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# Estimating Water Requirement and Scheduling Irrigation for Tomato Crops In Dhi Qar Governorate By Using The CropWat Program

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**Abstract:** This study addresses the increasing need to predict crop productivity responses to irrigation levels, crucial for optimizing water use under limited availability and enhancing agricultural returns. Focusing on tomato crops in Nasiriyah, the research evaluates the CropWat program's effectiveness in determining irrigation scheduling, water requirements, and evapotranspiration rates. Using climate, crop, and soil data, the program calculated irrigation schedules based on a 70% soil moisture depletion threshold. Results indicated that the tomato crop required nine irrigations, from September 18 to February 6, with a field irrigation efficiency of 70%. Water requirements peaked at 44.7 mm every ten days at the start of the growing season, decreasing to 10.1 mm by early February. Total irrigation values increased significantly, from 28.2 mm to 117.5 mm by the season's end. These findings highlight the utility of the CropWat program in improving irrigation management, essential for sustaining tomato production and maximizing economic returns in water-scarce conditions.

**Keywords:** Irrigation scheduling, Water requirements, Evapotranspiration, Field capacity, Water stress

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## 1. Introduction

Estimating the water requirements of agricultural crops is the first essential step required to develop future development plans and strategic planning for agricultural projects. In fact, estimating water requirements is one of the main elements when setting the water budget for any agricultural area. It is one of the most important topics in the field of irrigation, because it is the decisive element for all water calculations in any country. This topic has received the attention of those working in the field of irrigation and agriculture everywhere in order to reach reliable results in development plans and agricultural expansion projects. It is practically and scientifically proven that estimating and determining the water requirements of crops after the first and important stage of planning the optimal management of available water [1].

The farmers' failure to meet water requirements and the low cost of water compared to any other production input in most Arab countries, despite it being the most important input on which the crop depends in terms of quantity and quality, has pushed farmers to pump quantities of water greater than the crop's need. The amount of water used to irrigate one hectare in the Arab world has reached 12,000 m3 annually, while the required amount of water does not exceed 7,500 cubic meters annually, and thus there is a significant loss of irrigation water, deterioration of soil properties, and accumulation of salts in it [2].

The great development of computers and the emergence of simulation programs in the fields of irrigation water management have helped irrigation engineers, managers and researchers in estimating water requirements in irrigation projects, and the ability to predict and calculate water requirements accurately and create integrated programs for scheduling irrigation to achieve the highest productivity at the lowest costs. The CropWat program is considered one of the most important global programs that have been widely used in irrigation water [3].

The Food and Agriculture Organization (FAO) designed the CropWat computer model in Basic under the DOS operating system and published it in the organization's publication No. 46. This model was then developed in several versions, and the latest version of this model, which is available on the organization's website, is version 8 CropWat, which was designed using Visual Basic under the Windows environment and this model was linked to the climate database [4]. The research aims to use the CropWat program in studying and calculating water requirements and scheduling irrigation for tomato crops in Dhi Qar Governorate.

## 2. Materials and Methods

CropWat program was developed by the Land and Water Development Division of the Food and Agriculture Organization (FAO) with assistance from the University of Southampton to schedule crop irrigation. This program, in its current version CROPWAT 8.0, is considered a powerful simulation program that simulates irrigation water requirements for crops based on soil, climate, and crop data. In addition, the program allows crop irrigation to be scheduled under any water supply conditions according to the planned water quantities for different crop patterns. The program can also evaluate farmers' irrigation practices and estimate crop performance under both rainfall and irrigation conditions. This program is also considered a practical tool for estimating the water needs of crops [2]. This program depends on input data, which are called inputs data, and which simulate the environmental and agricultural reality. Among these inputs are the following data: climate data, rain, crop, farming pattern and soil, and climatic data includes data The following: maximum and minimum temperatures, humidity, wind speed, sunshine, solar radiation, and total precipitation.

