Original Research Article

Effect of automated drip irrigation system on yield and water use efficiency of tomato (*Solanum lycopersicum* L.)

R. Suvitha[1*], A. Velayutham[2], V. Geethalakshmi[1], S. Pannerselvam[1], P. Jeyakumar[1] and K. Nagarajan[1]

[1]Tamil Nadu Agricultural University, Coimbatore-614 003.Tamil Nadu, India

[2]Agricultural College and Research Institute, Thanjavur-614 902, Tamil Nadu, India

ABSTRACT: Field experiment was conducted to evaluate the performance of different automated drip irrigation on tomato crop under sandy clay loam soil in Tamil Nadu Agricultural University during *kharif* 2019 and *kharif* 2020. Five treatments comprising 4 different automated drip irrigation systems are time based drip irrigation, volume based drip irrigation, soil moisture sensor based irrigation, switching tensiometer based irrigation and one is conventional method of irrigation were tested. The results revealed that tensiometer based drip irrigation recorded higher fruit yield of 95.11 and 96.21 t ha^{-1} and water use efficiency of 21.10 and 25.42 t ha-mm^{-1} resulting in increment over conventional method of irrigation. However, the above treatment was followed by soil moisture sensor based drip irrigation in tomato. Tensiometer based drip irrigation helps to save the water up to 54.91 and 60.55 % compared to conventional method of irrigation during *kharif* 2019 and 2020.

Keywords: Tomato, automated drip irrigation, fruit yield, water use efficiency

Introduction

Water is becoming gradually scarce worldwide as a result of a combination of population expansion, socioeconomic development, shifting consumption patterns and climate change which has resulted in water shortages and poor quality of water[19]. Present day, agriculture is India's largest consumer of water, it is now necessary to reduce consumption, enhance water resource management and productivity of food crops need to be increased by 60-70 % during mid-century to keep the country self-sufficient[16]. Fresh water resources are becoming limited in India. So, there must be enforcement to achieve an efficient irrigation method for irrigating the crops. Several modern techniques for irrigating the crops will increase the efficiency of water use. The foremost irrigation method is drip irrigation, which is the most effective technique for supplying water near the root zone which leads to saving more water by about 90 percent over surface irrigation, whereas about 50 to

70 percent of water is wasted due to transport, evaporation, field application, and distribution losses. The losses prevailed in surface irrigation will be overcome by implementing drip irrigation, in which there are no such losses conquered during irrigation. Recent days, farmers in India practiced irrigation techniques through manual control. This process sometimes consumes more water and delivering late to the root zone leads to crops get dried. To overcome this problem can adopt an automatic drip irrigation system along with sensors which are installed in the root zone and connected to an irrigation controller. Sensors measure the moisture content and send values to the solenoid valve of the system to turn ON and OFF automatically for various intervals of time.

Tomato is one of the most preferred vegetables all over the world. Tomato ranks second followed by potato in terms of area cultivated, but first as a processing crop[7]. In India about 83 % of the freshwater resources are utilized for agriculture purposes. Tomatoes cover 5,023,810 hectares of land around the world[5]. However, Tomato crop requires 400 - 800 mm of water for total cropping period. Although, tomato is sensitive to water stress and it has a high correlation between evapotranspiration (ET) and crop yield[12]. In the successful cultivation of Tomato, Plant development and yield are heavily influenced by water[2]. They are very sensitive to water deficits during transplanting, at flowering and also during fruit development. Water stress will inhibit the growth at initial stage (20th day) compared to the later stage (30th day) of the crop[11]. In general, tomato crop irrigates through surface method of irrigation (furrow/check basin) wherein losses over conveyance, application, evaporation and percolation are common besides having adverse effects of cyclic over irrigation or water stress**.** Drip irrigation is a good adoption for achieving better productivity and quality in different crops. Micro irrigation is an efficient method which can save water and fertilizers, resulting in higher yield, quality and reduce the labour interventions in farm operations[17]. In the present decade, there has been a serious anxiety in global lack of water. It is assessed that in India by 2025, 33% of India's population will live under severe scarcity conditions[4]. Drip irrigation is the most effective way to supply water to the tomato, which not only saves water but also increases yield due to nonstop maintenance of moisture content near field capacity[14]. Farmers in India have been adopting irrigation techniques through manual control in which they irrigate the field at regular intervals in the modern period. This procedure can use a lot of water, or it can take a long time for the water to reach the crops, causing them to dry out. Water is crucial to assure the accessibility of vegetable crops throughout the year, which necessitates the use of an irrigation water management approach that can aid in attaining the

