Evaluation of the scheduling of an existing drip irrigation network: Fada

k Farm, Karbala, Iraq

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Abstract. Iraq has a subtropical semi-arid climate; it was previously considered to be rich in water, but for several reasons, including climate change and dam construction by neighbouring countries, a shortage of water resources has developed in recent years. Using the drip irrigation method is one of the most efficient ways to rationalise water consumption and avoid losses. This study was conducted in order to assess the scheduling of the drip irrigation system used on the Fada

k farm in the holy city of Karbala in Iraq, in order to investigate irrigation scheduling there and to compare this with established irrigation scheduling parameters. This required the study of the physical properties of the soil and water consumption calculations for the palm trees being irrigated using the CROPWAT 8.0 simulation program. The results indicated that the volume of water actually supplied to each plot of around dunum (2,500 m2) is 1,533.5 m3 annually, while the volume of water that should be supplied to the farm is 1,388 m3, suggesting that there is wastage of 145.5 m3, or 10.7%, annually. The monthly losses show that the irrigation scheduling system currently used on the farm exposes the plants to excess irrigation over many months, resulting in a loss of water, while causing plants to be exposed to a decrease in irrigation water, which causes stress, in other months. Using surface irrigation, the volume of water needed per dunum is 12,617 m3, however, causing water waste to the volume 11,229 m3. This study thus confirms the general efficiency of the drip irrigation system, as well as highlighting that the CROPWAT 8.0 program is useful for calculating water consumption.

Keywords: Crop water requirement (CWR), Drip Irrigation system, Efficiency, Irrigation scheduling.

1. Introduction

Iraq is situated in the Middle East and relies greatly on the Tigris and Euphrates rivers for its water supplies. Iraq has recently suffered from water shortages due to several factors, including the policies of neighbouring countries, global warming, and mismanagement of water resources [1][2].
Using the drip irrigation method is one of the most efficient ways to rationalise water consumption and avoid loss in farming. Drip irrigation is a method of supplying pre-filtered water, sometimes with additional fertilizers, directly into the soil [3]. The main aim of such irrigation is to use water to sustain crop evapotranspiration (ETc) when there is inadequate precipitation. Hess defines crop water requirements as referring to the total water required for evaporation from planting to harvesting for a specific crop in a given climate system; when sufficient soil water is provided by irrigation or rain, the growth of plants and crops proceeds as expected [3]. Scheduling of irrigation refers to deciding when irrigation is needed and how much water is applied. Once a system has been designed, installed and evaluated, irrigation scheduling is generally done using the climate data for the area in question, with irrigation water applied in quantities appropriate to substitute for the amount of water used by the plants. Evapotranspiration (ET) is used to determine the appropriate amount of water to be applied to a crop at a given time to achieve healthy plants and to retain the most water, ad this is dependent on radiation, temperatures, wind speed, and air humidity in the region. Regular water distribution across the field is also important for achieving the greatest benefits from irrigation scheduling [4].

Results from date palm water consumption studies in the Riyadh region suggest that the average quantities supplied to date palms per year are 108 m$^3$/tree (1.08 m/ha), 216 m$^3$/tree (2.16 m/ha), and 324 m$^3$/tree (3.24 m/ha) for water treatments at 50, 100, and 150% of the evaporation rate, respectively. In that experiment, economic yield analysis for different irrigation systems (drip, basin, and bubbler) showed that the highest yield was for drip irrigated palms, followed by basin systems. Water treatment variations were marginal, however, suggesting that the use of 108 m$^3$/year/tree is adequate to achieve maximum efficiency of water usage for date palms [5]. Abdul Salam and Al Mazrooei set al schedule to irrigate date palms grown in the clay sands of Kuwait, and determined the Net Irrigation Requirement rate of date palm as ranging from 97 litres tree$^{-1}$ d$^{-1}$ during December to 854 litres tree$^{-1}$ d$^{-1}$ during June. Localised (drip) irrigation has been shown to be more efficient than non-localised (flood) irrigation [6]. CROPWAT 8.0 is a piece of software developed by the Food and Agriculture Organization (FAO) to help irrigation engineers in the carrying out normal water irrigation study calculations and, chiefly, in the management and design of irrigation systems [7]. It is used to measure the requirements for crop water and irrigation based on soil and crop data and climate[8]. It is one of the models most widely used worldwide in water management [9]. Bhatt et al used the CROPWAT model to calculate water requirements and establish irrigation scheduling for maize crops, demonstrating that an irrigation management model can effectively and efficiently estimate crop water requirements [10]. The current study was conducted with the aim of evaluating the performance of drip irrigation systems used for date palm irrigation at Fadak Farm in Karbala, Iraq, after several years of use. Due to the advantages of drip irrigation, it was introduced in Iraq as one of the modern types of irrigation, especially in desert farms. The expansion of the agricultural area using drip irrigation in the Karbala governorate, where the area of land irrigated by drip irrigation method reached 2,477,500 m$^2$ within the irrigation boundaries and 226,495 m$^2$ outside the irrigation boundaries [11] means that detailed studies on drip irrigation efficiency with regard to water conservation through irrigation scheduling work are required; this study is one of the first in this field. The study was thus conducted to examine such irrigation’s scheduling, to compare it with both established irrigation scheduling and compare with the surface irrigation method.
2. Materials and Methods

