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Estimation of Crop Water Requirement and Determination of Irrigation Schedule for Tomato Crop by using CROPWAT 8.0 Model

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ABSTRACT

A study was conducted to estimate the crop water requirement and also to determine the irrigation schedule of tomato crop using CROPWAT 8.0 model at College of Agricultural Engineering Madakasira, Andhra Pradesh. The experiment was carried out under two methods of irrigation scheduling (Traditional furrow irrigation method and CROPWAT irrigation scheduling method). The total volume of water applied to the crop under traditional furrow irrigation method and CROPWAT irrigation scheduling method was 73.188 m^3 and 47.0611 m^3 respectively. Hence 35.69% of water saved in CROPWAT irrigation scheduling method. It was observed that the yield of the tomato crop in CROPWAT irrigation scheduling method was 36.8% more than the traditional furrow irrigation method. The crop water use efficiency in CROPWAT irrigation method was 58.36% more than the traditional furrow irrigation method. Thus, the study concluded that it is capable for strategic planning on irrigation management and scheduling in the view of water saving technology.

Keywords Irrigation, scheduling, Crop water use efficiency, CROPWAT, Yield.

INTRODUCTION

Dwindling water resources and increasing food demand due to population growth require efficiency in water use, both in rainfed as well as irrigated agriculture. The primary objective of irrigation is to apply water to maintain the crop to leads its evapotranspiration when precipitation is insufficient. Several computer models are now available to estimate the crop water requirement and irrigation schedule of the crop. CROPWAT is a computer program developed at Netherlands facilitate the estimate of the crop evapotranspiration, irrigation schedule, and agricultural water requirements with different cropping patterns for irrigation planning (Song *et al.* 2016, Tan and Zheng 2017, Abirdew *et al.* 2018, Ewaid *et al.* 2019, Moeski *et al.* 2019). Hence, the present study was designed to estimate irrigation scheduling compare the yield of the tomato crop between traditional furrow irrigation method and CROPWAT irrigation scheduling method.

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MATERIALS AND METHODS

The study area selected for the experiment in the College of Agricultural Engineering Madakasira, Anantapur district. The study area was subdivided into two equal plots. The size of each plot was 81 m^2. The tomato crop was cultivated in first plot using traditional furrow irrigation method and in second plot using CROPWAT irrigation scheduling method.

Methodology

The methodology consisted of the following main steps; data collection, estimation of crop water requirement and irrigation scheduling in CROPWAT 8.0 software and executing the irrigation schedule in the field and comparison of crop yield and water use efficiency for the crop under traditional furrow irrigation method and CROPWAT irrigation scheduling. The first step of this work was the collection of the data on weather parameters which were collected for the period 1997 - 2017 on a daily basis (air maximum and minimum temperature, humidity, wind speed, solar radiation and precipitation). This data were used for the calculation of reference evapotranspiration using modified Penman-Monteith equation in CROPWAT 8.0 model. The second step of the work was determining the estimation of crop water requirement and irrigation scheduling for tomato crop by using CROPWAT 8.0 model. The third step of the work includes application of irrigation water based on CROPWAT 8.0 model irrigation scheduling and traditional furrow irrigation method for tomato crop.

RESULTS AND DISCUSSION

Input data to CROPWAT

Climate

The climate data were essential to data input to CROPWAT simulation program, which required the following parameters (a) Temperature (Min and Max) (b) Humidity (c) Wind speed (d) Sunshine hours and calculated the average values of all the years then fed to the CROPWAT 8.0 model. Based on the climate data fed to the CROPWAT 8.0 model, the reference evapotranspiration was calculated using modified Penman–Monteith equation in CROPWAT 8.0 model.

Rainfall

The total daily rainfall was fed to the CROPWAT 8.0. It was observed that the 54.43% of total rainfall was received during monsoon months September – November. Also, it was found that the average total rainfall for the decade (1997-2017) was estimated to be 573.5 mm and effective rainfall of 495.5 mm was estimated based on USDA Soil Conservation service formula which was 86.4% of total rainfall.

Crop

The crop data (Fig. 1) was essentially data input requiring the general data: Coefficient of crop, duration