**Input Data Axis**

Using the program, as a first step, the study area was determined in Dhi Qar Governorate - Nasiriyah, its affiliated stations, and geographical location coordinates. The following required data is entered]

**1) Climate and evapotranspiration inputs (Climate/ETO)**

It includes the climate elements and climate data required after defining the study area. The climate data As Table (1) is included in the (Climate/ETO) element using the program and according to the software data available to FAO, and the results were as follows:

Table 1. Climate and evapotranspiration inputs (Climate/ETO) for the study location

Country: Location 6 Station: NASIRIYA

Altitude: 3 m. Latitude: 31.08 °N Longitude: 46.23 °E

| Month | Min Temp | Max Temp | Humidity | Wind | Sun | Rad | ETo |
|---|---|---|---|---|---|---|---|
| | °C | °C | % | km/day | hours | MJ/m²/day | mm/day |
| January | 5.9 | 17.8 | 63 | 207 | 6.7 | 12.0 | 2.23 |
| February | 7.7 | 20.4 | 60 | 225 | 7.5 | 15.0 | 2.93 |
| March | 11.5 | 24.9 | 46 | 268 | 8.4 | 18.9 | 4.76 |
| April | 16.6 | 30.7 | 42 | 277 | 9.6 | 22.9 | 6.50 |
| May | 22.4 | 36.9 | 39 | 285 | 10.5 | 25.5 | 8.34 |
| June | 25.3 | 40.2 | 33 | 337 | 11.3 | 26.9 | 10.24 |
| July | 26.1 | 42.8 | 32 | 328 | 12.4 | 28.4 | 10.92 |
| August | 25.2 | 43.6 | 28 | 294 | 12.9 | 28.0 | 10.53 |
| September | 22.0 | 41.3 | 28 | 242 | 12.5 | 25.2 | 8.65 |
| October | 17.1 | 35.4 | 39 | 225 | 11.1 | 20.0 | 6.23 |
| November | 12.0 | 26.1 | 52 | 225 | 8.3 | 14.0 | 3.80 |
| December | 6.8 | 18.9 | 61 | 199 | 6.9 | 11.4 | 2.31 |
| **Average** | **16.6** | **31.6** | **44** | **259** | **9.9** | **20.7** | **6.45** |

**2) Rain data inputs (Rain)**

It includes rain data and the percentage of total and actual precipitation. After determining the study area, the rain data was entered into the (Rain) element using the program and according to the software data available to the FAO. The results were as follows in Table (2):

Table 2. Rain data input window for the study location

| | Rain | Eff rain |
|---|---|---|
| | mm | mm |
| January | 24.0 | 23.1 |
| February | 16.0 | 15.6 |
| March | 15.0 | 14.6 |
| April | 18.0 | 17.5 |
| May | 9.0 | 8.9 |
| June | 0.0 | 0.0 |
| July | 0.0 | 0.0 |
| August | 0.0 | 0.0 |
| September | 0.0 | 0.0 |
| October | 4.0 | 4.0 |
| November | 8.0 | 7.9 |
| December | 13.0 | 12.7 |
| **Total** | **107.0** | **104.3** |

**3) Crop inputs data and planting pattern (Crop)**

Includes data for the targeted and planted crop in terms of planting and harvesting dates, growth stages and root zone depth, as the tomato crop was targeted and studied.

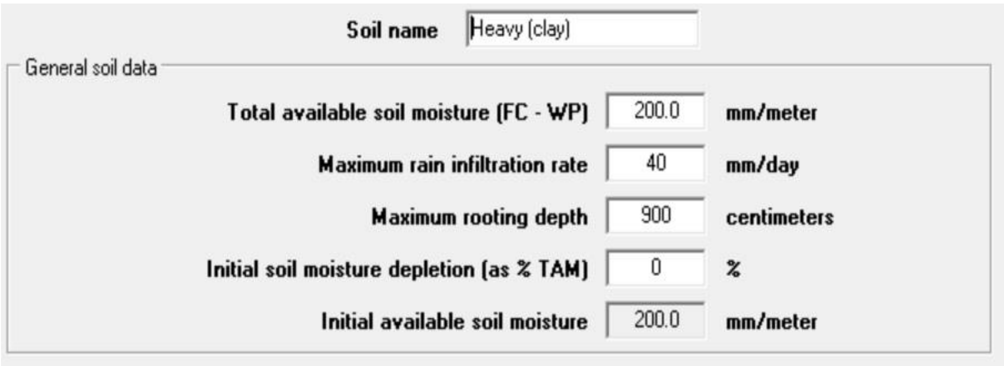
**4) Soil data inputs (Soil)**

Includes data on soil texture and some physical, Hydrological and moisture properties of the soil. The program allows us to choose the texture class (Soil name) as a main group (figure 1) from the following three main classes for light (sand), medium (Loam) or heavy (Clay) soils. To match this, the texture was also estimated in the laboratory using the hydrometer method, and the initial results were as follows, as in Table 3 and 4:

Table 3. Some basic physical and chemical properties of soil

| **Soil Depth (cm)** | | **Soil separators** | |
|---|---|---|---|
| **30-15** | **15-0** | | |
| **53.5** | **53.8** | **$g\ kg^{-1}$** | **Sand** |
| **322.5** | **336.8** | | **Silt** |
| **625.7** | **598.7** | | **Clay** |
| **Clay** | **Clay** | | **Soil Texture** |
| **1.232** | **1.254** | **Bulk density** | **$Mg\ m^{-3}$** |
| **2.653** | **2.648** | **Practical density** | **$Mg\ m^{-3}$** |
| **52.4** | **53.4** | **Total porosity %** | |
| **7.5** | **7.6** | **pH** | |
| **12.35** | **13.12** | **ECe $dS\ m^{-1}$** | |

Table 4. Soil input window for the study location


Soil name: Heavy (clay)

General soil data

| | | |
|---|---|---|
| Total available soil moisture (FC - WP) | 200.0 | mm/meter |
| Maximum rain infiltration rate | 40 | mm/day |
| Maximum rooting depth | 900 | centimeters |
| Initial soil moisture depletion (as % TAM) | 0 | % |
| Initial available soil moisture | 200.0 | mm/meter |

## 3. Results and Discussion

### Planting date and growth stages:

It is noted from Figure 1 that the best date for planting a tomato crop in the study area is mid-September and the harvest date is at the beginning of February. The results show that the length of the tomato season is 145 days and is divided into the stages of the beginning of growth of 30 days, then the development or vegetative growth stage of 40 days, the flowering stage in the middle of the season of 45 days, and the maturity or end of the season stage of 30 days.

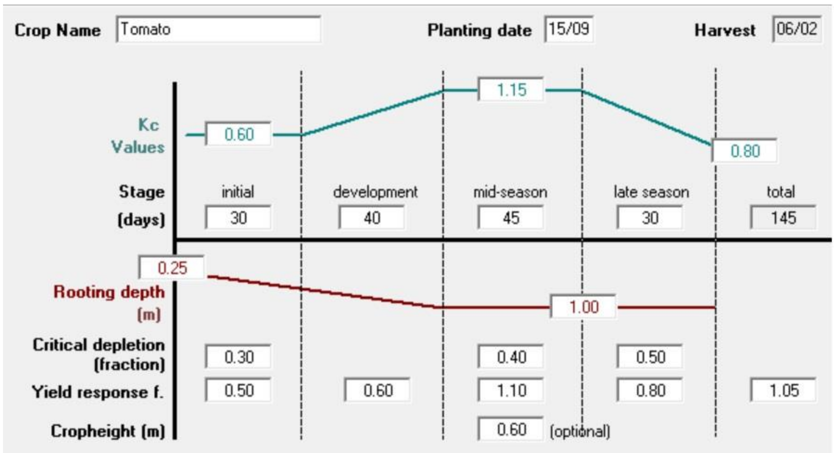



Figure 1. Tomato crop and planting pattern data for the study location

**Water requirement of a crop (Irr. Req.) :**

The results in Table 5 show that the crop water requirement values increased at the beginning of the growing season and were around 44.7 mm/10 days at the end of September due to the low rainfall in the early stages of growth, while the crop water requirement values decreased as the growth period progressed and the lowest water requirement for the crop was at the beginning of February, i.e. at the end of the growing season, and was around 10.1 mm/10 days. The reason for the decrease in water requirement at the end of the season is attributed to the completion of the plant's physiological processes and the approach to maturity and harvest [5;6].

Table 5. Water requirement data for tomato crop (Irr. Req.) and crop evapotranspiration (ETc) for the study location

