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EFFECTS OF DIFFERENT IRRIGATION REGIMES ON EGGPLANT YIELD IN GREENHOUSE CONDITIONS

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Abstract

The water-yield relation of eggplant (*Solanum melongena* L.) was investigated under partial root drying (PRD) technique. In PRD technique, irrigation was applied to one half plant root zone and leaving the other half dry. Relevant measurements and monitoring were carried out regarding the fruit width-height (size), yield, water-use efficiency (WUE), effectiveness of irrigation water-use (IWUE), yield reaction factor (Ky) and etc. The findings of the study suggest that different amount of irrigation water and irrigation water application techniques had effects on yield and yield parameters. The highest yield (83103 kg/ha) and IWUE (194.4 kg/(ha×mm)) values were found in the control (FULL). The second highest yield (59483 kg/ha) and IWUE (177.97 kg/(ha×mm)) value was found in the APRD75 in which 25% water deficit were applied. The yield and IWUE under the DI50 treatment in which 50% water deficit was applied were found to be, 39886 and 165.60 kg/(ha×mm), respectively. The APRD75 and the DI75 techniques may be applied on eggplant under deficit irrigation.

Introduction

Deficit irrigation and partial root drying (PRD) techniques are the irrigation methods in which irrigation water delivered to plants are reduced compared to full irrigation methods. In deficit irrigation applications, the decreases in the amount of water given to plants is closely related to the plant species to be grown and it is the purpose to have the maximum yield with minimum water use in irrigation (Ahmadi *et al.* 2010). In PRD technique, half of root is left dry, and the other half wet. In PRD application, it may be possible to use available resources more effectively using less water in irrigation in the regions where water is scarce and expensive.

Some of the researches regarding PRD, had suggested that if equal amount of water is used in PRD and DI practices, PRD practice was found to lead to higher quality fruits and more water efficiency (Sepaskhah and Kamgar-Haghighi 1997, Kang *et al.* 1998, Shahnazari *et al.* 2007). However, Wakrim *et al.* (2005) had suggested that there has been no significant relationship between PRD and DI practices with regards to water efficiency effectiveness (WUE), but when compared to full irrigation treatment, water deficit treatment was found to have higher WUE values.

PRD and conventional deficit irrigation techniques had significantly increased WUE values and this might be due to the fact that the roots left under dry soil conditions are encouraged to produce more abscisic acid (ABA) compared to the roots left under wet soil conditions (Davies and Zhang 1991), and the produced ABA hormone helps limiting stomal conductivity against water stress and decreases transpiration (Stoll *et al.* 2000, Bauerle *et al.* 2006).

In the cases when water resources are limited, do the PRD and DI techniques which are used in deficit irrigation treatments have any superiority over one another? This is the underlying

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question regarding how to come up with a solution to eggplant agriculture. In PRD technique, there is no obligation to know well in advance the critical periods when plants need more water differently from conventional deficit irrigation. Under the light of the researches carried out in Turkey and abroad, it is considered that the irrigation water efficiency could be higher and that it could be used as an alternative choice in irrigation planning. With this regard, (when 50 and 25% water deficit is implemented in irrigation) it was the aim of this study to test the effectiveness of conventional deficit irrigation and PRD techniques on eggplant with regards to yield and water efficiency.

Materials and Methods

This study was conducted in 2011 and 2012 spring and fall seasons at the research field of Akdeniz University, Faculty of Agriculture (36°53' 15" - 36° 54' 15" N latitude, 30°38' 30" - 30°39' 45" E longitude; 54 m altitude). The experiment was carried out in a monoglassed and saddle roofed greenhouse positioned in the direction of north-south and the total area of the greenhouse is 992 m^2 (62 ×16 m).

The type of soil where this study was carried out was clay loamy. There was no problem regarding underground water, salinity and sodification limiting normal growth of the plants in the research site. Some physical characteristics regarding the experimental site are given in Table 1. There was no negativity in the soil of the experimental site limiting or hindering plant growth.

Table 1. The physical properties of soil.

Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture	Field capacity (%)	Wilting point (%)	Bulk density (g/cm^3)
0 - 20	31.61	28.66	39.73	CL	30.0	22.0	1.28
20 - 40	36.28	23.92	39.80	L	23.0	16.0	1.52

In this study, Faselis F_1 grafted on AGR-703 rootstock was used as the plant material. As this eggplant species is durable for long shipping conditions, highly productive and have high fruit quality, they are commonly cultivated in greenhouses in the province of Antalya. The responses of Faselis F_1 eggplant plant under 7 different irrigation treatments were examined. Seven different irrigation treatments were applied through drip irrigation in the study, one of which was control (FULL), two of which were conventional deficit irrigation (DI75, DI50) and four of which were PRD techniques (APRD75, FPRD75, APRD50, FPRD50). The irrigation treatments used in the study and descriptions are given in Table 2.

The experiment was carried out in randomized block design with three replications for each irrigation treatment. The each experimental parcel had a 19.5 m^2 (3 × 6.5 m) area and there were 4 plant rows on the area. The distance between plant rows was 1.0 m, and the plant spacing in rows was 0.50 m. There were 14 plants on each row, and there were 56 plants on each experimental parcel. The irrigation was done through drip irrigation method. Class-A evaporation pan located in the centre of each greenhouse was used to estimate irrigation water requirement (I, liter/plant) for FULL irrigation using the equation:

$$I = k_c \times k_p \times E_p \times A$$

where k_p and k_c are evaporation pan and plant coefficient, respectively; E_p is total amount of evaporation measured through the A-class evaporation pan which is equal to irrigation intervals (mm) and A is the area of a plant (m^2). Following the start of the deficit irrigation treatments, measuring the amount of decreased water on each evaporation pan prior to every irrigation, the amount of water to be given to the control group was calculated through the equation.

Table 2. Irrigation treatments and their descriptions.

Irrigation treatments	Descriptions
FULL	Full, control treatment where the full amount of irrigation water, which was measured using Class A-pan evaporation data, was applied to the roots on all sides of the plant.
DI75	All roots were wetted but received 25% less water, compared to full irrigation.
APRD75	25% less water was applied compared to full irrigation, irrigation sides of the root zone were alternated in every irrigation.
FPRD75	25% less water was applied compared to full irrigation. Only half side of the rooting zone was irrigated and the other half was dried throughout the season.
DI50	All roots were wetted but received 50% less water compared to full irrigation.
APRD50	50% less water was applied compared to full irrigation, irrigation sides of the root zone were alternated in every irrigation.
FPRD50	50% less water was applied compared to full irrigation. Irrigated only half side of the rooting zone and the other half was dried throughout the season.

Harvesting was done 78 days after the plantation. Sixteen harvestings were done between 7 December, 2011 and 14 June, 2012. The fruits which have ripened were cut with a pruning shear and then weighed on an electronic scale in the treatment site. The yield obtained from each treatment was recorded. Five fruits randomly chosen from each treatment were measured regarding their diameter and height using calipers.

For the purpose of comparison among values regarding yields, irrigation-water-use efficiency (IWUE), water-use efficiency (WUE), fruit size of treatments, variance analysis technique (which is one of the randomized block designs) was used in the study. Significance was found for all the analyses at 0.01 probability level. Next Tukey multiple comparison tests were used to find out the differences among irrigation treatments.

Results and Discussion

The amount of irrigation water in the study was found to change between 240 and 427 mm. The values of evapotranspiration were found to change between 242 and 440 mm. Whereas, the highest evapotranspiration was found to be in the control group (FULL), the lowest evapotranspiration was found to be in DI50.

The results of leaf area indices of the treatments in which the FULL and 25% water deficit was implemented are presented in Fig. 1. When the treatments in which the FULL and 25% water deficit were implemented and considered, there has been no significant difference among leaf area indices of treatments before the start of water deficit implementation. The values of leaf area indices regarding the FULL and the FPRD75 treatments on the 74th day following the plantation were found to have made less progress as compared to the APRD75 and the DI50 treatments. This continued till the 111st day following the plantation. The values of the leaf area indices on the 191st day after the plantation revealed that the FULL has progressed better compared to the APRD75 and the FPRD75. This might be that with the increase in the values regarding the evapotranspiration depending on the setting within the greenhouse between the 111st and 191st day, the increase in the values regarding the maximum and average temperatures. In such cases, water stress is needed more severely.

