*Original Research Article*

# EFFECT OF PARTIAL ROOT DRYING AND DEFICIT IRRIGATION ON YIELD AND WATER USE EFFICIENCY OF TOMATO GROWN UNDER GREENHOUSE

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## ABSTRACT

Water conservation strategies are becoming increasingly important as a result of shortage of water and climate change. The objective of this research is to addresses water-saving irrigation strategies by evaluating the effect of the partial root drying irrigation (PRD) and Deficit Irrigation (DI) practice on the, yield and water use efficiency of tomato (Shivam variety). The treatments were partial root drying (PRD) at 75% and 50% crop evapotranspiration, $ET_c$ ($PRD_{25}$ and $PRD_{50}$, respectively) and deficit irrigation (DI) at 75% and 50% crop evapotranspiration, $ET_c$ ($DI_{25}$ and $DI_{50}$, respectively). The PRD practice requires wetting of one half of the root zone and keeping the other half dry, consequently using less amount of irrigation water that was applied. In the successive irrigations, the wet and dry sides were alternated. Over a growing season after transplanting, the highest fruit yield was obtained under FULL irrigation (225 t $ha^{-1}$). In comparison to deficit irrigation that received the same quantity of water, the PRD treatments produced an increased yield of 5–10%. PRD and DI irrigation improved WUE considerably, and that was 30.35% and 25.71% respectively higher than FI. Results suggest that PRD treatment can be an option in a water shortage.

*Keywords: Water saving; Partial root drying (PRD); Deficit irrigation (DI); Full irrigation (FI); Water use efficiency (WUE), Tomato yield.*

## 1. 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, as well as to 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.

Conventional 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]. Grimes et al. (1968)

were the first to apply this concept 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, PRD has been shown to be successful in grapevines and in other vegetables [10] [11]. Nevertheless, PRD could be successfully applied to tomato and impacted bioactive compounds and antioxidant activity [12] [13]. A tomato cultivated in a 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 aim of this paper was to evaluate the effect of partial root drying and deficit irrigation on the yield and water use efficiency under greenhouse grown tomato.

## 2. MATERIAL AND METHODS

### 2.1 Experimental Site

The experiment was carried out under the greenhouse for the period of March to June, 2022 in the Tamil Nadu Agricultural University, Coimbatore. The crop was Tomato (*Lycopersicon esculentum* L). The site location was 11.00689$^o$N, 76.93606$^o$E, and altitude is 426.6 m above mean sea level. An area of planting was 240 m$^2$ (15 × 16 m) has been allocated out of total area of greenhouse 380 m$^2$ (20 × 19m) for the experiment, divided into four randomized block with 2 m buffer distance from all side of experimental field. Each block, with an area of 60 m$^2$ (7.5 m × 8 m). The soil of experiment site was sandy clay loam. Soil sample was taken to a depth of 45 cm at every 15 cm for performing physical and chemical analyses of soil with standard methods [15]. Soil texture, field capacity (FC), wilting point (WP), saturated hydraulic conductivity ($K_S$), saturation moisture content (Sat), and bulk density (b) were investigated in the physical analysis (Table 1). Hydrogen ion concentration (pH), electrical conductivity (EC), and available N, P, and K were examined in the chemical analyses and 213 kg/ha, 330 kg/ha and 555 kg/ha were observed. The layout of the experimental setup was shown in Figure 1.