2.1 Experimental sites

The study was carried out at Fadak Farm in Karbala, Iraq, which is located at longitude 43° 52’ 44” E and latitude 32° 43’ 23” N, on the road linking Karbala governorate and Ain Al-Tamr district to the west of the holy city of Karbala. The total area of the farm is 2000 dunums, with most of the area allocated to palm trees, citrus, and other fruit. Figure 1 shows the location of Fadak Farm in relation to Karbala city. In general, the climate here in the central region of Iraq is a desert climate with hot, dry weather in the summers and cold wet weather in the winters, with the spring and autumn being relatively short and of moderate temperature. The maximum rainfall occurs in January and March, with about 17 mm per month. The average total annual rainfall in the area is about 97.2 mm, while the mean annual maximum and minimum temperatures are 31.1°C and 17.63°C, respectively, with a mean relative humidity of 46.9%.

![Figure 1. Geographical location of the study area in Iraq.](image)

2.2 Soil investigation

Determination of Fadak farm soil properties was carried out in two stages: experimental and field work. Three samples were taken from experimental blocks; several experiments were carried out in the laboratories of the College of Engineering of the University of Karbala, such as bulk density, specific gravity (Gs), water content, and particle size distribution analysis, while others were conducted in the field as site measurements, such as field capacity and infiltration rate. Field capacity refers to the quantity of soil water stored in a unit volume of soil after free water (gravitational water) passes through the soil profile, which is sometime referred to as the 2- to 3-day drainage or soil water potential. At -1/3 bar for sandy soil, this might occur in less than one day, however [12].

A segment of farm measuring 2 x 2 metres was chosen, and water was then poured on the soil to the point of saturation; the area was covered with a plastic cover to avoid evaporation, and this was left for two days. Water was once again added to the point of saturation and the area covered with a plastic cover before being left for a further day. After that, a sample was taken to measure the moisture content.
of the soil, and this process was repeated three times, covering nine days in total. Infiltration rate was determined in the field using a ring infiltrometer placed into the soil to a depth of 20 cm by hammering. Water was poured into the cylinder, and the depth of water infiltrated measured and recorded at 1, 2, 3, 5, 10, 15, 20, 30, 60, 75, 90, and 105 minutes. This process was repeated three times in different parts of the field, though the data showed identical behaviour with regard to infiltration in all different locations. This is a traditional method, which offers acceptable accuracy and has been used by many researchers, such as Ankidawa and Zakariah [8].

2.3 Measurement of discharge from drippers

The simplest approach to evaluating the performance of drip irrigation systems involves undertaking physical measurements of application rates using a catch can, measuring cylinders, and a stop watch[9].

2.4 Irrigation scheduling

2.4.1 Irrigation Depth

The maximum net water depth required for irrigation, \(d_x\), is defined by the following equation.

\[
d_x = \frac{MAD}{100} \times AW \times \frac{P_w}{100} \times Z
\]

where

- \(p_w\) = Percentage of wetted area
- \(d_x\) = maximum net water depth of, ( mm)
- \(MAD\) = management allowed deficit (%), 50%for deep-root row crops like date palm [3]
- \(AW\) = available water of the soil (mm/m), as determined by equation 2.
- \(AW = (FC-PWP)\)

where

- \(FC\) = volumetric water content at field capacity (mm/m).
- \(PWP\) = volumetric water content at the permanent wilting point (mm/m).
- \(Z\) = root depth, for the date palm (m) as mentioned by[6].