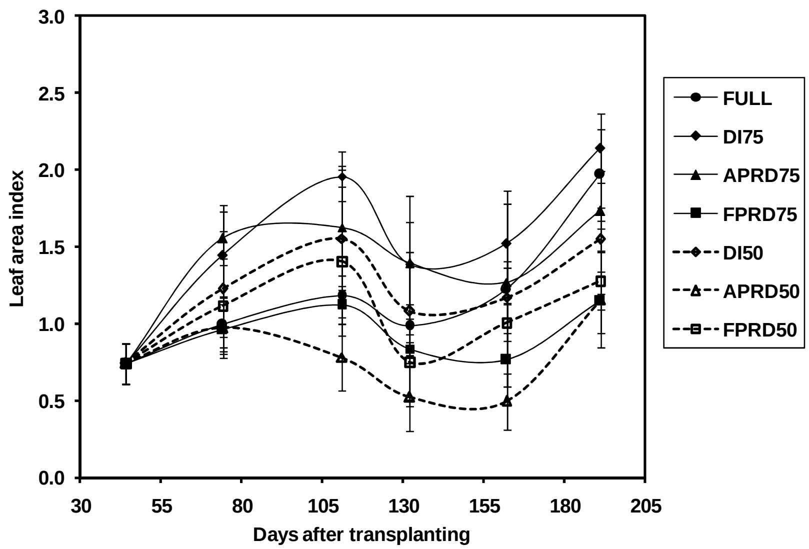

Fig. 1. Seasonal changes in leaf area index for all treatments. The data points represent means ± Sd (n = 3).

Among the treatments in which 50% water deficit was implemented, the DI50 was found to have the highest index. On the other hand, the APRD50 was found to have the lowest leaf index value. In the treatment in which high water deficit rates were implemented, the leaf area developments of the plants under semi wetting irrigation technique were found to be at lower levels compared to the conventional deficit irrigation treatments.

The values regarding WUE and IWUE were found to differ significantly among the irrigation treatments ($p < 0.01$) (Table 3). The yield values were found to change between 23373 and 83103 kg/ha depending on the irrigation treatment used. The FULL was found to have the highest yield efficiency with 83103 kg/ha. The highest second yield value was found to be the APRD75 with 59483 kg/ha. The lowest yield among the treatments was found to be in the APRD50 with 23373 kg/ha. Whereas WUE values among the treatments changed between 192.7 and 96.8 kg/(ha×mm), IWUE values among the treatments were found to change between 194.4 and 97.0 kg/(ha×mm) (Table 3).

According to the findings of the study, the highest eggplant yield was obtained in the FULL. In the treatments (DI75, APRD75 and FPRD75) in which 25% water deficit was applied when compared to that of the FULL 21.82% water saving was provided. APRD75, DI75 and FPRD75 treatments was found to have a decrease in the yield 28.42, 31.03 and 38.72%, respectively when compared to that of the FULL.

In the treatments (DI50, APRD50 and FPRD50) 43.66% water was saved in which 50% water deficit was applied when compared to that of the FULL treatment. The DI50, FPRD50 and APRD50 treatments were found to have a decrease in the yield 52, 67.17 and 71.87%, respectively when compared to that of the FULL treatment. The highest yield out of the treatments in which 50% water deficit (DI50, APRD50 and FPRD50) was applied was obtained in DI50 treatment.

Table 3. Effects of different irrigation treatments on eggplant yield, water use efficiency (WUE) and irrigation water use efficiency (IWUE)[a].

Treatments	Yield kg/ha	WUE kg/(ha mm)	IWUE kg/(ha mm)
FULL	83103 ± 8386 a	192.70 ± 19.40 a	194.40 ± 19.60 a
DI75	57312 ± 5682 ab	172.20 ± 17.10 ab	171.50 ± 17.00 ab
APRD75	59483 ± 2402 ab	179.87 ± 7.26 ab	177.97 ± 7.19 ab
FPRD75	50924 ± 6068 bc	150.00 ± 17.90 ab	152.40 ± 18.20 ab
DI50	39886 ± 1927 bc	163.52 ± 7.90 ab	165.60 ± 8.00 ab
APRD50	23373 ± 3801 c	96.80 ± 15.70 c	97.00 ± 15.80 c
FPRD50	27284 ± 3843 c	111.70 ± 15.70 ab	113.30 ± 16.00 ab

[a] Data in columns followed with different letters are significantly different based on Tukey's mean range test ($p < 0.01$).

In every harvest, fruit diameter and height were measured. The results of TUKEY multiple comparison of these values are presented in Table 4 at $\alpha=0.01$ significance level. The statistical analysis carried out regarding the values of fruit width and height suggested no difference among the treatments used in the study.

Table 4. Effects of irrigation treatments on eggplant fruit size (cm)[a].