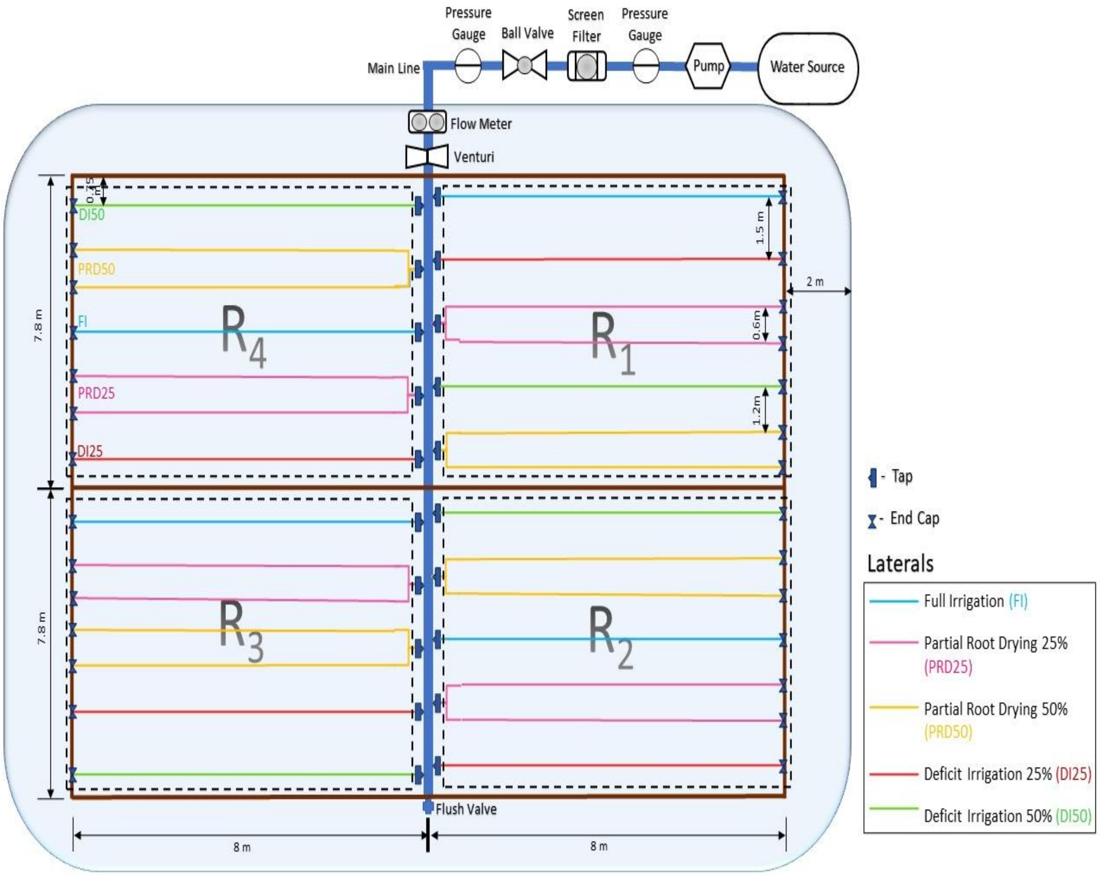

**Fig. 1.** Experimental Plot

**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 |

## 2.2 Irrigation treatments

A surface drip irrigation system was used for irrigation. Drip lines 16 mm in diameter with in-line emitters 0.30 m apart delivered 4L/h each at an operating pressure of 100 kPa.

A randomized complete block (RCB) design was used. For FI and DI water was applied on both sides and in PRD on either from one side of the plant. All treatment as shown in Table 2. In FI and DI laterals were installed at the center of two crop rows, whereas there were two laterals for each row separated by a distance of 0.6 for PRD treatment. A separate valve was used to control the water flow of these two laterals. Irrigation in the PRD was shifted between the two sides of plants in the PRD every alternate irrigation. The flow meter was installed in the water delivery unit of 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 in a week, until mid-season after transplanting , after that at 3- and 4-day intervals two irrigations were applied in a week.

**Table 2. Irrigation Treatments**

| S. 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 $ET_c$ ($DI_{25}$) |
| 3. | $T_3$ | Partial root drying at 75% crop evapotranspiration $ET_c$ ($PRD_{25}$) |
| 4. | $T_4$ | Deficit irrigation (DI) at 50% crop evapotranspiration $ET_c$ ($DI_{50}$) |
| 5. | $T_5$ | Partial root drying at 50% crop evapotranspiration $ET_c$ ($PRD_{50}$) |

## 2.3 Weather conditions

All the meteorological parameter 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 $ET_c$. The crop coefficient (Kc), with the values of 0.6 in the beginning, 1.15 in the middle, and 0.80 in the end of the growing season was used [16].

The estimation of $ET_c$ has given below:

$$ET_c = K_c \times ET_o \tag{1}$$

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

$$ET_0 = \frac{0.408\Delta(Rn-G)+\gamma\frac{900}{Ta+273}\mu2(es-ea)}{\Delta+\gamma(1+0.34\mu2)} \tag{2}$$

Where, $ET_o$ is the reference evapotranspiration (mm $day^{-1}$), $R_n$ 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 $°C^{-1}$), $u_2$ is the wind speed at 2 m height (m $s^{-1}$), G is the soil heat flux (MJ: $m^{-2}$ $day^{-1}$), $T_a$ is the mean air temperature at 2 m height (°C), γ is the psychrometric constant [kPa $°C^{-1}$], $e_a$ is the actual vapor pressure (kPa), and $e_a$ is the saturation vapor pressure (kPa).