ETo station: NASIRIYA — Crop: Tomato
Rain station: NASIRIYA — Planting date: 15/09

| Month | Decade | Stage | Kc | ETc | ETc | Eff rain | Irr. Req. |
|---|---|---|---|---|---|---|---|
| | | | coeff | mm/day | mm/dec | mm/dec | mm/dec |
| Sep | 2 | Init | 0.60 | 4.93 | 29.6 | 0.0 | 29.6 |
| Sep | 3 | Init | 0.60 | 4.48 | 44.8 | 0.1 | 44.7 |
| Oct | 1 | Init | 0.60 | 4.04 | 40.4 | 0.9 | 39.5 |
| Oct | 2 | Deve | 0.63 | 3.77 | 37.7 | 1.3 | 36.4 |
| Oct | 3 | Deve | 0.77 | 4.03 | 44.3 | 1.8 | 42.5 |
| Nov | 1 | Deve | 0.91 | 4.11 | 41.1 | 2.2 | 38.9 |
| Nov | 2 | Deve | 1.05 | 3.95 | 39.5 | 2.6 | 36.8 |
| Nov | 3 | Mid | 1.16 | 3.76 | 37.6 | 3.2 | 34.5 |
| Dec | 1 | Mid | 1.16 | 3.14 | 31.4 | 3.6 | 27.8 |
| Dec | 2 | Mid | 1.16 | 2.54 | 25.4 | 4.0 | 21.3 |
| Dec | 3 | Mid | 1.16 | 2.54 | 27.9 | 5.3 | 22.6 |
| Jan | 1 | Late | 1.15 | 2.56 | 25.6 | 7.1 | 18.5 |
| Jan | 2 | Late | 1.06 | 2.32 | 23.2 | 8.5 | 14.7 |
| Jan | 3 | Late | 0.94 | 2.27 | 25.0 | 7.4 | 17.6 |
| Feb | 1 | Late | 0.84 | 2.17 | 13.0 | 3.5 | 10.1 |
| | | | | | **486.4** | **51.5** | **435.5** |

**Irrigation Schedule:**

The results in Table 6 show the number of irrigations and irrigation dates for tomato crop, if the number of irrigations was 9 (the first irrigation on 18 September and the last irrigation on 6 February) taking into account the amount of rainfall (Rain) and water stress (Ks) and with a net irrigation rate (Net Irr.) calculated for each irrigation and with a field irrigation efficiency of 70% with no decrease in productivity (Yield red.) 0% and for all growth stages and with no losses (Loss) 0 mm and no water deficit (Deficit) 0 mm and the total irrigation values (Gr. Irri.) increased from 28.2 mm to 117.5 mm at the end of the growing season. Thus, the efficiency of irrigation scheduling (Efficiency irrigation schedule) according to the data was around 100% [7;8].

Table 6. Irrigation Schedule Data for Tomato Crop for the Study location

ETo station NASIRIYA | Crop Tomato | Planting date 15/09 | Yield red.
Rain station NASIRIYA | Soil Heavy (clay) | Harvest date 06/02 | 0.0 %

Table format
- (•) Irrigation schedule
- ( ) Daily soil moisture balance

Timing: Irrigate at critical depletion
Application: Refill soil to field capacity
Field eff. 70 %

| Date | Day | Stage | Rain | Ks | Eta | Depl | Net Irr | Deficit | Loss | Gr. Irr | Flow |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | mm | fract. | % | % | mm | mm | mm | mm | l/s/ha |
| 18 Sep | 4 | Init | 0.0 | 1.00 | 100 | 34 | 19.7 | 0.0 | 0.0 | 28.2 | 0.81 |
| 23 Sep | 9 | Init | 0.1 | 1.00 | 100 | 34 | 23.2 | 0.0 | 0.0 | 33.2 | 0.77 |
| 29 Sep | 15 | Init | 0.0 | 1.00 | 100 | 33 | 26.8 | 0.0 | 0.0 | 38.3 | 0.74 |
| 7 Oct | 23 | Init | 0.4 | 1.00 | 100 | 32 | 31.9 | 0.0 | 0.0 | 45.5 | 0.66 |
| 17 Oct | 33 | Dev | 0.7 | 1.00 | 100 | 31 | 37.2 | 0.0 | 0.0 | 53.1 | 0.61 |
| 31 Oct | 47 | Dev | 0.0 | 1.00 | 100 | 36 | 53.8 | 0.0 | 0.0 | 76.9 | 0.64 |
| 21 Nov | 68 | Dev | 0.0 | 1.00 | 100 | 41 | 79.4 | 0.0 | 0.0 | 113.5 | 0.63 |
| 21 Dec | 98 | Mid | 0.0 | 1.00 | 100 | 41 | 82.2 | 0.0 | 0.0 | 117.5 | 0.45 |
| 6 Feb | End | End | 0.0 | 1.00 | 0 | 39 | | | | | |