2.4.2 Irrigation Interval

Keller and Bliesner [3] defined the irrigation interval as the correct period for irrigation, which is the time between the start of two consecutive irrigations as calculated by

\[
II = \frac{d_n}{ET_C}
\]

where

- \(II\) = irrigation interval,( days)
- \(d_n\) = net depth of water application per irrigation, (mm)
- \(ET_C\) = daily crop water requirement,( mm/day)

2.4.3 Gross depth of irrigation water

To calculate the total depth of irrigation water, the following relationship was used

\[
d_g = \frac{dn}{Ea}
\]

where

- \(d_g\) = gross depth of irrigation, (mm)
- \(dn\) = net depth of irrigation, Ea the efficiency of irrigation (90% for drip irrigation)[15]

2.4.4 Irrigation time of system

The time of operation of each emitter was determined using equation 5;

\[
t = K \times \frac{d_g^{es}\times a}{N\times q_a}
\]

where

- \(t\) = time of irrigation, (hr.)
- \(K\) = a constant equal to 1.00 for metric system.
- \(N\) = number of emitters per plant
Se = distance between the emitters on the lateral line, (m)
sl = distance between the lateral lines, (m)
$q_a$ = average discharge of emitter, (l/h).
$d_g$ = gross depth of irrigation over the area, (mm) \[16\]

### 2.4.5 Capacity of System

System capacity depends on the time span, irrigation rate, and interval of irrigation. Wu \[17\] suggested an equation to calculate the system capacity as follow:

\[
Q = \frac{d_g \cdot A}{t}
\]

where

- $Q$ = capacity of drip irrigation system (m$^3$/h)
- $d_g$ = Gross depth of irrigation (m).
- $A$ = the global area to be irrigated (m$^2$)
- $t$ = irrigation time, (hr.).

Table 1 shows the irrigation scheduling in the field based on data obtained from workers:

| Month | Oct | Nov | Dec | Jan | Feb | March | Apr | May | June | July | Sep | Oct |
|-------|-----|-----|-----|-----|-----|-------|-----|-----|------|------|-----|-----|
| Irrigation interval (II), day | 2   | 2   | 2   | 2   | 2   | 1     | 1   | 1   | 1    | 1    | 1   | 1   |
| Time ,hr. | 2   | 2   | 2   | 1.5 | 1.5 | 1.5   | 1.5 | 2   | 2    | 2    | 1.5 |

### 3. Calculation of crop water requirements

The CROPWAT program was used to calculate the water requirements of date palms. CROPWAT enables crop evapotranspiration calculation, crop water needs assessment, and irrigation scheduling based on specific irrigation preparation and field patterns. As the need for water by the same crop varies according to these and other factors such as weather conditions, precise information was required with regard to soil type and weather conditions to achieve the successful planning of water supplies\[10\].

### 4. Results and Discussion

#### 4.1 Soil Physical Properties

Tests carried out on soil samples showed that the soil is sandy, suitable for palm cultivation as noted by Ankidawa and Zakariah \[13\]. Keller and Bliesner \[3\] also noted that sandy soils are suitable for drip irrigation systems. The values for average bulk density, average specific gravity, infiltration rate, field capacity, and wilting point were 1.45 gm/cm$^3$, 2.65, 146 mm/hr., 14.5%, and 7% respectively. These results were consistent with those produced by Cuenca \[18\].

#### 4.2 Crop Water Requirement

CROPWAT 8.0 was used to calculate the crop water requirements (CWR) using the Penman-Monteith equation, which required the following parameters: climatic parameters, longitude and latitude of the location, and soil type. Climatic data was obtained from the Karbala meteorological station for the period 1980 to 2016, and included the main climatic parameters such as mean maximum monthly air temperature, mean minimum monthly air temperature, mean average monthly air temperature, mean average monthly air temperature, mean sun shine duration, wind speed, mean monthly evaporation, and mean relative humidity and rainfall. A summary of the data is given in Table 2.
Table 2. Summary of mean climatic date for the area of study

|                | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Mean Min-Temp C | 5.3 | 7.6 | 11.6| 17.4| 22.8| 26.8| 29.1| 28.5| 24.5| 19.3| 11.8| 6.9 |
| Mean Max-Temp C | 16.2| 19.2| 24.2| 30.9| 37.1| 41.8| 44.3| 44.2| 40.3| 33.5| 23.8| 17.8|
| Humidity%       | 73  | 61  | 51  | 42  | 34  | 28  | 29  | 31  | 35  | 45  | 62  | 72  |
| Wind m/s        | 1.6 | 2   | 2.3 | 2.3 | 2.4 | 3   | 3   | 2.5 | 1.8 | 1.6 | 1.4 | 1.5 |
| Sunshine (hours)| 6.2 | 7.2 | 7.9 | 8.5 | 9.2 | 11.2| 11.4| 11  | 10.1| 8.2 | 7.1 | 6.2 |
| Rain(mm)        | 16.9| 14.5| 17.1| 12.3| 3   | 0   | 0   | 0   | 0   | 4.4 | 14  | 15  |