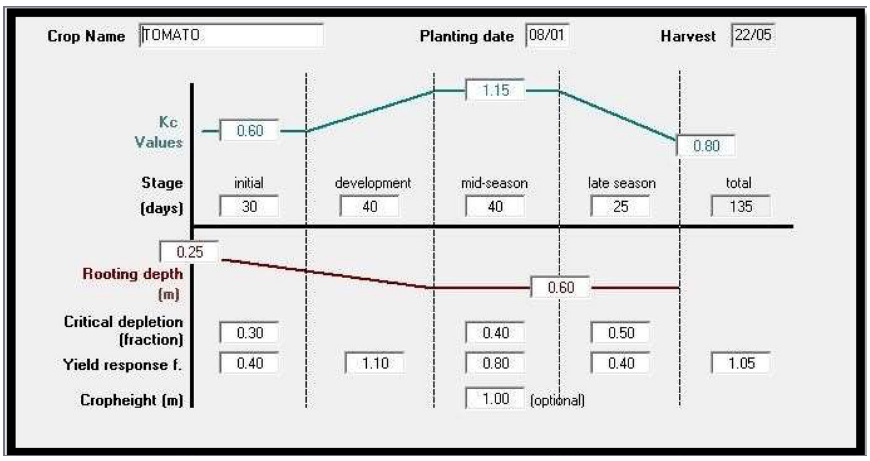
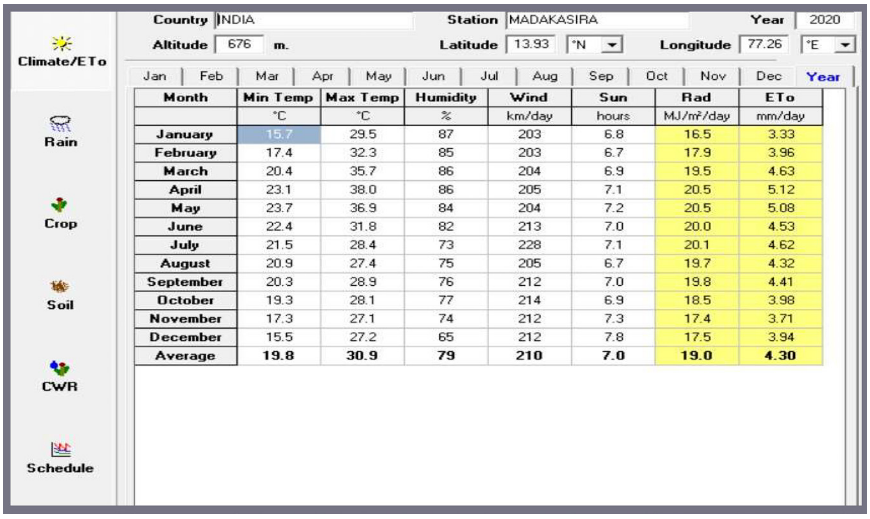


Fig. 1. Crop data used in CROPWAT model.



Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	15.7	29.5	87	203	6.8	16.5	3.33
February	17.4	32.3	85	203	6.7	17.9	3.96
March	20.4	35.7	86	204	6.9	19.5	4.63
April	23.1	38.0	86	205	7.1	20.5	5.12
May	23.7	36.9	84	204	7.2	20.5	5.08
June	22.4	31.8	82	213	7.0	20.0	4.53
July	21.5	28.4	73	228	7.1	20.1	4.62
August	20.9	27.4	75	205	6.7	19.7	4.32
September	20.3	28.9	76	212	7.0	19.8	4.41
October	19.3	28.1	77	214	6.9	18.5	3.98
November	17.3	27.1	74	212	7.3	17.4	3.71
December	15.5	27.2	65	212	7.8	17.5	3.94
Average	**19.8**	**30.9**	**79**	**210**	**7.0**	**19.0**	**4.30**

Fig. 2. Reference evapotranspiration.

of crop stages, rooting depth, critical depletion, yield response, crop height.

Soil

The soil data were essentially data input requiring the following general data. Total available water, maximum rain infiltration rate, maximum rooting depth, initial soil moisture depletion.

Output data

Reference evapotranspiration

Based on the climate data fed to the CROPWAT 8.0 model, the reference evapotranspiration was calculated using modified Penman – Monteith equation in CROPWAT 8.0 model. It was observed that the total average reference evapotranspiration estimated to be 4.30 mm/day. The calculated reference evapotranspiration is presented in (Fig.2). The reference evapotranspiration ranged from 3.33 mm/day to 5.12 mm/day and also it was observed that the reference evapotranspiration (ET_0) is maximum in the month of April with the value of 5.12 mm/day due to highest temperature in this month and minimum in the month of January with the value of 3.33 mm/day due to minimum temperature in this month.

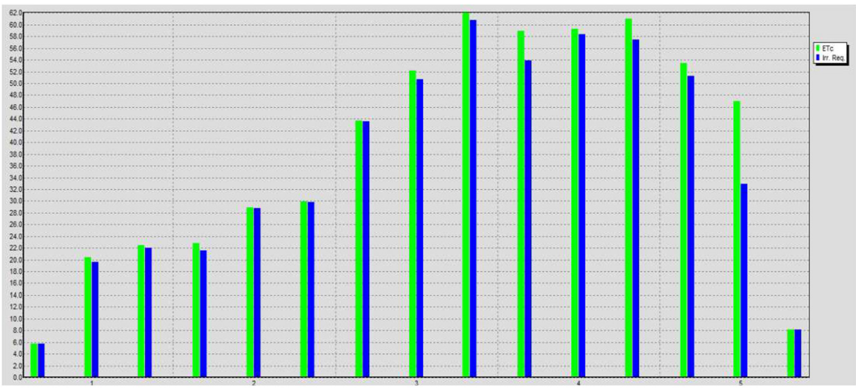


Fig. 3. Crop evapotranspiration and irrigation requirement graph.