goal of growing more crops per drop of water through drip irrigation. Water losses through transportation, evapotranspiration, percolation, and runoff were prevalent under surface irrigation. A drip irrigation system is the best alternative to the surface method of irrigation because it eliminates losses like evapotranspiration because water is delivered only to the root zone drop-by-drop under drip irrigation. The water requirement of a tomato crop is 0.89–2.31 litres plant^{-1} day^{-1} under drip irrigation. Implementation of a drip irrigation system with an automation setup for tomato crops will irrigate the crops only when there is a high demand for water, which can save the water as well as reduce labour intervention. The objective of this work was to evaluate a different method of automatic drip irrigation system compared with common grower practice (furrow irrigation) in the area and scheduling methods of irrigation which may help farmers to enhance the productivity of tomato fruits, saves water and reduced the labour cost.

Materials and methods

The experiment was carried out during *kharif* 2019 and *kharif* 2020 at Tamil Nadu Agricultural University, Coimbatore situated at 11° North latitude and 77° East longitude at an altitude of 426.7 m above mean sea level. Weather parameters were obtained from the Agro Climate Research Centre, TNAU. Initial soil sample was collected and tested. It indicated that the experimental field was sandy clay loam in texture, medium organic carbon (5.8 g kg^{-1}), low available nitrogen (210.5 kg ha^{-1}), high available phosphorus (33.4 kg ha^{-1}) and high in available potassium (756 kg ha^{-1}). Whereas, field capacity (22.35 %), permanent wilting point (12.56 %) and pore space (31.87 %) were present in the sandy clay loam soil. Tomato (*Solanum lycopersicum* L.) crop, variety shivam hybrid with 135 days of duration was transplanted in the gross plot size of each plot about 86.4 m^2 with the spacing of 60 × 60 cm in all irrigated plots. The experiment was laid out in randomized block design with four replications and five treatments. The treatments consist of 4 different automated drip irrigation systems, viz., T$_1$-time based drip irrigation (Irrigation at fixed interval per stage and refill soil to field capacity), T$_2$-volume based drip irrigation (critical depletion along with refill soil to field capacity), T$_3$-soil moisture sensor based irrigation (EC H$_2$O- Capacitance sensor), T$_4$- switching tensiometer based irrigation (Irrometer) and T$_5$-conventional method of irrigation (furrow irrigation). To evaluate the different methods of automated drip irrigation system over surface irrigation, all agronomic practices such as weeding, disease and pest control were carried out according to the conditions. Data on yield components of

tomato crop were observed and analysed from the treatment plots. These data were also necessary for calculating total water use, water saving percent and water use efficiency.

Estimation of crop water requirement

The test crop was tomato (*Solanum lycopersicum* L.) The crop cycle length was 135 days with development stages of initiation, vegetative, reproductive and maturity stages, respectively. The actual crop evapotranspiration was (ETa) calculated by multiplying the reference evapotranspiration (ETo) with crop coefficient (Kc) for different growth stages of the crop. The major input data has been used in CROPWAT model was climatic data, crop data and soil data. Climatic data of previous year (2016-2018) were collected from ACRC, TNAU (Figure 1). The results derived from the CROPWAT model are used for experimental trial on scheduling automated drip irrigation for time based and volume based irrigation. Soil moisture sensor (EC- H_2O) based irrigation depends on resistivity principle, transmits the real data of soil moisture content to microcontroller and irrigation event take place automatically as per availability of moisture content with respect to predefine value stored in database of controller (field capacity of 22.34 %) for irrigation scheduling. Switching tensiometer irrigation depends on soil moisture tension above 0.45 bars. To evaluate conventional method of irrigation, the climatic data of 2019 and 2020 were collected from ACRC and used to calculate irrigation water requirement as per the IW/CPE ratio of 0.8 for tomato.

Estimation of water use studies:

Total water use (mm)

It is the sum of irrigation water applied during cropping period and effective rainfall.

Total water use (mm) = Total irrigation water + Effective rainfall

Field water use efficiency (t ha-mm^{-1})

Field water use efficiency (WUE) is the yield that can be produced from a given quantity of water with effective rainfall utilized by the crop (total water use).

$$WUE = \frac{\text{Economic yield (t ha}^{-1})}{\text{Total water use (mm)}} \times 100$$

Percent of water saving over control

Water saving % calculated by subtracting the total water utilized in treatments with total water consumed for conventional method of irrigation and then divided by total water consumed for conventional method of irrigation. From the derived values were multiplied by 100 to get percent of water saved over control treatment.