CROPWAT calculations of reference crop evapotranspiration (ET0), based on climate data, are shown in Figure 2, while the rain data applied in CROPWAT to obtain effective rainfall is shown in Figure 3. The program used information about date palm crops as shown in Figure 4. The soil type in Fadak farm, according to laboratory tests is sandy; this was matched in the program to general soil data with regard to features such as total available water; maximum rate of infiltration, maximum depth of root, initial soil moisture depletion, and initial available soil moisture. These data were obtained from the FAO manual and field experiments. Figure 5 thus shows the calculated crop water requirements (CRW) for date palms.

Figure 2. Input climate data
Figure 3. Input rain data.

Figure 4. Crop types (date palms).

Figure 5. Crop water requirements (CRW) for dt l
4.3 Irrigation Scheduling

To improve irrigation management in the field, crop water requirements and irrigation schedules must be evaluated. Irrigation water management is used to control the amount, rate, and timing of irrigation in an effective manner. In this case, irrigation scheduling was set for the farm as in real life for two cases: the first was where half of the farm area was cultivated, and the percentage of wetted area was 16.5%, which is half of the percentage of wetted area of the drip irrigation system in reality (33%) [14]. The second case was for full planting of the farm. For scheduling, the maximum net water depth was calculated using equation 1, with $d_w$ values of 12.5 mm and 25 mm for each case, respectively. Equation 3 was applied to calculate the irrigation interval, while ETc was calculated within CROPWAT 8.0. The effect of an oasis (temperature increase in an isolated source of moisture surrounded by an arid environment) [19] was introduced at the percentage (50%) as suggested by Kharrufa, [20]. The ETc2 in the irrigation scheduling tables was thus equal to the value of ETc1 multiplied by the percentage of wetted area and the oasis effect.

To calculate the gross depth of irrigation water by applying equation (4), the irrigation efficiency of the drip irrigation system was set to 90%. The irrigation time in the system was calculated using equation 5. Se and $SI$ were measured in the field and their values were set to 9 m and 8 m, respectively. The volume of water was calculated using equation 6. Tables 3 and 4 show the scheduling of irrigation in both cases. To allow this scheduling of irrigation to more closely approximate reality, the irrigation time and the period between irrigations was then reduced, while the volume of water remained constant. Table 5 and 6 show the results of this.
### Table 3. Irrigation scheduling (percentage of wetted area 16.5%)

| Month | dn (mm) | daily crop water requirement ETc1 (mm/day) | daily crop water requirement ETc2 (mm/day) | irrigation interval II (day) | Gross depth of irrigation dg (mm) | Time of irrigation t (hr.) | Volume m$^3$/plant/day | Decade/II m$^3$/plant |
|-------|---------|------------------------------------------|------------------------------------------|-----------------------------|-----------------------------------|--------------------------|----------------------|------------------------|
| Oct   | 10.09   | 4.08                                     | 1.01                                     | 10                          | 11.21                             | 9.32                     | 0.81                 | 3.00                   | 2.42                   |
| Nov   | 5.69    | 2.3                                      | 0.57                                     | 10                          | 6.33                              | 5.26                     | 0.46                 | 3.00                   | 1.37                   |
| Dec   | 3.80    | 1.53                                     | 0.38                                     | 10                          | 4.22                              | 3.51                     | 0.30                 | 3.00                   | 0.91                   |
| Jan   | 3.51    | 1.42                                     | 0.35                                     | 10                          | 3.91                              | 3.25                     | 0.28                 | 3.00                   | 0.84                   |
| Feb   | 5.71    | 2.31                                     | 0.57                                     | 10                          | 6.34                              | 5.27                     | 0.46                 | 3.00                   | 1.37                   |
| Mar   | 9.53    | 3.85                                     | 0.95                                     | 10                          | 10.59                             | 8.80                     | 0.76                 | 3.00                   | 2.29                   |
| Apr   | 12.38   | 5.56                                     | 1.38                                     | 9                           | 13.75                             | 11.43                    | 0.99                 | 3.33                   | 3.30                   |
| May   | 12.71   | 7.33                                     | 1.82                                     | 7                           | 14.12                             | 11.74                    | 1.02                 | 4.29                   | 4.36                   |
| Jun   | 11.76   | 9.5                                      | 2.35                                     | 5                           | 13.06                             | 10.86                    | 0.94                 | 6.00                   | 5.64                   |
| Jul   | 12.27   | 9.91                                     | 2.45                                     | 5                           | 13.63                             | 11.33                    | 0.98                 | 6.00                   | 5.89                   |
| Aug   | 10.93   | 8.83                                     | 2.19                                     | 5                           | 12.15                             | 10.10                    | 0.87                 | 6.00                   | 5.25                   |
| Sep   | 11.29   | 6.52                                     | 1.61                                     | 7                           | 12.54                             | 10.43                    | 0.90                 | 4.29                   | 3.87                   |