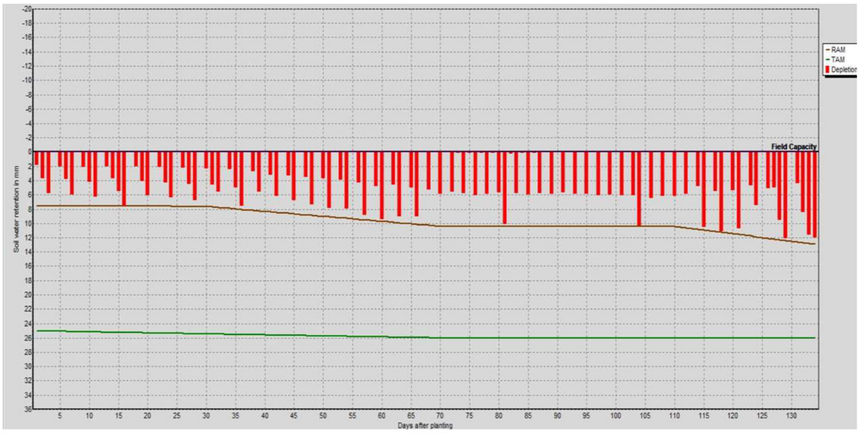


Fig. 4. Irrigation scheduling graph.

The reference evapotranspiration (ET_0) was varying with lowest during winter season to highest during summer season.

Crop water requirement

Based on the climate data, rainfall data, crop data, and soil data fed to the CROPWAT 8.0 model, the crop evapotranspiration for tomato crop was found to be 576.1 mm/crop period (Fig. 3).

It was observed that the maximum crop evapotranspiration of 232.6 mm was occurred at mid-season stage of crop and minimum crop evapotranspiration of 48.7 mm was occurred at initial stage of crop. Also, it was observed that the irrigation requirement of the tomato crop was found to be 544.9 mm. The maximum amount of water required for the irrigation was 223.9 mm at the mid-season stage of crop and the minimum amount of water required for the irrigation was 47.5 mm at the initial stage of crop.

Irrigation scheduling

The irrigation scheduling was prepared for tomato crop using CROPWAT 8.0 model based on the climate data, rainfall data, crop data, and soil data (Fig. 4).

It was observed that the total gross irrigation requirement and net irrigation requirement for the tomato crop was obtained as 761.3 mm and 532.9 mm respectively. The total irrigation loss was 0.3 mm. The actual amount of water applied to the crop without irrigation loss was 544.6 mm. It was also observed that the maximum number of irrigation intervals was more in mid-season stage of the crop and minimum number of irrigation intervals was found in initial and late season stage of the crop.

Irrigation water

The water has been used for irrigating the study area was drawn from the tube well located in the college campus. The porous pipe irrigation system was adopt-

Table 1. Details of the volume of water applied to the plot under traditional furrow irrigation method.

Sl. No.	Date	Day	Stage	Time	Volume of irrigation (L)
1	Volume of water applied to the crop at nursery				3888
2	02-02-2020	26	Initial		
3	09-02-2020	33	Development		
4	23-02-2020	47	Development		
5	04-03-2020	56	Development		
6	14-03-2020	66	Development	75 min	6300
7	23-03-2020	75	Mid		
8	1-04-2020	84	Mid		
9	11-04-2020	94	Mid		
10	20-04-2020	103	Mid		
11	1-05-2020	114	End		
12	16-05-2020	129	End		
		Total volume of irrigation			73,118

Table 2. Details of the volume of water applied to the plot under CROPWAT irrigation scheduling method.