Statistical analysis: Data collected from the field experiment were statistically analysed using the "Analysis of variance test" at 5 % critical difference over each other[9].

Results and Discussion

Fruit yield (t ha^{-1})

The maximum fruit yield of tomato was recorded with sufficient water to the crop (Table 1). During *kharif* 2019, tensiometer based drip irrigation gave significantly higher yield (95.11 t ha^{-1}) over surface irrigation (62.13 t ha^{-1}). During *kharif* 2020, the highest fruit yield (96.21 t ha^{-1}) was recorded under tensiometer based drip irrigation over surface irrigation (62.69 t ha^{-1}). The yield of 33 per cent was recorded with tensiometer based drip irrigation method over conventional method of irrigation during *kharif* 2019 and *kharif* 2020.The higher yield under tensiometer based drip irrigation might be due to application of required amount of water to the crop at required time. Similar results conveyed that utilizing switching tensiometers in Florida lowered irrigation requirements of tomatoes by 40–50% without dropping fruit yield[18]. Fruit yield of tomato was higher up to 7% with drip irrigation over furrow method of irrigation[15].

Water use studies

The total water utilized is given in Table 1, including effective rainfall for tomato crop. It can be seen that the total water used for tomato crop was higher for conventional method of irrigation which were irrigated during transplanting at 5 cm depth. Subsequently irrigation was given in accordance with the IW/CPE ratio of 0.8. Quantity of water applied was 583 and 750 mm during *kharif* 2019 and *kharif* 2020, respectively. An effective rainfall of 416 and 209 mm was received during the cropping period in *kharif* 2019 and 2020, respectively. The quantity of water used about 999 and 959 mm during *kharif* 2019 and 2020 for surface irrigated crops followed by time based drip irrigation (624 and 568 mm), volume based drip irrigation (470 and 418 mm), soil moisture sensor based drip irrigation (462 and 406mm) and tensiometer based drip irrigation (451 and 378 mm) treatment during both the years. The highest water use efficiency of 21.10 and 25.42 t ha-mm^{-1} was obtained for tensiometer based drip irrigation treatment which was followed by soil moisture sensor based drip irrigation treatment (20.29 and 23.31 t ha-mm^{-1}). The lowest water use efficiency (6.22 and 6.53 t ha-mm^{-1}) was noticed with control treatment during *kharif* 2019 and *kharif* 2020 (Figure 2). Tensiometer based drip irrigation recorded a water saving percent of 54.91 and 60.55 percent over conventional irrigation during *kharif* 2019 and *kharif* 2020 (Table 1). The reason behind the increase in WUE and less quantity of water utilized for all drip irrigation methods was due to considerable saving of irrigation water, greater increase in crop yield.

Similar results revealed the comparative performance of drip and surface methods of irrigation in tomato and stated that there is a water savings of 20-52 % over surface method of irrigation[13].Furthermore, low irrigation regime condensed deep percolation and enlarged water use by plants from the root zone soil[3]. Decrease in irrigation water requirements in the Florida region which displays that using tensiometer, the irrigation requirement of tomato crop was condensed by 40 to 50% but they need regular maintenance and blockage owing to algae growth[6]. The WUE was lower and total water use was greater in surface irrigation than other irrigation methods. It might be due to higher consumption of water resulting in lower yield than other treatments.

Conclusion

An automated irrigation system providing water on-demand was designed using time based, volume based, sensor based, tensiometer based drip irrigation proves to be a real time feedback control system which efficiently monitors and controls all drip irrigation system activities. The findings will be utilised to modernise farm operations on a wider scale as well as save manpower, water and ultimately money by increasing productivity. The present study indicated that tensiometer based drip irrigation resulted in significantly highest yield (95.11 and 96.21 t ha^{-1}) and water use efficiency (21.10 and 25.42 t ha-mm^{-1}) than the conventional method of irrigation in tomato during *kharif* 2019 and *kharif* 2020.

