 215 cm for both, and the lowest average plant height was 169 cm for both.

**Table 5.**the plant height rate for sunflower and yellow corn crops.

| <b>Plant height rate for sunflower after 44 day</b>   |                |          |          |          |          |          |          |          |          |
|-------------------------------------------------------|----------------|----------|----------|----------|----------|----------|----------|----------|----------|
| <b>Lines</b>                                          |                | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> |
| The Date<br>2023/5/12                                 | Highest height | 200      | 205      | 215      | 205      | 205      | 199      | 191      | 190      |
|                                                       | Lowest height  | 175      | 169      | 180      | 180      | 178      | 175      | 170      | 169      |
| <b>plant height rate for sunflower after 70 day</b>   |                |          |          |          |          |          |          |          |          |
| <b>Lines</b>                                          |                | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> |
| The Date<br>2023/5/20                                 | Highest height | 210      | 218      | 237      | 221      | 230      | 220      | 210      | 200      |
|                                                       | Lowest height  | 190      | 195      | 200      | 198      | 189      | 196      | 190      | 189      |
| <b>plant height rate for yellow corn after 44 day</b> |                |          |          |          |          |          |          |          |          |
| <b>Lines</b>                                          |                | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> |
| The Date<br>2023/5/12                                 | Highest height | 197      | 199      | 215      | 215      | 210      | 200      | 205      | 209      |
|                                                       | Lowest height  | 169      | 170      | 172      | 177      | 170      | 168      | 171      | 169      |
| <b>plant height rate for yellow corn after 70 day</b> |                |          |          |          |          |          |          |          |          |
| <b>Lines</b>                                          |                | <b>1</b> | <b>2</b> | <b>3</b> | <b>4</b> | <b>5</b> | <b>6</b> | <b>7</b> | <b>8</b> |
| The Date<br>2023/5/20                                 | Highest height | 220      | 230      | 235      | 238      | 220      | 209      | 218      | 220      |
|                                                       | Lowest height  | 190      | 192      | 196      | 190      | 185      | 189      | 193      | 190      |

#### *Plant Disk Space*

Table (6) shows the disc area values of the sunflower plant, based on a water budget study using the irrigation method. It was found that the highest disk area was 289.5 cm<sup>2</sup>, and the lowest disk area was 265 cm<sup>2</sup>.

**Table 6.**Shows the area of the sunflower disk.

| Plant disk spaceafter 70days |               |     |     |       |     |     |     |     |     |
|------------------------------|---------------|-----|-----|-------|-----|-----|-----|-----|-----|
| Lines                        |               | 1   | 2   | 3     | 4   | 5   | 6   | 7   | 8   |
| The Date<br>20/5/2023        | Highest space | 278 | 280 | 289.5 | 285 | 285 | 280 | 282 | 279 |
|                              | Less space    | 269 | 265 | 275   | 269 | 267 | 270 | 265 | 266 |

## Conclusion

We conclude from the results that determining the water budget is very important and monitoring the yield to know the amount of water entering and leaving the soil, which is reflected positively in the yield.

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