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QUANTITATIVE PREDICTION OF TOMATO IRRIGATION NEEDS USING CROPWAT MODEL

Elena Grancharova*, Blagoj Elenov, Emilija Janevska

Institute of Soil Science, Agrotechnologies and Plant Protection “Nikola Poushkarov”, Sofia, Bulgaria
*e-mail: eveha@abv.bg

ABSTRACT

Emerging climate changes and rapidly growing demand for food are creating preconditions for making water an increasingly valuable resource and irrigation management assumed greater importance and increasingly responsible essential role. This study uses CROPWAT 8.0 model by FAO to predict and simulate crop water requirements for greenhouse tomato production in Chelopechene experimental field of the Institute of soil science, agrotechnologies and plant protection in Sofia, Bulgaria. The main input data are climatic data, crop data and soil data. The simulation results analysis suggests that an actual irrigation requirement of tomato is 489.5 mm. This study has proved that decision support tools like CROPWAT 8.0 are useful for irrigation planning and management and could be used by farmers to determine irrigation requirement and frequency, as well as contribute to saving water resources.

Key words: CROPWAT 8.0, Irrigation water requirement, Tomato, Greenhouse.

INTRODUCTION

Emerging climate changes and rapidly growing demand for food are creating preconditions for making water an increasingly valuable resource and irrigation management assumed greater importance and increasingly responsible essential role. The proper irrigation requirement, proper irrigation scheduling, crop water requirements, and evapotranspiration determination are one of key elements of sustainable water management. The computer-based simulation models are an irrigation scheduling tool which aid to adaptive water resource management, production yield improvement and production cost reduction, as well as improving irrigation water use efficiency. Application of these models is being highly used in agriculture sector to increase efficiency of decision making (Kumara et al., 2015). Simulation models contribute to better understanding how microclimate effects on transpiration and photosynthesis (Jones, 2007) and for optimizing irrigation water management (Droogers et al., 2000). The models allow a combined assessment of various factors affecting yield to obtain optimal irrigation in different scenarios (Liu et al., 2007) and are particularly useful in expensive studies or in studies where long-term effects may be difficult to observe (Xiang et al., 2022).

CROPWAT 8.0 is a decision support program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data developed by the Land and Water Development Division of FAO (Smith, 1992). It is developed based on methodologies presented in FAO Irrigation and Drainage Papers No. 24 "*Crop water requirements*" and No. 33 "*Yield response to water*”. CROPWAT 8.0 could be used to evaluate the irrigation practices and crop productivity (Gabr & Fattouh, 2021; Solangi et al., 2022), to calculate crop evapotranspiration in different climatic conditions (Mehta & Pandey, 2016; Veeranna & Mishra, 2017; Bhat et al., 2017, Aydin, 2022) or different crops (Memon & Jamsa, 2018; Moseki et al., 2019; Ewaid et al., 2019; Gebremariam et al., 2021). The model has been successfully used for analysis of crop water requirements in Bulgaria for maize (Popova, 2008),

wheat (Georgieva, 2013), beans (Petrova, 2014; Ilcheva, 2017). For this study CROPWAT 8.0 model was used to investigate the irrigation water requirements and irrigation scheduling in greenhouse tomato crop in the Chelopechene experimental field of the Institute of Soil Science, Agrotechnologies and Plant Protection “Nikola Poushkarov”, Sofia, Bulgaria.
Tomato (*Solanum lycopersicon L.*) is one of the most popular vegetables in the world which is growed in a wide range of climatic conditions. According to FAOSTAT (2022) 251 687 023 t of tomato yileds has been produced in 168 countries in 2020. In Bulgaria 115 790 t tomatoes has been produced in 2020 (FAOSTAT, 2022). Tomato is a high water demanding crop (Patane et al., 2011) and irrigation is a factor significantly influenced the yield. In greenhouse cultivation only the irrigation system is relied on to supply the needed water for irrigation, so the issues related to effective water use are of particular importance. Therefore, the main aim of this study is to estimate the reference evapotranspiration (ETo), irrigation water requirement and irrigation scheduling in greenhouse tomato production in the Chelopechene experimental field. The results from this study can be used for similar climate condition and regions in tomato farmer`s production.