37.51
| Month | dn (mm) | daily crop water requirement ETc1 (mm/day) | daily crop water requirement ETc2 (mm/day) | irrigation interval II (day) | Gross depth of irrigation dg (mm) | Time of irrigation t (hr.) | Volume m$^3$/plant/day | Decade/II | volume m$^3$/plant |  
|------|--------|------------------------------------------|------------------------------------------|----------------------------|-------------------------------|-------------------|------------------------|-----------|-------------------|
| Oct  | 20.18  | 4.08                                     | 2.02                                     | 10                         | 22.42                         | 18.64             | 1.61                   | 3.00      | 4.84              |
| Nov  | 11.39  | 2.3                                      | 1.14                                     | 10                         | 12.65                         | 10.52             | 0.91                   | 3.00      | 2.73              |
| Dec  | 7.59   | 1.53                                     | 0.76                                     | 10                         | 8.43                          | 7.01              | 0.61                   | 3.00      | 1.82              |
| Jan  | 7.03   | 1.42                                     | 0.70                                     | 10                         | 7.81                          | 6.49              | 0.56                   | 3.00      | 1.69              |
| Feb  | 11.42  | 2.31                                     | 1.14                                     | 10                         | 12.69                         | 10.55             | 0.91                   | 3.00      | 2.74              |
| Mar  | 19.06  | 3.85                                     | 1.91                                     | 10                         | 21.18                         | 17.61             | 1.52                   | 3.00      | 4.57              |
| Apr  | 24.75  | 5.56                                     | 2.75                                     | 9                          | 27.51                         | 22.87             | 1.98                   | 3.33      | 6.60              |
| May  | 25.41  | 7.33                                     | 3.63                                     | 7                          | 28.23                         | 23.47             | 2.03                   | 4.29      | 8.71              |
| Jun  | 23.51  | 9.5                                      | 4.70                                     | 5                          | 26.13                         | 21.72             | 1.88                   | 6.00      | 11.29             |
| Jul  | 24.54  | 9.91                                     | 4.91                                     | 5                          | 27.26                         | 22.67             | 1.96                   | 6.00      | 11.78             |
| Aug  | 21.86  | 8.83                                     | 4.37                                     | 5                          | 24.29                         | 20.20             | 1.75                   | 6.00      | 10.49             |
| Sep  | 22.58  | 6.52                                     | 3.23                                     | 7                          | 25.09                         | 20.86             | 1.81                   | 4.29      | 7.74              |

