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Water Use Efficiency and Yield Response of Greenhouse-Grown Tomato to Partial Root Drying and Deficit Irrigation

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ABSTRACT

Water saving techniques in agriculture are gaining importance because of scarcity of water due to climate change and lower share of water for agriculture due to globalization. To overcome these challenges this research study was designed is to evaluate the effect of the partial root drying irrigation practice (PRD) and deficit irrigation (DI) practice on the, yield and water use efficiency of tomatoes (Shivam variety) grown under a greenhouse. The following irrigation treatments were formulated to study the effect of PRD and DI. The treatments were, partial root drying (PRD) at 75% and 50% crop evapotranspiration, ETc (PRD25 and PRD50, respectively), and deficit irrigation (DI) at 75% and 50% crop evapotranspiration, ETc (DI25 and DI50, respectively) and FULL Irrigation (FI). The PRD practice requires wetting oalf of the root zone and keeping the other half dry, consequently using less lied irrigation water. In successive irrigations, the wet and dry sides are alternated. The highest fruit yield was obtained under FULL irrigation (225 t ha-1).

Keywords: *Deficit Irrigation, Evapotranspiration, Full Irrigation, Partial Root Drying, Root Zone, Tomato, Water Use Efficiency*

INTRODUCTION

Irrigated agricultural land is the primary user of water resources, representing roughly 70% of total water withdrawal [1]. However, worldwide irrigated land area must be increased by more than 20%, and total irrigated crop yield must be increased by 40% by 2025 to ensure food security for 8 billion people [2]. As a result, water resources should be used more efficiently or productively. Improving agricultural water management is the most effective way to maximize the use of limited water resources. Water saving is needed to deal with competition between industrial and potable water sectors and ensure the long-term viability of irrigation schemes. The traditional irrigation method is now considered a luxury water use that can be improved with or without yield loss [3]. Several water-saving irrigation strategies have been used in recent years. In areas of recurrent water scarcity and long drought spells.

Deficit irrigation (DI) is a common and widely recommended practice for mitigating significant yield reductions [4]. However, the effective use of DI requires prior knowledge of specific crop-growth stages demonstrating tolerance to water stress, so growers may have difficulty using it. Partial root-zone drying (PRD), is an advancement of DI and one of the promising techniques for conserving irrigation water [5]. The deficit irrigation concept was first applied in the United States [6]. PRD is an irrigation technique in which half of the root zone is irrigated while the other half is allowed to dry out. The water supply is then reversed cyclically, allowing the earlier well-watered side of the root system to dry whereas fully irrigating the previously dried side. According to PRD, by allowing the soil on one half of a root zone to dry, the roots will send drought signals to the shoot, reducing vegetative growth and stomatal conductance, resulting in less water use. The expected outcome is acceptable yields with significant water savings and increased water use efficiency (WUE). PRD also stimulates the development of secondary roots, which reduces drought susceptibility [7].

Many studies have proven the benefit of PRD in reducing water input by 30–50% while maintaining yield or even improving quality [8]. PRD was applied to apple trees in a humid climate and showed that it did not reduce yield or fruit quality while increasing IWUE by 20% [9]. PRD has been successfully used in several crops such as tomatoes, corn, cotton, and others, and PRD has been shown to be successful in grapevines and in other vegetables [10][11]. Nevertheless, PRD could be successfully applied to tomatoes and impacted bioactive compounds and antioxidant activity [12] [13]. A tomato cultivated in a

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greenhouse was used to test partial root drying (PRD), a new irrigation technique for saving irrigation water. The best way of testing plants' responses to PRD is under controlled conditions in a greenhouse on plants with a split-root system [14]. The objective of this research work was to evaluate the effect of partial root drying and deficit irrigation on the yield and water use efficiency under of greenhouse-grown tomatoes.

MATERIALS AND METHODS

Experimental site

The experiment was carried out under the greenhouse from March to June, 2022 in the Tamil Nadu Agricultural University, Coimbatore. The crop was tomato (Lycopersicon esculentum L). The site location was 11.00689oN, 76.93606oE, and the altitude is 426.6 m above mean sea level. The size of the greenhouse was 20 × 20 m (400 m2) with an experimental area of planting of 240 m2 (15 × 16 m). The experimental area was divided into four blocks (60 m2) with a 2 m buffer distance in on all sides of the experimental area. The soil of the experiment site was sandy clay loam. The soil sample was taken to a depth of 45 cm at every 15 cm and physical and chemical analyses were was performed with standard methods [15]. Soil texture, field capacity (FC), wilting point (WP), saturated hydraulic conductivity (KS), saturation moisture content (Sat), and bulk density (b) are all investigated in the physical analysis. (pH), electrical conductivity (EC), and available N, P, and K were all examined in the chemical analyses, and 213, 330, and 555 kg ha-1 were observed. The layout of the experimental setup is shown in Fig. 1.

