EFFECT OF DEFICIT IRRIGATION ON ROOT WATER UPTAKE IN PEPPER CULTIVATION UNDER GREENHOUSE CONDITION

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ABSTRACT

Root water uptake is a component of water balance that it should be understood more effectively. In this study evaluation of the root water uptake (RWU) affected by irrigation water on pepper plant has been investigated. This study was carried out as a randomized complete design. Irrigation treatments comprised of a full irrigation level surface (FI) and three deficit irrigation levels in %80, %60 and %40 of the plant's water requirement called DI_{80}, DI_{60} and DI_{40}, respectively. A no plant treatment was used to measure the value of evaporation from the soil surface. Through daily measurements of volumetric soil moisture (VSM) of each ten cm of the soil column considering as a layer, the differences between measured VSM and VSM in the next day, and also evaporation value of the soil surface at the same layer of no plant treatment, were calculated and eventually the value of RWU in each layer per day was estimated. The results showed that the maximum and minimum RWUs are in FI and DI_{40}, respectively. The averages of root water uptakes (RAWUs) in $DI_{80,}$ DI_{60} and DI_{40} were reduced by 17.1, 48.8, and 68.3 percentages. Also, in treatment DI_{80} the reduced rate of uptake was less than the reduced rate of plant's given water.

Keywords: Greenhouse, Irrigation, Pepper, Root, Soil moisture and Water scarcity.

1. Introduction

Without a doubt, with the growth of global population, crop production should be doubled by 2050 to maintain pace in the world. The increasing costs of production factors and environmental concerns can bind extension of cultivated land and more management in this regard. Therefore, new methods to food security need a more efficient resource use (Raza *et al*., 2012). An understanding of water uptake patterns has become increasingly important as we seek to develop modern and environmentally friendly practices involving high frequency irrigation and fertilization (Clothier and Green, 1994). Root water uptake (RWU) is a dynamic process influenced by plant, soil and climate conditions. It depends on a number of factors such as soil hydraulic conductivity, osmotic head (in saline condition), soil water pressure head, rooting depth, root density distribution, plant properties and evaporative demand (Kumar, 2013). Studies and Estimating RWU of the plants are important to how do predict that they respond to the quantity and the quality of water irrigation (Kleidon and Heimann, 1998; Feddes and Raats, 2004). How does uptake water happen by plant roots has been considered by many scholars in the fields of biology, agriculture, and environmental soil physics. To do so, they have tried to design models for this phenomenon using real data of the farm (Li *et al*., 2006). The value and intensity of uptake depend on the characteristics of the plant, soil and atmospheric conditions. Therefore, the root water uptake root distribution can be very variable in the root zone (Meinzer *et al*., 2004, Raats, 2007, Xi *et al*., 2013). Deficit irrigation (DI) is a strategy that leads to increase net income where water supplies are limited or where water costs are high (Kirda *et al*., 2002). The decline in water availability for irrigation and the positive results obtained in some fruit tree crops have renewed the interest in developing information on deficit irrigation for a variety of crops (Dorji *et al*., 2005; Fereres and Soriano, 2007). Information on uptake patterns is useful to better understand crop responses to irrigation, especially with the limited wetted soil volumes. Therefore, estimating of RWU by the plants in deficit irrigation condition can be useful for irrigation scheduling and management (Coelho and Or, 1999). The main objective of this study was then to evaluate the RWU by roots affected by different levels of irrigation water on pepper plant in greenhouse condition.

2. Materials and methods

In order to evaluate the root water uptake (RWU) affected by irrigation water level, an experiment was performed in the greenhouse of Shahrekord University, Shahrekord, Iran in 2012. The soil was a mixture of clay, sandy soils and manure with the ratios of 3, 1 and 1, respectively. Table 1and 2 show physical properties of the soil and Irrigation water quality.

Table 1: Physical properties of the soil.

Bulk density (gr/cm3)	Clay (%)	Silt (%)	Sand (%)	Moisture saturation (%)	Wilting point moisture (%)	Field capacity moisture (%)	Soil texture
1.35	32.2	27	40.8	47.84	13.93	30.13	Loam-clay

Table 2: Characteristics of irrigation water.

NO3	NO2	NH4	PO4-	SO42-	CO32-	HCO3-	CL-	Mg2+	Ca+	EC	pH
					mg.lit^{-1}					ds.m^{-1}	
28.09	0.05	0.1	0.16	9.8	0	207	12.5	25.7	51.3	0.35	7.93

This study was done as a randomized complete design in five treatments and three replications of the potted cultivations. Irrigation treatments included four levels as following: A full irrigation level surface (FI) and three decreased irrigation levels (DI_{80}, DI_{60} and DI_{40}) comprising %80, %60 and %40 of the plant's water requirement. Complete irrigation or 100 % water requirement was attributed to the control treatment (FI). A treatment of no plant was used to measure the value of evaporation from the soil surface. Irrigation was done by surface irrigation in all treatments. Plastic pots were used as lysimeters with 55 cm height and 45 cm diameter, respectively. Deficit irrigation was started 79 days after cultivation and continued 64 days. The FI was characterized as the criterion and soil moisture index was used in order to determine irrigation schedule. Accordingly, volumetric soil moisture (VSM) was measured in each five cm of the soil column, using the moisture meter device namely SM300 on a daily basis. In each pot, soil column was divided to 5 layers ten cm hight (Table 3). An average of VSM of each layer considered as volumetric soil moisture of that layer.

Table 3: Introducing each layer.