MATERIAL AND METHODS

The experiment was conducted in 2017 in unheated plastic greenhouse located in the Chelopechene experimental field of the Institute of Soil Science, Agrotechnologies and Plant Protection ”Nikola Pushkarov” (42° 44′ 23″ N, 23° 28′ 4″ E and 550 m a.s.l.), Sofia region on drip irrigated tomato (*Solanum lycopersicum “Big Beef”*) under mulch. The climate is moderate continental. According National Institute of Meteorology and Hydrology data (NIMH, 2018) during period from 17 to 24 April 2017 average daily temperatures have been between 1 and 6.5°C. The last spring frost has been occurred on 24 April (-2.4°C), while the average daily temperature above 10°C has been occurred after 26 April. The soil type in this investigation is *Chromic Luvisol*. For the 40 cm deep soil layer the average values are: field capacity - 21.9 %, PWP 9.7 % and dry bulk density – 1.46 g cm^{-3}. Water physical characteristics of the soil, field capacity (FC %), permanent wilting point (PWP %) and available water content of experimental field were analysed according to Simeonov (1958). Average monthly climate data for the period 15 May 2017 to 30 September 2017 (maximum and minimum temperatures, relative humidity, wind speed, sunshine hours and precipitation) were collected from the nearest meteorological station.
Input data used for referent evapotranspiration (ETo) calculation were: temperature, humidity, wind speed and sunshine and, while radiation was calculated according to Climate/ETo module by CROPWAT 8.0 software.
Crop module input data are: planting date (15 May 2017), crop coefficient (Kc), stages (initial - 18 days, development - 40 days, mid-season - 45 days, late - 35 days), rooting depth (from 0.05 m to 0.40 m), critical depletion fraction (0.40), yield response factor (between 0.50 and 1.10) and crop height (2.10 m). Kc values of tomatoes were as follows: initial stage 0.9, development stage 0.94-1.09, mid-season stage 1.24, and late season stage 1.21-0.81. The crop cycle was 138 days. Crop characteristic data were collected according own developed data.
Soil module requests initial available soil moisture, initial soil moisture depletion, maximum infiltration rate, maximum rooting depth and Total Available Water (TAW) according to Climate/ETo module by CROPWAT 8.0 software.
The CWR module includes calculations, producing the irrigation water requirement of the crop on a decade basis and over the total growing season.
The Schedule module calculates soil water balance on a daily step and allows to develop indicative irrigation schedules or alternative water delivery schedules under restricted water supply conditions, allows to evaluate crop water productivity and crop production (FAO, 1992).

RESULTS AND DISCUSSION

The results for ETo are presented in Table 1 in decades and for all growing season was estimated at 451.56 mm. The maximum average reference evapotranspiration in 2017 was recorded 4.78 mm day^{-1} on 30 June. The high values in last decade of June are due to high maximum temperature in this period Considering ETo depends on climatic factors and higher values in last decade of June compared to first and second decades of July are due to higher temperature in this period. ETo also depends on precipitation but the experiment was conducted in greenhouse and only the irrigation system apply water to the crops.

Table 1. Reference evapotranspiration (ETo) and irrigation rate (IR) of tomatoes presented by decades

Month	**Decade**	**ETo mm decade^{-1}**	**IR mm decade-^{1}**
May	2	29.43	19.4
May	3	32.60	25.2
June	1	25.56	28.1
June	2	30.03	26.5
June	3	43.88	47.2
July	1	38.68	51.5
July	2	35.40	38.5
July	3	41.94	57.3
August	1	40.73	45.5
August	2	34.78	43.4
August	3	33.24	40.9
September	1	26.59	27.4
September	2	27.63	25.7
September	3	11.07	11.9
TOTAL		**451.56**	**488.5**

Crop water requirement (CWR) for tomatoes during the growing season was estimated at 490.4 mm (Table 2). ETc values were relatively low during the initial stage compared to the other growth stages in season. It increases during initial and development stages and keeps high values during middle stage and decreases during late stage. The highest daily value is 15.8 mm on 3 August. CWR was expressed through crop coefficient (Kc), decreases and is low in the start and end stages and increases through the middle when the crops were at their productive stage. The highest values were observed in middle stage between day 69 and day 78 and it was 51.9 mm decade $^{-1}$. CWR varied and depends on development crops stage and climatic conditions. CWR was between 20 and 30 mm for decade at initial and late stages and between 40 and 50 mm for decade at middle stage. Similar results for irrigation rate in tomatoes crop was calculated by pan class A data (Patamanska et al., 2018) for the same experimental plot in greenhouse, as well as in the open area for the same experimental field in 2017 (Petrova-Branicheva et al., 2020).