Table 1: Physical properties of soil

Depth/ cm	Particle size %			Texture	FC/%	WP/%	KS /mm·h^{-1}	Sat/%	ρb/g·cm^{-3}	pH	EC
	Clay	Silt	Sand								
0-45	32.3	12.4	48.2	Sandy clay loam	19.8	13.7	3.41	33.37	1.43	7.71	1.45

Irrigation treatments

A surface drip irrigation system was used for irrigation. 16 mm drip lines in diameter with 4 LPH in-line emitters 30 cm apart delivered were installed.

Irrigation treatments of Full irrigation (FI) at 100% crop evapotranspiration (ETc), Deficit irrigation (DI) at 75% of ETc (DI25), Partial root drying (PRD) at 75% of ETc (PRD25), DI at 50% of ETc (DI50) and PRD at 50% of ETc (PRD50) as shown in Table 2. In full irrigation treatment water is applied at 100% ETc, in PRD25 and DI25 water is applied at 75% of ETc, and in PRD50 and DI50 water is applied at 50% of ETc. A randomized complete block (RCB) design was used. For FI and DI water was applied on both sides of the plant root zone and in PRD two laterals were laid on both sides of the plant and water was applied alternatively in successive irrigation to the plant root zone. In FI and DI, laterals were installed at the center of two crop rows, whereas in PRD two laterals (separated by a distance of 0.6 m) for each crop row were used. A separate valve was used to control the water flow of these two laterals. In PRD irrigation was shifted between the two sides of the plant root zone in every successive irrigation. The flow meter was installed in the water delivery unit of the irrigation system to measure the irrigation water applied to the experiment plot. The screen filter was installed in the water delivery unit to prevent the clogging of drippers. Irrigation interval had fixed once a week, until mid-season after transplanting, after that at 3- and 4-day intervals two irrigations were applied in a week. The growth period was divided into four stages as given in Table 3.

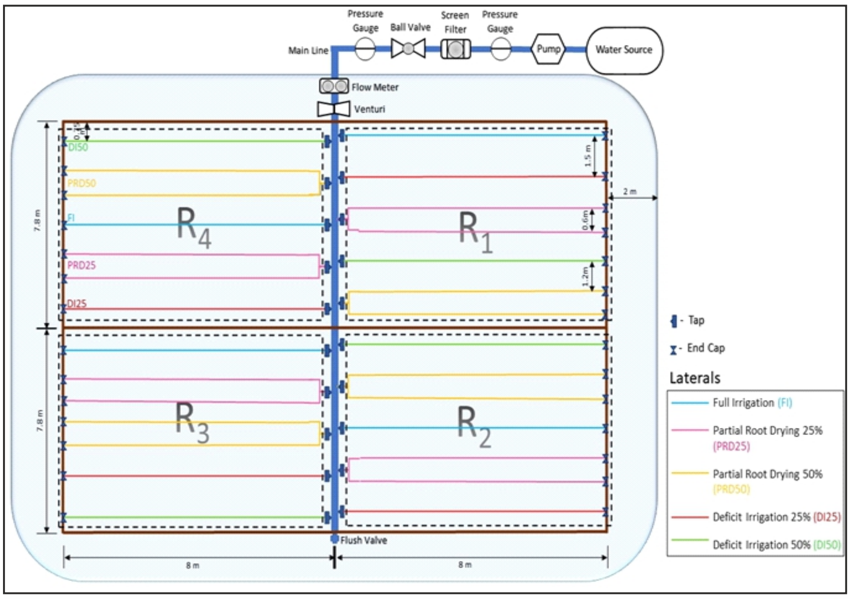

Fig. 1: Experimental Plot

Table 2: Irrigation treatments

Sl. No.	Irrigation treatments	Description
1	T_1	Full irrigation at 100% crop evapotranspiration, ET_c
2	T_2	Deficit irrigation (DI) at 75% crop evapotranspiration, ETc (DI25)
3	T_3	Partial root drying at 75% crop evapotranspiration, ET_c (PRD25)
4	T_4	Deficit irrigation (DI) at 50% crop evapotranspiration, ET_c (DI50)
5	T_5	Partial root drying at 50% crop evapotranspiration, ET_c (PRD50)

Weather conditions

All the meteorological parameters such as maximum and minimum air temperature, air relative humidity, solar radiation, wind speed and direction at 2 m above ground, etc were measured throughout the growing season as shown in Figure 2,3,4,5 respectively. For estimation of the actual ETc, The crop coefficient (Kc), with the values of 0.6 in the beginning, 1.15 in the middle, and 0.80 at the end of the growing season was used [16].