Layers	1st layer	2nd layer	3nd layer	4th layer	5th layer
Depth (cm)	0-10	10-20	20-30	30-40	40-50

The total available water (TAW) and readily available water (RAW) Was estimited by θfc, θpwp and an MAD=0.3 for the pepper plant (Allen *et al*., 1998). Irrigation for the control treatment (FI) was done in a point between FC and PWP (namely θ_d= 25.20%). When the average VSM in the plant root' development zone of full irrigation treatment reached to θd, applying different water regimes was launched. Through daily measurements of VSM in each layer of the no plant treatment and their differences with VSM of those layers one day later, evaporation value (E) in each layer was estimated. The summation of RWU in the development zone of plant roots in different treatments on a daily basis was considered as the total value of daily RWU by the equation (1).

$$WU=\sum_{i=0}^{5}(\theta i-\theta_{i+1} -E)*100 \quad (1)$$

Which, θ_i, is VSM in each layer (cm^3/cm^3), θ_{i+1}, is VSM in each layer one day after (cm^3/cm^3), and E is the value of evaporation in the same layer (cm^3/cm^3) and RWU is water uptake rate (mm/day). Furthermore, proportion of each layer in RWU was calculated according to the value of RWU in each layer and the total RWU value in each day. Then different irrigation treatments were statistically compared. Data analyses were performed using SAS and also EXEL software was used to plot the graphs.

3. Results

The details of statistical analysis of average daily water uptake (RWU) in all of five layers are shown in Table 4. Results showed significant differences among various treatments regarding RWU by the roots. In Figure 1 daily uptake changes' trend in different irrigation treatments are illustrated. As it is shown in Figure 1, measured RWU value in treatments DI_{80}, DI_{60} and DI_{40}, were less than calculated RWU value in full irrigation treatment. The reason was that water consumption (ratios 80, 60 and 40 percent of full irrigation treatment) in above-mentioned treatments was less than the full irrigation treatment (FI). Asseng *et al*. (1998); Aliyari (2010) and Dathe *et al*. (2014) showed that maximum and minimum percentages of water uptake occurred in full irrigation treatment and the treatment which experienced the highest range of deficit irrigation.

Table 4: Analysis of average daily RWU variance in all layers.

Variance sources	d_f	Average of water uptake (RAWU, mm/day)
Treatment	3	0.09*
Prediction error	8	0.018
CV	-	1.59
P	-	0.0001>

*Significant at the 0.05 probability level

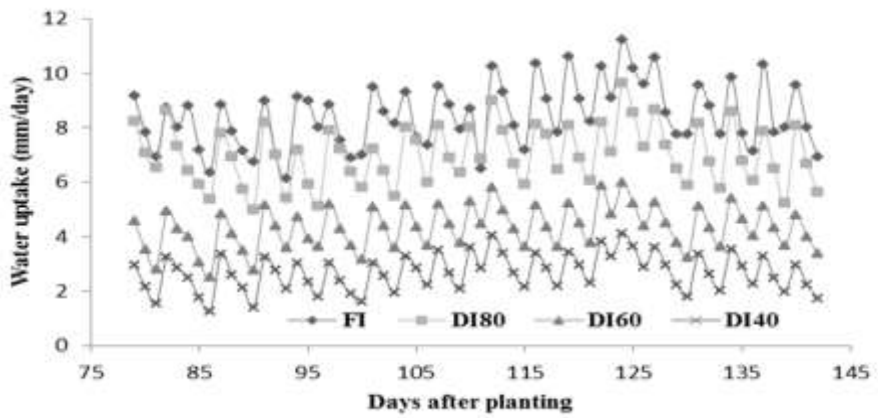

Figure 1: Comparison of daily RWU changes in different treatments.

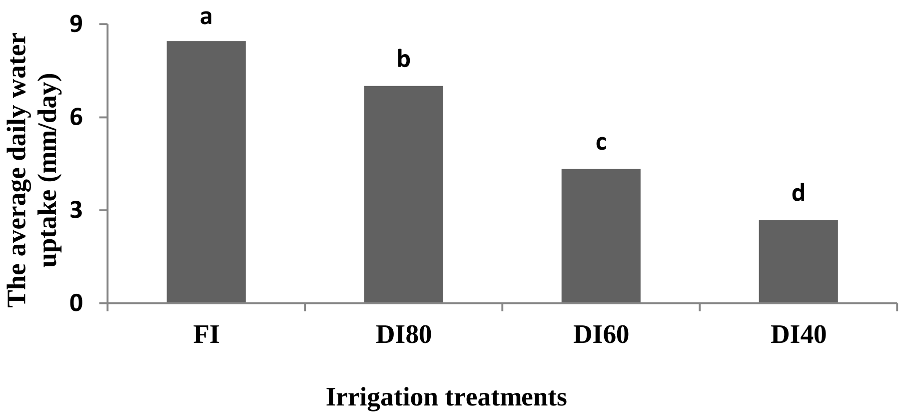

Figure 2: RAWUs in different treatments.
* Columns with the same letter are not significantly different at 5% level by Duncan's multiple range test.

4. Conclusion

In this study measuring averages of root water uptakes (RAWUs) illustrate that the maximum and minimum root water uptakes (RWUs) were happened in FI (8.5 mm/day) and DI_{40} (2.7 mm/day) treatments, respectively. Additionally, the RAWUs in DI_{80}, DI_{60} and DI_{40} treatments were reduced 17.08, 48.72, and 68.25 percentages in comparison with the full irrigation treatment (FI). It shows the fact that in treatment DI_{80}, the reduced rate of uptake was less than the reduced rate of plant's given water. Therefore, this result can be used in agricultural management methods, specifically in the regions with water-limited resources**.**

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