Totals

| | | | | | |
|---|---|---|---|---|---|
| Total gross irrigation | 506.2 | mm | Total rainfall | 52.2 | mm |
| Total net irrigation | 354.3 | mm | Effective rainfall | 52.1 | mm |
| Total irrigation losses | 0.0 | mm | Total rain loss | 0.2 | mm |
| Actual water use by crop | 484.2 | mm | Moist deficit at harvest | 77.8 | mm |
| Potential water use by crop | 484.2 | mm | Actual irrigation requirement | 432.2 | mm |
| Efficiency irrigation schedule | 100.0 | % | Efficiency rain | 99.7 | % |
| Deficiency irrigation schedule | 0.0 | % | | | |

**Water balance curve for irrigation scheduling and available moisture:**

The results in Figure 2 show the irrigation schedule for the tomato crop, as the number of irrigations was nine irrigations, and as shown in the figure, the subsequent irrigation begins after the depletion of the daily available moisture (RAM) at the field capacity before reaching the wilting point represented by RAM and the total available moisture (TAM). The results also show an increase in the daily available moisture immediately after irrigation, and then it decreases as a result of the increase in moisture depletion due to the water consumption of the soil and the crop, reaching values close to the depletion of the field capacity, after which the date of the subsequent irrigation is determined and scheduled to provide the moisture and water requirement necessary for plant growth and avoid wilting and plant death as a result of the decrease in the available moisture and water requirement necessary for growth [9 ; 10].

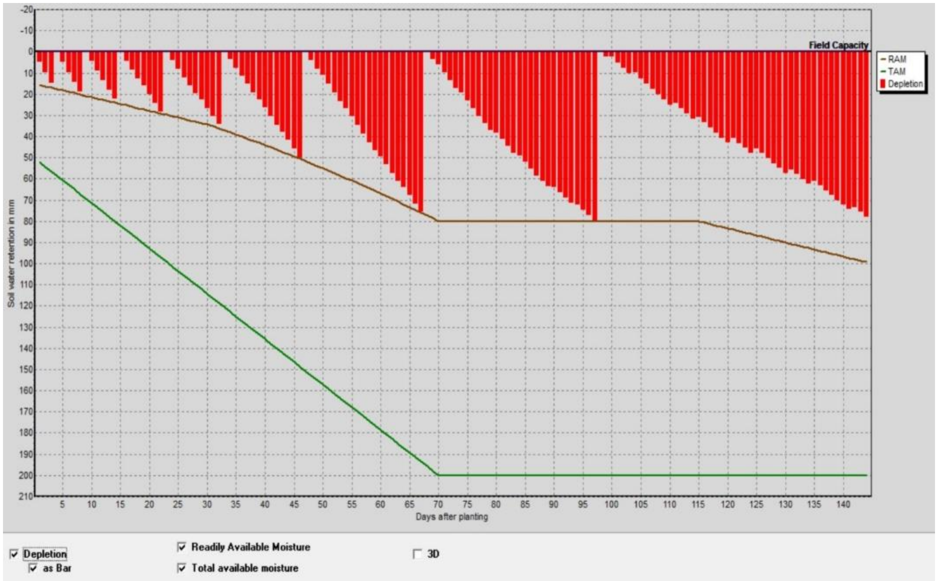



Figure 2. Water balance curve and irrigation scheduling for tomato crop and ready moisture for the study location

## 4. Conclusion and Recommendations

1. The rapid development in the field of computers provides its services in the field of irrigation, especially in the FAO CROPWAT program, where CropWat 8 version was used. From this research, we conclude that the best irrigation scheduling is when the irrigation timing is scheduled when the moisture depletion reaches 70% of the available water, and thus the number of irrigations increases and the irrigation interval decreases, and thus the efficiency of water use and irrigation efficiency increases.
2. The CropWat 8 water requirements and irrigation scheduling program is an effective program in developing an acceptable methodology for estimating the water requirements of agricultural crops, in the event that the evaporation transpiration values are adopted according to the values taken from agricultural research stations and meteorological stations, and this will lead to ensuring the correct calculation of the water requirements of crops and irrigation scheduling.
3. We conclude from this study that by using this program, it is possible to determine and know the role of total rainfall and effective rainfall in calculating water requirements, as the effective rainfall amount reached 67.8 mm / season and 51.5 mm / season for the tomato crop.
4. We recommend conducting studies on deficit irrigation and different moisture coefficients and on soils of different textures and simulating them with this CropWat program.

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