Table 2. Crop water requirement of tomatoes

Month	**Decade**	**Stage**	**Kc**	**ETc**	**ETc**

				mm day^{-1}	mm decade^{-1}
May	2	Int	0.9	3.25	19.5
May	3	Int	0.9	2.67	29.3
June	1	Deve	0.94	2.40	24.0
June	2	Deve	1.02	3.07	30.7
June	3	Deve	1.11	4.86	48.6
July	1	Deve	1.19	4.61	46.1
July	2	Mid	1.24	4.38	43.8
July	3	Mid	1.24	4.72	51.9
August	1	Mid	1.24	5.04	50.4
August	2	Mid	1.24	4.30	43.0
August	3	Late	1.28	3.66	40.2
September	1	Late	1.08	2.87	28.7
September	2	Late	0.94	2.43	24.3
September	3	Late	0.81	1.08	9.7
TOTAL					**490.4**

Irrigation requirement (IR) of tomatoes is presented at Table 1. IR was low in the start and end stages and increased through the middle when the crops were at their productive stage. Total IR for tomato crop in this investigation was 488.5 mm. Similar results are calculated by pan class A data from Patamanska et al., (2018) for the same experimental plot.

According to our results, tomato need about 30 irrigation applications by drip irrigation (Fig. 1).

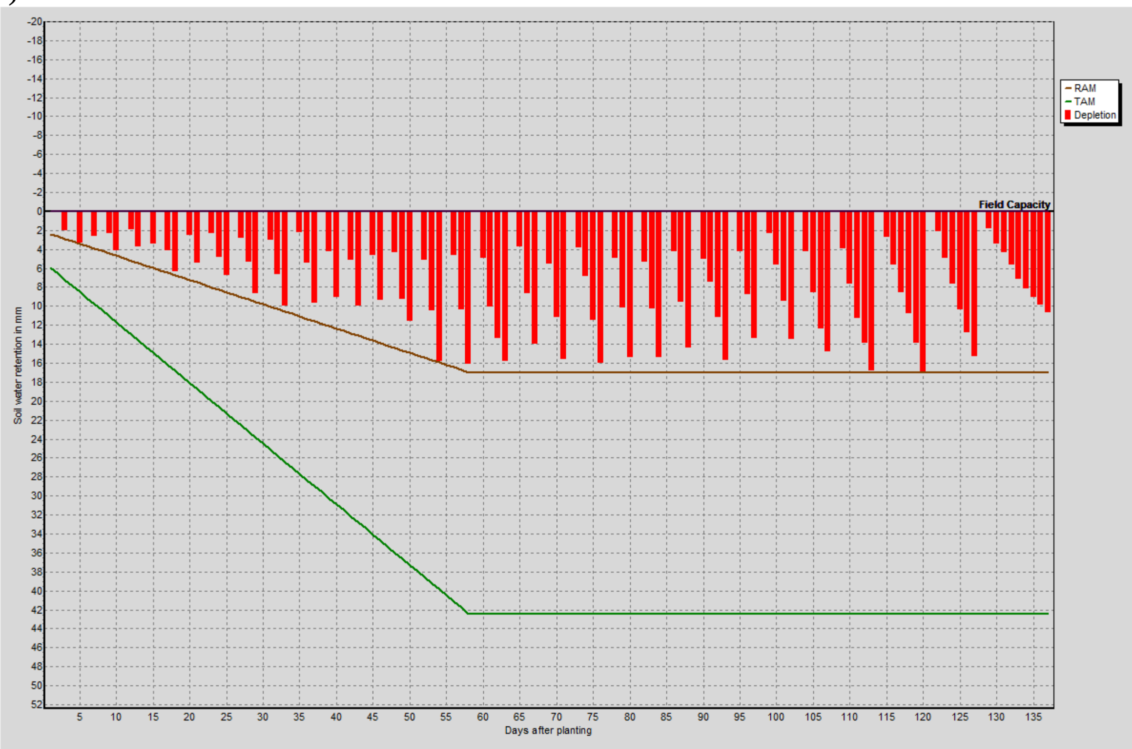

Figure 1. Irrigation scheduling of tomato by drip irrigation

CONCLUSIONS

The crop water requirement was estimated at 490.4 mm and total irrigation requirement was estimated at 488.5 mm for greenhouse tomatoes during the growing season. The irrigation scheduling includes 30 irrigations. The results of this study could increase knowledge of the water requirement of tomatoes could assist in enhancing the management of water and crop yield. This study has proved that decision support tools like CROPWAT are useful for irrigation planning and management and could be used by farmers to determine irrigation volume and frequency, as well as contribute to saving water resources.

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