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*Full Length Research Paper*

# Effects of different irrigation programs on yield and quality parameters of eggplant (*Solanum melongena L.*) under greenhouse conditions

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**This study was carried out to determine the effects of different irrigation programs on yield and quality parameters of eggplant under greenhouse conditions, using Class A pan evaporation calculations and different plant-pan coefficients. Irrigation water was applied through drip irrigation method twice a week during the growing period. Irrigation treatments consisted of five plant-pan coefficients (S1: $k_{cp}$ = non-irrigation, S2: $k_{cp} = 0.50$, S3: $k_{cp} = 0.75$, S4: $k_{cp} = 1.00$ and S5: $k_{cp} = 1.25$). The amount of irrigation water ranged between 95.2 and 238.7 mm among the treatments. Evapotranspiration (ET) values varied from 93.1 to 466.3 mm for the treatments. The highest yield was obtained from the S3 and S4 treatments. A significant polynomial correlation was obtained between the yield and irrigation water, and between the yield and ET ($P < 0.01$). This indicated that when irrigation water and ET increased, yield also increased to a certain point. However, when the amount of irrigation water exceeded the plant water requirement, eggplant yield decreased. Yield response factor ($K_y$) was determined as 0.81. Since $K_y < 1$, eggplants were not sensitive to water deficiency. In addition, the highest water use efficiency (WUE) and irrigation water use efficiency (IWUE) values were calculated in the S3 (12.9 kgm$^{-3}$) and S2 (44.2 kgm$^{-3}$) treatments, while the lowest WUE and IWUE values were calculated in the S5 (7.9 and 15.5 kgm$^{-3}$) treatment to which the highest irrigation water was applied. This finding indicated that WUE and IWUE values decreased with the increasing irrigation water and ET. These results suggested that S3 ($k_{cp} = 0.75$) treatment can be the most appropriate irrigation program for eggplant with higher yield and WUE under greenhouse conditions.**

**Key words:** Eggplant, yield response factor, water use efficiency, Class A pan, evapotranspiration.

## INTRODUCTION

Currently, world eggplant production is 35.3 million tonnes from 1.9 million ha according to the data of 2009. 93% of the eggplant production takes place in Asia, while 7% is produced in Africa, Europe and America (FAO, 2010). Turkey is the third biggest producer in the world with 816000 tonnes production, of which 250000 tonnes are produced in greenhouses (TSI, 2010). In addition to the field production, the reasons why greenhouse production of the eggplant gains importance, is because of more profit and greenhouse producers want to get rid of their dependence on the tomato production. Plantation area of eggplant in greenhouses increases year by year with application of improving agricultural technologies, and the eggplant is the fourth in rank within the greenhouse products, after tomato, pepper and cucumber (Boyaci, 2007).

Greenhouse production is more advantageous than field production since irrigation water and fertilizer are used more effectively and controlled (Van OS, 1994). Irrigation is a vital importance for successful vegetable production. Because vegetables need irrigation water during the all growing period and get adequate benefit from irrigation, amount of the irrigation water applied and the irrigation duration must be calculated scrupulously (Cevik et al., 1996; Ertek et al., 2002). Both higher water use efficiency (WUE) and higher yield are obtained in the cultivated plants such as the eggplant (Chartzoulakis and

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**Table 1.** Some physical characteristics of the soil in the greenhouse.

| Soil depth (cm) | Structure | Bulk density (gcm$^{-3}$) | Field capacity | | Wilting point | | Total available soil water content | |
|---|---|---|---|---|---|---|---|---|
| | | | % | mm | % | mm | % | mm |
| 0-30 | CL | 1.52 | 27.7 | 126.1 | 13.2 | 60.0 | 14.5 | 66.2 |
| 30-60 | CL | 1.36 | 28.1 | 114.6 | 14.1 | 57.4 | 14.0 | 57.2 |
| 60-90 | CL | 1.35 | 31.0 | 125.6 | 16.2 | 65.7 | 14.8 | 59.8 |
| 90-120 | CL | 1.26 | 32.5 | 122.8 | 17.4 | 65.8 | 15.1 | 57.0 |
| Total (0 to 90 cm depth) | | | | 366.2 | | 183.1 | | 183.2 |
| Total (0 to 120 cm depth) | | | | 489.0 | | 248.9 | | 240.2 |