75.01
| Month | dn (mm) | daily crop water requirement ETc1 (mm/day) | daily crop water requirement ETc2 (mm/day) | irrigation interval II (day) | Gross depth of irrigation dg(mm) | Time of irrigation t(hr.) | Volume m³/plant/day | Decade/II | Volume m³/plant |
|-------|---------|------------------------------------------|------------------------------------------|---------------------------|-------------------------------|-------------------------|---------------------|-----------|----------------|
| Oct   | 2.02    | 4.08                                     | 1.01                                     | 2                         | 2.24                          | 2.00                    | 0.17                | 15.00     | 2.60           |
| Nov   | 2.28    | 2.3                                      | 0.57                                     | 4                         | 2.53                          | 2.00                    | 0.17                | 7.50      | 1.30           |
| Dec   | 1.90    | 1.53                                     | 0.38                                     | 5                         | 2.11                          | 1.75                    | 0.15                | 6.00      | 0.91           |
| Jan   | 1.76    | 1.42                                     | 0.35                                     | 5                         | 1.95                          | 1.50                    | 0.13                | 6.00      | 0.78           |
| Feb   | 2.85    | 2.31                                     | 0.57                                     | 5                         | 3.17                          | 3.00                    | 0.26                | 6.00      | 1.56           |
| Mar   | 3.81    | 3.85                                     | 0.95                                     | 4                         | 4.24                          | 3.50                    | 0.30                | 7.50      | 2.27           |
| Apr   | 1.38    | 5.56                                     | 1.38                                     | 1                         | 1.53                          | 1.50                    | 0.13                | 30.00     | 3.90           |
| May   | 1.82    | 7.33                                     | 1.82                                     | 1                         | 2.02                          | 1.75                    | 0.15                | 30.00     | 4.55           |
| Jun   | 2.35    | 9.5                                      | 2.35                                     | 1                         | 2.61                          | 2.50                    | 0.22                | 30.00     | 6.50           |
| Jul   | 2.45    | 9.91                                     | 2.45                                     | 1                         | 2.73                          | 2.50                    | 0.22                | 30.00     | 6.50           |
| Aug   | 2.19    | 8.83                                     | 2.19                                     | 1                         | 2.43                          | 2.00                    | 0.17                | 30.00     | 5.20           |
| Sep   | 1.61    | 6.52                                     | 1.61                                     | 1                         | 1.79                          | 1.50                    | 0.13                | 30.00     | 3.90           |
|       |         |                                          |                                          |                            |                               |                         |                     |           |                |

Table 5. Realistic irrigation scheduling (percentage of wetted area 16.5%)
Table 6. Realistic irrigation scheduling (percentage of wetted area 33%)

| Month | dn (mm) | daily crop water requirement ETc1 (mm/day) | daily crop water requirement ETc2 (mm/day) | irrigation interval II (day) | Gross depth of irrigation dg (mm) | Time of irrigation t (hr.) | Volume m³/plant/day | Decade/II | volume m³/plant |
|-------|---------|------------------------------------------|------------------------------------------|----------------------------|---------------------------------|--------------------------|------------------|------------|----------------|
| Oct   | 4.04    | 4.08                                     | 2.02                                     | 2                          | 4.48                            | 4.00                     | 0.35             | 15.00     | 5.20           |
| Nov   | 2.28    | 2.3                                      | 1.14                                     | 2                          | 2.53                            | 2.50                     | 0.22             | 15.00     | 3.25           |
| Dec   | 1.52    | 1.53                                     | 0.76                                     | 2                          | 1.69                            | 2.00                     | 0.17             | 15.00     | 2.60           |
| Jan   | 1.41    | 1.42                                     | 0.70                                     | 2                          | 1.56                            | 1.50                     | 0.13             | 15.00     | 1.95           |
| Feb   | 2.28    | 2.31                                     | 1.14                                     | 2                          | 2.54                            | 2.50                     | 0.22             | 15.00     | 3.25           |
| Mar   | 3.81    | 3.85                                     | 1.91                                     | 2                          | 4.24                            | 3.50                     | 0.30             | 15.00     | 4.55           |
| Apr   | 2.75    | 5.56                                     | 2.75                                     | 1                          | 3.06                            | 2.50                     | 0.22             | 30.00     | 6.50           |
| May   | 3.63    | 7.33                                     | 3.63                                     | 1                          | 4.03                            | 3.50                     | 0.30             | 30.00     | 9.09           |
| Jun   | 4.70    | 9.5                                      | 4.70                                     | 1                          | 5.23                            | 4.50                     | 0.39             | 30.00     | 11.69          |
| Jul   | 4.91    | 9.91                                     | 4.91                                     | 1                          | 5.45                            | 4.50                     | 0.39             | 30.00     | 11.69          |
| Aug   | 4.37    | 8.83                                     | 4.37                                     | 1                          | 4.86                            | 4.00                     | 0.35             | 30.00     | 10.39          |
| Sep   | 3.23    | 6.52                                     | 3.23                                     | 1                          | 3.58                            | 3.00                     | 0.26             | 30.00     | 7.79           |