Sl. No.	Date	Day	Crop stage	Net irrigation (mm)	Volume of irrigation (L)
1	Volume of water applied to the crop at nursery				3888
2	05-02-2020	29	Initial	9.1	737.1
3	09-02-2020	33	Development	8.0	648
4	13-02-2020	37	Development	10.1	818.1
5	16-02-2020	40	Development	8.6	696.6
6	19-02-2020	43	Development	9.2	745.2
7	22-02-2020	46	Development	10.3	834.3
8	25-02-2020	49	Development	10.9	882.9
9	28-02-2020	52	Development	11.9	963.9
10	03-03-2020	55	Development	12.0	972
11	06-03-2020	58	Development	13.1	1061.1
12	09-03-2020	61	Development	14.0	1134
13	12-03-2020	64	Development	13.4	1050.4
14	15-03-2020	67	Development	14.1	1142.1
15	17-03-2020	69	Development	10.5	850.5
16	19-03-2020	71	Mid-season	11.7	947.7
17	21-03-2020	73	Mid-season	11.0	891
18	23-03-2020	75	Mid-season	11.3	915.3
19	25-03-2020	77	Mid-season	11.4	923.4
20	27-03-2020	79	Mid-season	11.4	931.5
21	30-03-2020	82	Mid-season	15.5	1255.5
22	01-04-2020	84	Mid-season	11	891
22	03-04-2020	86	Mid-season	12.0	972
23	05-04-2020	88	Mid-season	11.9	963.9
24	07-04-2020	90	Mid-season	11.5	931.5
25	09-04-2020	92	Mid-season	11.5	931.5
26	11-04-2020	94	Mid-season	11.6	939.6
27	13-04-2020	96	Mid-season	11.8	955.8
28	15-04-2020	98	Mid-season	12.2	988.2
29	17-04-2020	100	Mid-season	11.5	931.5
30	19-04-2020	102	Mid-season	12.1	980.1
31	22-04-2020	105	Mid-season	15.2	1231.2
32	24-04-2020	107	Mid-season	12.5	1012.5
33	26-04-2020	109	Mid-season	12.5	1012.5
34	28-04-2020	111	Late-season	12.1	980.1
35	30-04-2020	113	Late-season	11.7	947.7
36	03-05-2020	116	Late-season	14.4	1166.4
37	06-05-2020	119	Late-season	16.3	1320.3
38	09-05-2020	122	Late-season	16.0	1296
39	12-05-2020	125	Late-season	12.6	1020.6
40	17-05-2020	130	Late-season	14.7	1190.7
	03-05-2020		Late-season		
		Total			47,061.1

ed for irrigating the plot under CROPWAT irrigation scheduling. The length of the porous pipe was 216 m. The traditional furrow irrigation method was adopted for another plot to irrigate the study area. The details of the volume of water applied for the crop under traditional furrow irrigation method and CROPWAT

Table 3. Water use efficiency for tomato crop under traditional furrow irrigation method and CROPWAT scheduling method.

Water use efficiency (kg/ha mm)	Crop under traditional furrow irrigation method	Crop under CROPWAT scheduling method
Crop water use efficiency	2.57	4.07
Field water use efficiency	1.63	4.03

scheduling method presented in Tables 1 - 2.

From the Tables 1 - 2, it was observed that the total volume of water applied to the crop under traditional furrow irrigation method and CROPWAT irrigation scheduling method was 73.188 m^3 and 47.0611 m^3 respectively. Also, it was found that 35.69% of water saved in CROPWAT irrigation scheduling method than the traditional furrow irrigation method.

Crop yield

The yield of the tomato crop under traditional furrow irrigation method was 1481.48 kg ha^{-1} whereas under CROPWAT irrigation scheduling method was 2345.67 kg ha^{-1}. Therefore, it was observed that the yield of the tomato crop in CROPWAT irrigation scheduling method was 36.8% more than the traditional furrow irrigation method with application of less water (35.69%) than the traditional furrow irrigation water.

From Table 3, it was concluded that the crop and field water use efficiency for the tomato crop under traditional furrow irrigation method was 2.57 kg ha mm^{-1} and 1.63 kg ha mm^{-1} respectively and the crop and field water use efficiency for the tomato crop under than the CROPWAT irrigation scheduling method was 4.07 kg ha mm^{-1} and 4.03 kg ha mm^{-1} respectively. Also, it was found that the crop water use efficiency in CROPWAT irrigation method was 58.36% more than the traditional furrow irrigation method. The field water use efficiency in CROPWAT irrigation scheduling method was more than the traditional furrow irrigation method.

CONCLUSION

The total volume of water applied to the crop under traditional furrow irrigation method and CROPWAT irrigation scheduling method was 73.188 m^3 and 47.0611 m^3 respectively. Hence 35.69% of water saved in CROPWAT irrigation scheduling method. It was observed that the yield of the tomato crop in CROPWAT irrigation scheduling method was 36.8% more than the traditional furrow irrigation method. The crop water use efficiency in CROPWAT irrigation method was 58.36% more than the traditional furrow irrigation method.

Thus, the study concluded that with optimum water application to the tomato crop by adopting irrigation scheduling of the CROPWAT 8.0 software has a possibility to get more amount of crop yield as compare with the application of excess amount of water in traditional methods without considering any weather, soil, crop parameters. Also, this study is capable for strategic planning on irrigation management and scheduling in the view of water saving technology.

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