**Table 2.** Chemical properties of the irrigation water.

| Parameter | Value |
|---|---|
| EC (ds m$^{-1}$) | 0.81 |
| pH | 7.7 |
| **Cations (me L$^{-1}$)** | |
| Ca$^+$ | 1.2 |
| Na$^+$ | 0.11 |
| Mg$^+$ | 6.8 |
| K$^+$ | 0 |
| **Anions (me L$^{-1}$)** | |
| HCO$_3^-$ | 7.36 |
| Cl$^-$ | 0.27 |
| SO$_4^-$ | 0.48 |
| SAR | 0.06 |
| Class | C$_3$S$_1$ |

Drosos, 1995; Aujla et al., 2007), cucumber (Yuan et al., 2006) and pepper (Antony and Singandhupe, 2004; Sezen et al., 2006) in drip irrigation method according to traditional irrigation methods.

An important portion of the natural water resources are used in agriculture. Decreasing available water resources brings a serious water shortage problem. In order to deal with this problem, the studies for the efficient use of irrigation water by providing water saving gain importance (Zhang et al., 1999; Oweis et al., 2000; Pandey et al., 2000; Motilva et al., 2000; Li et al., 2001; Fabeiro et al., 2001). However, more studies are still needed for deficit irrigation of vegetables (Chartzoulakis and Drosos, 1995; Mendezr, 1987, Mannini and Gallina, 1996). Deficit irrigation aims to increase the efficiency of irrigation water, to generate water stress at a level without excessive yield loss in the production period of the plant and, consequently, to obtain the highest yield corresponding to each unit of water (Kirda, 2002). While designing deficit irrigation programs, it should be designed according to the relationship between water and yield. Researches indicated that there is a linear correlation between relative evapotranspiration deficit and relative yield decrease, and this correlation is defined as yield response factor ($K_y$) (Stewart et al., 1977; Doorenbos and Pruitt, 1977).

The use of irrigation programs based on pan evaporation method is very common due to its simple and easy usage (Elliades, 1988). This research aimed to determine the effects of different irrigation programs on the yield and quality parameters of the eggplant under greenhouse conditions using Class A pan evaporation calculations and different plant-pan coefficients.

## MATERIALS AND METHODS

This study was carried out in plastic covered greenhouse of which the long axis was placed in the east-west direction, in Agricultural Research and Experimental Center at the Campus of Süleyman Demirel University, Isparta, Turkey during 2010. The study area was between 37° 50$^{I}$ 2$^{II}$ N latitude and 30° 32$^{I}$ 0$^{II}$ E longitude and 1010 m altitude. Isparta region defined as Lakes region indicates a transition characteristic between the Mediterranean climate and Middle Anatolian continental climate. It resembles the Mediterranean climate in terms of precipitation regime, while it resembles the Middle Anatolian continental climate in terms of temperature since summer season is hot and dry, and winter season is cold and snowy. In Isparta, long-term average annual temperature, relative humidity and precipitation are 12°C, 61%, 520 mm, respectively (TSMS, 2008). Automatic recorders and Class A pan were used in order to determine the monthly values of inner greenhouse average temperature, relative humidity, the sunshine duration and evaporation during the growing season.

The greenhouse soil was sandy-loam, and the dry soil bulk density average was 1.37 g cm$^{-3}$ throughout the 1.2 m deep profile. The total available soil water content within top 1.2 m of soil profile was 240.2 mm and no water problem was found. Some soil characteristics related to irrigation are presented in Table 1.

Seedlings of the eggplant were transplanted at 0.60 x 0.90 m spacing on May 10th, 2010. The plots consisted of 14 plants in 7.47 m$^2$. Burnt farm manure were implemented before transplanting, and 19.6 kg ha$^{-1}$ mono ammonium phosphate, 14 kg ha$^{-1}$ phosphoric acid, 174 kg ha$^{-1}$ potassium nitrate and 140 kg ha$^{-1}$ ammonium nitrate were applied with irrigation water by drip system after transplanting, and also agricultural pest control were done during the growing period (from beginning of June to end of August).