77.94
A comparison between the irrigation scheduling developed in this study and the established irrigation scheduling of the farm was made based on data obtained from workers on the farm, as shown in table 7. The results indicated that the volume of water actually supplied per dounum is 1,533.5 m$^3$ annually, while the volume of water that should be supplied to the farm, according to Table 3, is 1,388 m$^3$, suggesting a waste of water of about 145.5 m$^3$ or 10.5% annually. As shown in Table 8, the monthly losses in the actual irrigation scheduling expose the plants to excess irrigation in November, December, February, and March, resulting in a loss of water, while in May, June, and July the plants are exposed to a decrease in the amount of irrigation water that may stress the plants. Nevertheless, a comparison with the method of surface irrigation with 60% efficiency and 100% wetting shows that the volume of water needed per dounum would be 12,617 m$^3$, creating a waste of water in a quantity of 11,229 m$^3$. This confirms the efficiency of drip irrigation as noted by previous researchers [21].

**Table 7. Irrigation scheduling (percentage of wetted area 16.5%) currently.**

| Month | irrigation interval II(day) | Time of irrigation t(hr.) | volume m$^3$/plant/day | Decade/II | volume m$^3$/plant |
|-------|-----------------------------|--------------------------|------------------------|-----------|-------------------|
| Oct   | 2.00                        | 2.00                     | 0.17                   | 15        | 2.60              |
| Nov   | 2.00                        | 2.00                     | 0.17                   | 15        | 2.60              |
| Dec   | 2.00                        | 2.00                     | 0.17                   | 15        | 2.60              |
| Jan   | 2.00                        | 2.00                     | 0.17                   | 15        | 2.60              |
| Feb   | 2.00                        | 2.00                     | 0.17                   | 15        | 2.60              |
| Mar   | 1.00                        | 1.50                     | 0.13                   | 30        | 3.90              |
| Apr   | 1.00                        | 1.50                     | 0.13                   | 30        | 3.90              |
| May   | 1.00                        | 1.50                     | 0.13                   | 30        | 3.90              |
| Jun   | 1.00                        | 2.00                     | 0.17                   | 30        | 5.20              |
| Jul   | 1.00                        | 2.00                     | 0.17                   | 30        | 5.20              |
| Aug   | 1.00                        | 2.00                     | 0.17                   | 30        | 5.20              |
| Sep   | 1.00                        | 1.50                     | 0.13                   | 30        | 3.90              |

| Month | volume m$^3$/plant | volume m$^3$/plant | losses% |
|-------|-------------------|-------------------|---------|
| Oct   | 2.6               | 2.6               | 0.00    |
| Nov   | 2.6               | 1.3               | 100.00  |
| Dec   | 2.6               | 0.91              | 185.71  |
| Jan   | 2.6               | 0.78              | 233.33  |
| Feb   | 2.6               | 1.56              | 66.67   |
| Mar   | 3.9               | 2.27              | 71.81   |
| Apr   | 3.9               | 3.9               | 0.00    |
| May   | 3.9               | 4.55              | -14.29  |
| Jun   | 5.2               | 6.5               | -20.00  |
| Jul   | 5.2               | 6.5               | -20.00  |
| Aug   | 5.2               | 5.2               | 0.00    |
| Sep   | 3.9               | 3.9               | 0       |
5. Conclusions

The drip irrigation system is considered one of the most important irrigation methods because it uses water much more efficiently than other irrigation methods. The expansion of the agricultural area that uses drip irrigation systems in Karbala Governorate has led to a need for detailed studies on this efficiency, however. An evaluation of irrigation system applied to a date palm plantation was carried out at the Fadak farm in Karbala, Iraq. The result of particle size analysis showed that the soil there is sandy and suitable for date palms. CROPWAT 8.0 was used for the calculation of the average water consumption for each month, as this is a widely used program with high accuracy. A lack of knowledge of water management has played a large role in previous irrigation schedules, and given the issue of increasing costs and water scarcity for irrigation purposes, this research has provided important information to management regarding the exact amount of irrigation water required for the farm. The scheduling of farm irrigation calculated in this research suggests that there is currently a waste of water in an amount 145.5 m$^3$, or 10.5%, per dunum annually. The monthly losses also show that the irrigation scheduling system currently used on the farm exposes the plants to excess irrigation in November, December, January, February, and March, resulting in a loss of water, while in May, June, and July, the plants are exposed to a decrease in the amount of irrigation water, which may stress the plants. However, even the current regime is effective in comparison with surface irrigation, which would lead to a waste of water in the region of 11,229 m$^3$ per dunum annually.

6. References

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