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Table 1: Effect of automated drip irrigation on yield (t ha^{-1}) and Total water use (mm) of tomato

| Treatment	Yield (t ha^{-1})		*Total water use (mm)		*Water saving (%)	
	kharif 2019	*kharif* 2020	*kharif* 2019	*kharif* 2020	*Kharif* 2019	*Kharif* 2020
T1- Time based drip irrigation	88.22	89.90	624	568	37.61	40.79
T2- Volume based drip irrigation	91.53	92.26	470	418	53.02	56.48
T3- Soil moisture sensor based drip irrigation	93.79	94.78	462	406	53.76	57.64
T4- Tensiometer based drip irrigation	95.11	96.21	451	378	54.91	60.55
T5- Conventional method of irrigation	71.55	72.38	999	959	-	-
Sed	0.50	0.39	-	-		
CD (P=0.05)	1.09	0.86	-	-		

* Data not statistically analysed
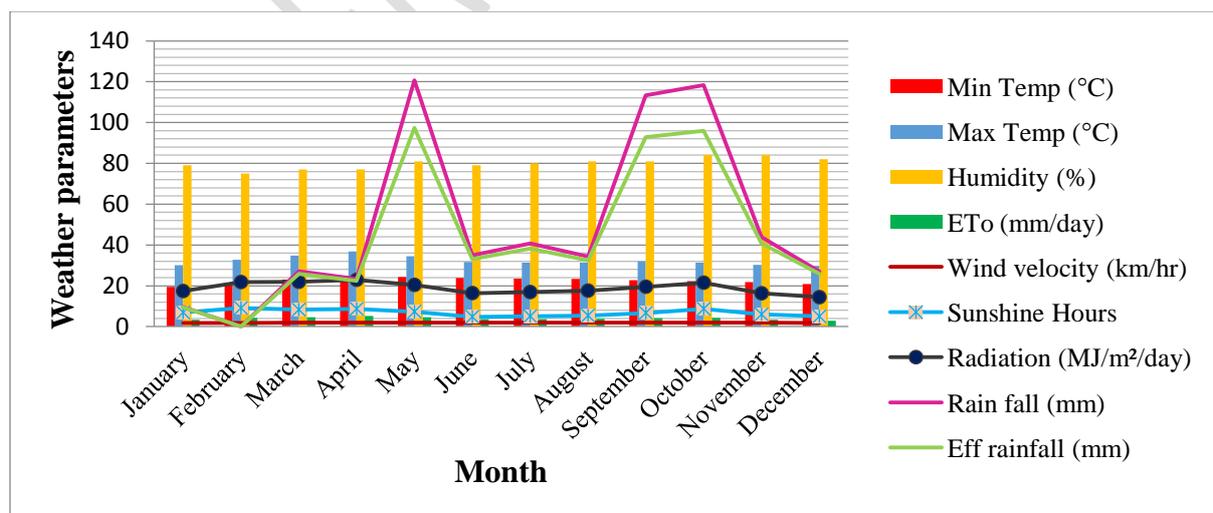
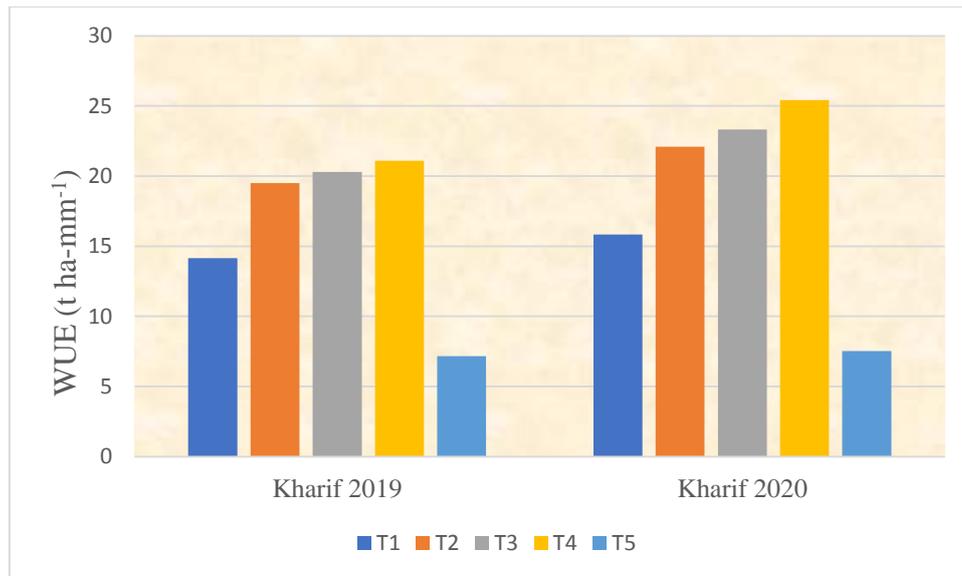Figure 1: Weather parameters prevailed during 2016-2018

Figure 2. Effect of different automated drip irrigation on water use efficiency (t ha-mm^{-1}) of tomato during *kharif* 2019 and *kharif* 2020