The estimation of ETc has given below:

$$ETc = K_c \times ET_o$$

From the climatic data, Daily reference evapotranspiration (ETo) was estimated using the Penman–Monteith FAO-56 equation [16], [17]

$$ET_0 = \frac{0.408\Delta(Rn - G) + \gamma \frac{900}{Ta+273} \mu 2 (es - ea)}{\Delta + \gamma(1 + 0.34\mu 2)}$$

Where, ETo is the reference evapotranspiration (mm day−1), Rn is the net radiation (MJ m−2 day−1), Δ is the slope of the saturation vapor pressure−temperature curve at mean air temperature (kPa °C−1), u2 is the wind speed at 2 m height (m s−1), G is the soil heat flux (MJ: m−2 day−1), Ta is the mean air temperature at 2 m height (°C), γ is the psychrometric constant [kPa °C−1], ea is the actual vapor pressure (kPa), and ea is the saturation vapor pressure (kPa).

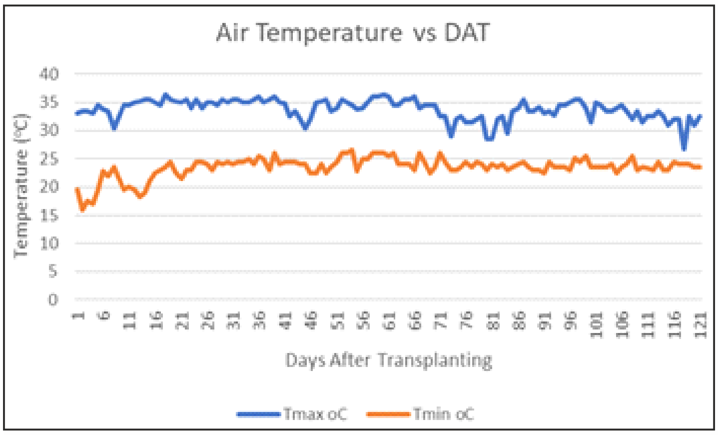

Fig. 2: Air temperature vs Days After Transplanting (DAT)

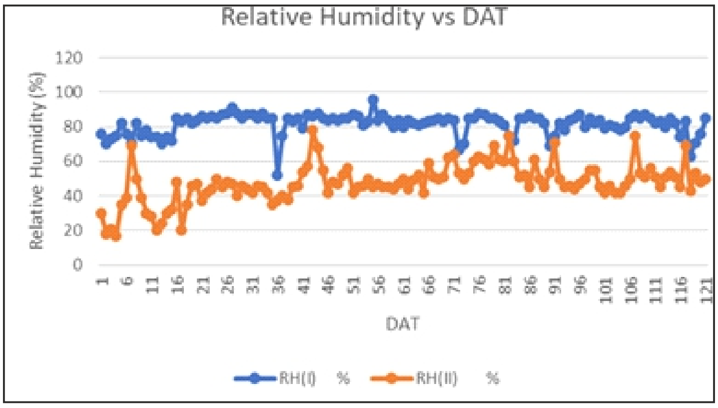

Fig. 3: Relative humidity vs Days After Transplanting (DAT)

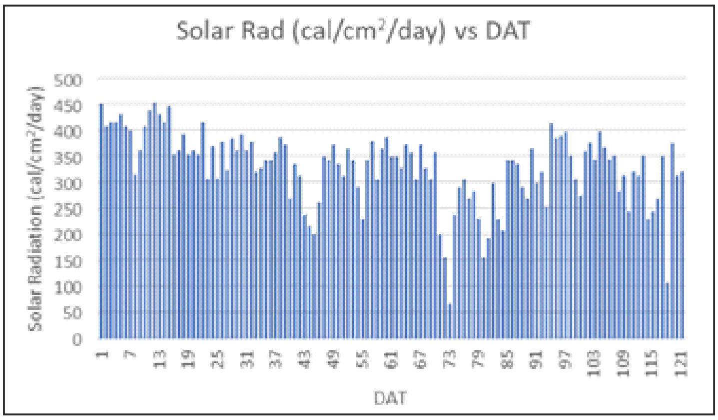

Fig. 4: Solar radiation vs Days After Transplanting (DAT)