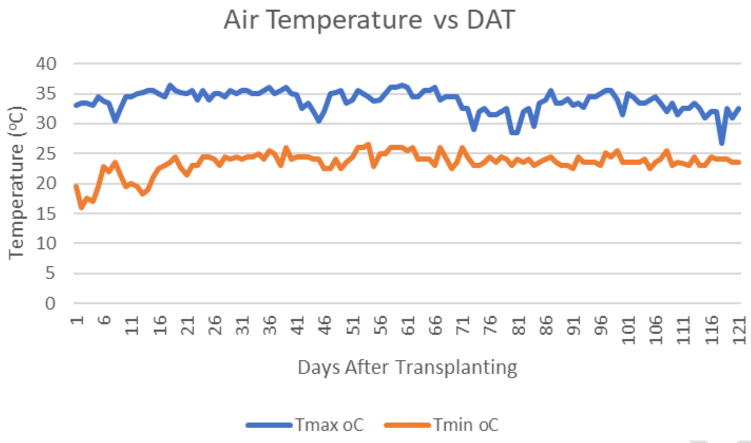

**Fig. 2. Air temperature vs Days After Transplanting (DAT)**

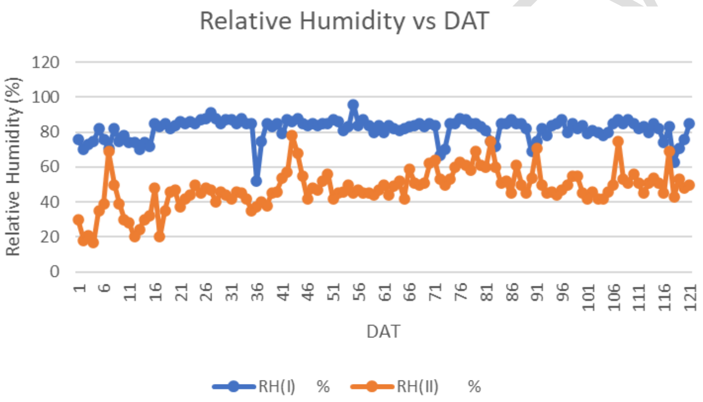

**Fig. 3. Relative humidity vs Days After Transplanting (DAT)**

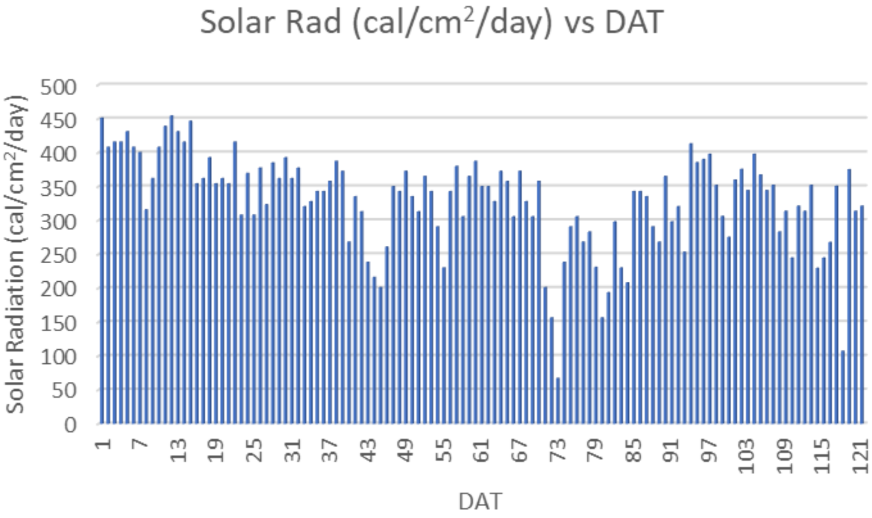

**Fig. 4. Solar radiation vs Days After Transplanting (DAT)**

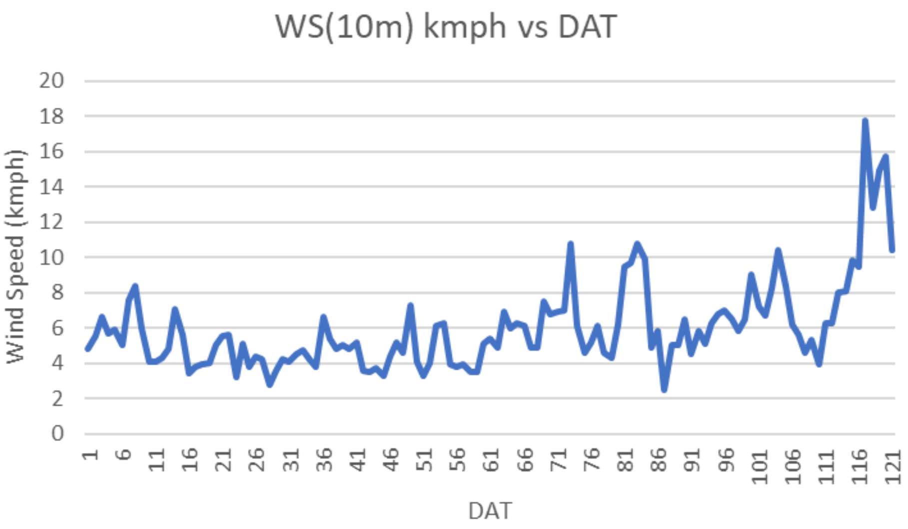

**Fig. 5. Wind speed vs Days After Transplanting (DAT)**

The field was ready for laying out the irrigation system after the completion of initial preparatory works (i.e., plowing, grading, and leveling). Soil samples taken from every 0.2 m depth up to 0.45 m, and Physical analysis was carried out as shown in the Table 1. Seedlings were taken from nursery and transplanted on March 16, 2022. Soil drenching were done by treatment of *Trichoderma* on next day of transplanting for better establishment of seedlings. The seedlings were planted at 0.30 m distances. Treatment wise fertilizer were applied as 131 kg/ha NPK (19: 19:19), 499 kg/ha potassium nitrate ($KNO_3$), 61 kg/ha mono-ammonium phosphate and 222 kg/ha urea ($NH_2CONH_2$) through drip irrigation system with different phase. The Growth period was divided into four stages as given in Table 3.

**Table 3. Growth stage time (days)**

| Growth stage | Initial | Development | Mid-season | Late-season |
|---|---|---|---|---|
| **days** | 25 | 30 | 30 | 25 |

Leaf area index (LAI) was measured monthly from selected plant samples (five plant for each replicate) of each replication, also yield parameters like number of fruit, fruit weight and vegetative growth were recorded throughout the season. Water-use efficiency was used for evaluation of comparative benefits of the irrigation treatments. It was calculated using the equation [18]:

$$WUE=\frac{Y}{ET}\times 100 \quad (3)$$

Where, WUE is the water use efficiency kg $(ha\text{-}m)^{-1}$, Y is the marketable yield ($t\ ha^{-1}$) and ET is the total evapotranspiration (mm).