Treatments	Fruit height	Fruit diameter
FULL	16.64 ± 0.75 NS	5.24 ± 0.15 NS
DI75	16.74 ± 0.75 NS	5.09 ± 0.10 NS
APRD75	17.26 ± 0.41 NS	5.16 ± 0.15 NS
FPRD75	16.98 ± 0.90 NS	5.18 ± 0.05 NS
DI50	16.65 ± 0.96 NS	5.19 ± 0.15 NS
APRD50	14.94 ± 0.65 NS	5.03 ± 0.05 NS
FPRD50	15.59 ± 0.26 NS	5.04 ± 0.05 NS

[a] Data represent means ($n = 3$). NS = Non significant ($p \geq 0.01$).

To find out the effect of the change in the yield value resulting from the difference in the irrigation techniques, Ky value obtained from every irrigation technique was separately calculated (Fig. 2). Because of the difference in irrigation techniques in which the same amount of irrigation water was used, reactions in yield differed. The Ky values for the whole growing season were 1.16 for conventional deficit irrigation (DI), 1.65 for APRD technique and 1.60 for FPRD technique.

It was found that the average seasonal water consumption of eggplant plant changed from 380 mm to 1373 mm depending on the climate zone where the plant is grown, irrigation method to be used, plant characteristics and the growth environment and fully meeting the needs of plant (Eliades 1992, Ertek *et al.* 2002, Kirnak *et al.* 2002, Aujla *et al.* 2007, Lovelli *et al.* 2007, Karam *et al.* 2011, Çolak *et al.* 2015). The ET values obtained from the conditions in which plant water need was fully met in this study and the ET values reported by Eliades (1992) and Lovelli *et al.* (2007) were similar.

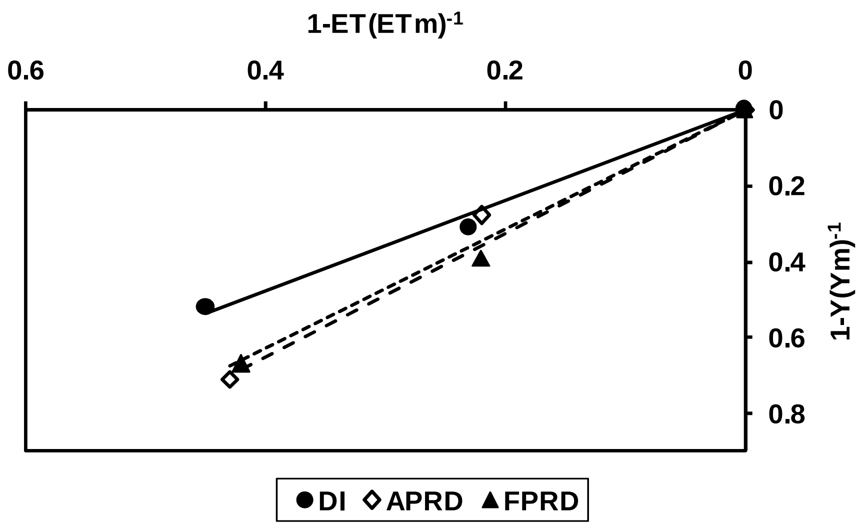

Fig. 2. Relative eggplant yield reduction as a function of relative ET deficit (for all development seasons, according to irrigation techniques).

In the whole growth season, the Ky was found to be 1.16 for the DI, 1.65 for the APRD, 1.60 for the FPRD (Fig. 2). The fact that there has been a significant decrease in the yield regarding the APRD under the conditions in which 50% water deficit was applied led an increase in the Ky value calculated for the APRD. Whereas proportional yield was found to be similar to one another in the DI75 and the APRD75. The proportional yield loss for the APRD50 was found to be higher than that of the DI50. In other words, the most dominant factor leading the difference among the Ky values of treatment techniques can be suggested to be the decrease in the yield obtained in the conditions when 50% deficit was applied.

According to the findings obtained in this study, water irrigation techniques (APRD, FPRD, DI) have significant effects on yield and water usage efficiency depending on the level of water deficit appiled. Whereas there was no significant difference among irrigation treatments with regards to the yield and WUE in the cases in which 25% water deficit was implemented in the irrigation. DI and FPRD techniques were found to be superior to APRD techniques with regards to water usage when 50% water deficit was implemented. However, eggplant species was found to be durable to water stress in the three irrigation techniques.

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