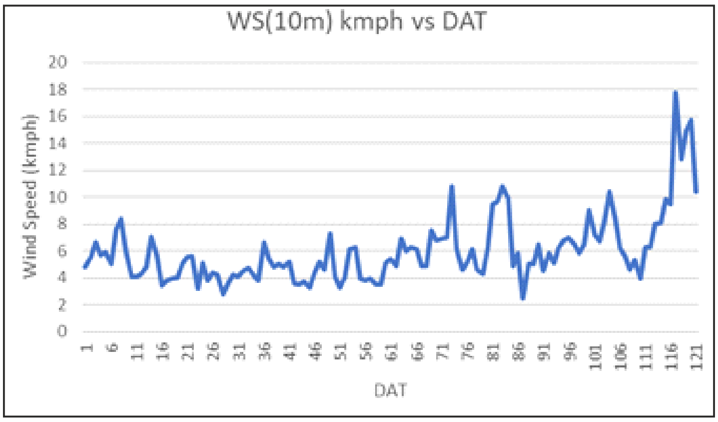

Fig. 5: Wind speed vs Days After Transplanting (DAT)

Water-use efficiency was used for evaluation of comparative benefits of the irrigation treatments. It was calculated using the equation [18]:

$$WUE=\frac{Y}{ET}\times 100$$

Where, WUE is the water use efficiency kg (ham)-1, Y is the marketable yield (t ha-1) and ET is the total evapotranspiration (mm).

RESULTS AND DISCUSSION

Effect of Partial Root Drying and Deficit Irrigation on Yield

The effect of irrigation treatments (FI, DI25, PRD25, DI50, PRD50) in on the tomato yield was given in the table 4. The maximum yield (22.5 kgs in 400 m2) was obtained in the full irrigation (FI) treatment. Then, it was followed by PRD25 and DI25 treatments. The yield in FI was increased by 30.8% when compared to DI25 and PRD25. Also, it was increased by 39.8% when compared to DI50 and PRD50. From the results, it can be understood that the PRD treatments had a higher yield than the DI treatments. Results of this study showed that the partial root drying and deficit irrigation practice can save up to 50% of irrigation water. These water usage decreases at the DI and PRD have resulted in savings of 23 and 46 mm of irrigation water, respectively.

Table 4. Total Yield (in Kgs/ 400 m2)

Treatments	R_1	R_2	R_3	R_4	Ave. yield
T_1 (FI)	23.6	22.3	21.5	22.6	22.5
T_2 (DI25)	17.9	16.7	15.9	17.4	17.0
T_3 (PRD25)	18.2	16.8	16.1	17.6	17.2
T_4 (DI50)	17.0	15.4	14.3	15.3	15.5
T_5 (PRD50)	17.5	15.8	15.1	15.8	16.1

Effect of Partial Root Drying and Deficit Irrigation on water use efficiency (WUE)

Water use efficiency (WUE) for the different irrigation treatments such as FI, DI25, PRD25, DI50, and PRD50. was given in the table 5. WUE for different irrigation treatments ranged from 24.45 t ha-1 cm-1 (T1 FI) to 35.10 t ha-1 cm-1 (T5 PRD50). The WUE was found to be higher in Partial root drying at 50% ETc (PRD50) than the full irrigation at 100% ETc. The deficit irrigation and PRD treatments resulted in significantly lower evapotranspiration (ET) than the full irrigation treatment (FI) [19]. The PRD and DI treatments utilized 50% less water and increased WUE by 30.35% and 25.71% respectively.

Table 5. Water Use Efficiency (WUE) (t ha-1 cm-1)

Treatments	Water applied (cm)	Yield (t/ha)	Water use efficiency ($t\ ha^{-1}\ cm^{-1}$)
T_1 (FI)	9.2	225.0	24.45
T_2 (DI25)	6.9	169.5	24.56
T_3 (PRD25)	6.9	173.3	25.11
T_4 (DI50)	4.6	154.4	32.91
T_5 (PRD50)	4.6	161.5	35.10

CONCLUSION

The results of this study revealed that the PRD irrigation method and conventional deficit irrigation, is the practical and advantageous alternative irrigation method to mitigate the yield reduction when and if there is a water shortage. If the PRD technique is used, high crop yields can also be maintained under water shortage conditions. it can be concluded that, the use of PRD and DI with 50% of ETC has a advantages compared to full irrigation in terms of improving the water use efficiency, with minimum yield reduction.

Future Scope of the Study

The same experiment can be conducted in the open field condition to study the effect of partial root drying and deficit irrigation on the yield and water use efficiency of Tomatoes.

Conflict of Interest

The authors declare that there is no conflict of interest.

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