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of Partial Root Drying and Deficit Irrigation on Plant Growth

Throughout the growth season, tomato plants in all of the t$_1$, t$_2$, t$_3$, t$_4$ and t$_5$ treatments grown well. Plant height at different stages such as 20, 60 and 90 days after transplanting (DAT) were measured. Average plant height for t$_1$ (FI), t$_2$ (DI$_{25}$), t$_3$ (PRD$_{25}$), t$_4$ (DI$_{50}$) and t$_4$ (PRD$_{50}$) has given in the Table 4. The average plant height for t$_1$ (FI) at 20, 60 and 90 days after transplanting were 45.2, 94.8 and 142.8 cm which observed higher than other irrigation treatments. As compared to the full irrigation treatment, vegetative parts produced throughout the experimental period were observed less for the DI and PRD treatment, indicating that vegetative growth may have been slightly suppressed. The results have shown that for the experimental period the maximum vegetative growth was found that in full irrigation treatment and vegetative growth in DI$_{50}$ and PRD$_{50.}$ As a result, the plant height has recorded and was found 18.04 and 19.20% respectively decreased than full irrigation treatment.

**TABLE 4.** Average plant height (cm)

| Treatments | 20 (DAT) | 60 (DAT) | 90 (DAT) |
|---|---|---|---|
| **T$_1$ (FI)** | 45.2 | 94.8 | 142.4 |
| **T$_2$ (DI25)** | 35.3 | 83.6 | 128.5 |
| **T$_3$ (PRD25)** | 34.4 | 84.7 | 129.1 |
| **T$_4$ (DI50)** | 29 | 76.6 | 119.3 |
| **T$_5$ (PRD50)** | 30.2 | 77.7 | 120.7 |

### 3.2 Effect of Partial Root Drying and Deficit Irrigation on Yield

The effect of Partial Root drying and Deficit irrigation treatment (FI, DI$_{25}$, PRD$_{25}$, DI$_{50}$, PRD$_{50}$) in the tomato yield was given in the Table 5. In this context, tomato yield for FI at harvest is important than, DI$_{25}$, PRD$_{25}$, DI$_{50}$, PRD$_{50}$ treatments. The maximum yield was achieved in the treatment FI and it was equal to 225 (t ha$^{-1}$).

Then, the yield for $PRD_{25}$ was more i.e. 173.25 (t $ha^{-1}$) than the yield in $DI_{25}$ i.e 169.50 (t $ha^{-1}$). The yield in $DI_{50}$ and $PRD_{50}$ were 154.75 and 161.52 (t $ha^{-1}$) respectively. The yield in FI was increased by 24.67 and 23% when compared to $DI_{25}$ and $PRD_{25}$ respectively. Also, it was increased by 31.23 and 28.23% compared to $DI_{50}$ and $PRD_{50}$ respectively. The yield of tomato for the treatments $DI_{25}$ and $DI_{50}$ observed lowest (Table 5), which revealed that the $PRD_{25}$ and $PRD_{50}$ treatments had higher yield than the DI. Results of this study showed that the partial root drying and deficit irrigation practice can save up to 50% of irrigation water with only marginal yield reduction in tomato yield (Table 5) and revealed that the $PRD_{25}$ and $PRD_{50}$ treatments had higher yield than the DI with same amount of water applied. These water usage decreases at the DI and PRD have resulted in savings of 23 and 46 mm of irrigation water, respectively.

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

Water use efficiency (WUE) was influenced by different irrigation treatments such as FI, $DI_{25}$, $PRD_{25}$, $DI_{50}$ and $PRD_{50}$ and it was given in the Table 5. WUE for different irrigation treatment ranged from 24.45 t $ha^{-1}$ $cm^{-1}$ (FI) to 35.10 t $ha^{-1}$ $cm^{-1}$ ($PRD_{50}$). The WUE was found to be higher in Partial root drying at 50% crop evapotranspiration, $ET_c$ (PRD50). The deficit irrigation and PRD treatments resulted in significantly lower evapotranspiration (ET) than the full irrigation treatment (FI) [19]. The PRD and DI treatment utilized 50% less water and increased WUE by 30.35% and 25.71% respectively.

**Table 5. Water Use Efficiency (WUE) (t $ha^{-1}$ $cm^{-1}$) of tomato**

| Treatments | Water applied (cm) | Yield (t/ha) | Water use efficiency (t $ha^{-1}$ $cm^{-1}$) |
|---|---|---|---|
| $T_1$ (FI) | 9.2 | 225 | 24.45 |
| $T_2$ ( DI25 ) | 6.9 | 169.50 | 24.56 |
| $T_3$ ( PRD25 ) | 6.9 | 173.25 | 25.11 |
| $T_4$ ( DI50 ) | 4.6 | 154.40 | 32.91 |
| $T_5$ ( PRD50 ) | 4.6 | 161.50 | 35.10 |

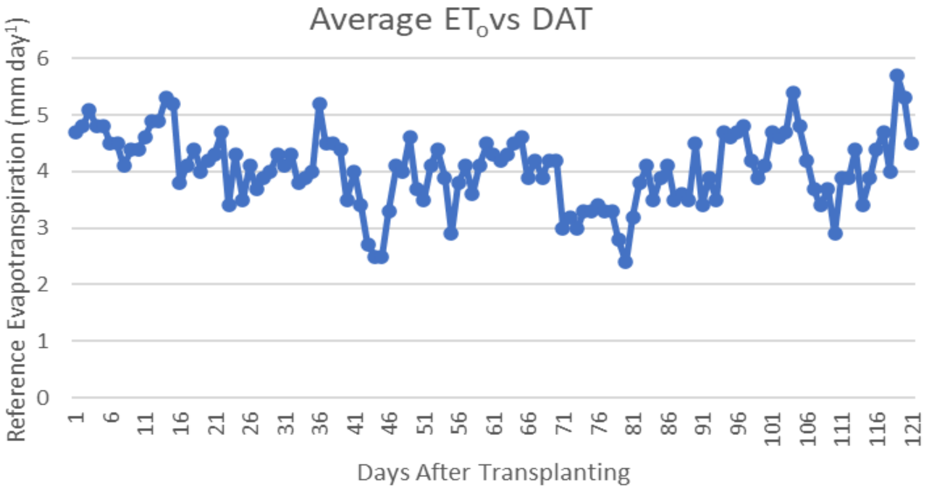

Fig. 6. Average $ET_o$ vs Days After Transplanting (DAT)

## 4. CONCLUSION

The findings of this study implies that PRD method can be a practical and advantageous alternative, to conventional deficit irrigation, for mitigating agricultural output reduction when there is a water scarcity. 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 $ET_C$ methods of irrigation has a advantage compared to full irrigation in terms of improving the water use efficiency, while maintaining the same yield as that of the full irrigation.

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