Irrigation water was obtained from the hydrants on the irrigation network near the greenhouse and distributed to the pilots by laterals. Discharge rate of the irrigation water taken from the irrigation network was 1.5 L s$^{-1}$. The chemical properties of the irrigation water are presented in Table 2.

**Table 3.** Monthly mean climate values in greenhouse related to growing period.

| Month | Mean temperature (℃) | Mean humidity (%) | Duration of sunshine (h) |
|---|---|---|---|
| May | 24.2 | 58.4 | 8.3 |
| June | 31.9 | 56.8 | 7.6 |
| July | 34.2 | 53.7 | 10.3 |
| August | 34.6 | 56.6 | 13.5 |

Experimental treatments were determined according to five different plant-pan coefficients (S1: $k_{cp} = 0.00$, S2: $k_{cp} = 0.50$, S3: $k_{cp} = 0.75$, S4: $k_{cp} = 1.00$ and S5: $k_{cp} = 1.25$). The coefficients used in this study included pan coefficient and plant coefficient factors as indicated in Ertek et al. (2002). In the study, experiment was carried out according to the completely randomized design with three replicates. Plots were irrigated up to field capacity at the beginning of the irrigated growth period. Irrigation water was applied through drip irrigation method twice a week during the growing period. Class A pan was used to determine the amount of applied irrigation water. Irrigation was initiated based on the cumulative pan evaporation in daily values measured in each irrigation interval with the Class A pan located in the greenhouse. Engineering characteristics and working principles related to the drip irrigation method were determined on the fundamentals given in Kanber (2010). Drip irrigation system consisted of PE laterals of Φ16 mm in diameter in-line type drippers with pressure regulators at 0.33 m distance. The drippers had a discharge rate of 3 L $h^{-1}$ under an operational pressure of 4 atm. One lateral was placed in each plant row and the percentage of the wetted area was determined as 36%. In calculating irrigation water volume, equation 1 described by Doorenbos and Pruitt (1977) was used:

$$I = Axk_{cp}xE_{p}xP \tag{1}$$

Where, *I* is the volume of irrigation water applied (L), *A* is the pilot area ($m^2$), $k_{cp}$ is the plant-pan coefficient, $E_p$ is the cumulative evaporation at Class A pan in the irrigation intervals (mm) and *P* is the wetted area percentage (36%). Evapotranspiration related to the treatments were estimated using the water balance method (Equation 2) (James, 1988):

$$ET = I + P + C_p - D_p \pm R_f \pm \Delta S \tag{2}$$

Where, *ET* is the evapotranspiration (mm), *I* is the depth of irrigation water (mm), *P* is precipitation (mm), $C_p$ is the capillary rise (mm), $D_p$ is the water loss by deep percolation (mm), $R_f$ is runoff loss (mm) and $\Delta S$ is the change in the soil water content determined by the gravimetrical method in the 120 cm soil depth (mm). In the experiment area, since there was no capillary water entrance from the water table and runoff loss due to the drip irrigation method, $C_p$ and $R_f$ values were neglected in the calculations. Besides, since the sum of soil moisture before the irrigation and the amount of irrigation water applied did not exceed the field capacity, Dp values were neglected (Kanber et al., 1993) and since the study was carried out in a greenhouse, P value was also neglected.

Equation 3 as described by Doorenbos and Kassam (1986) was used in order to determine the yield response factor ($K_y$). Therefore, the relationship between relative decrease in evaporatranspiration and relative decrease in yield was determined.

$$Ky = \frac{\left(1 - \frac{Y}{Ym}\right)}{\left(1 - {}^{ET}/_{ETm}\right)} \tag{3}$$

Where, *Y* and $Y_m$ are actual and maximum yields (tonnes $ha^{-1}$), respectively, *ET* and $ET_m$ are actual and maximum evapotranspiration (mm), respectively and $K_y$ is yield response factor.

WUE and irrigation water use efficiency (IWUE) in all the treatments were calculated using Equations 4 and 5 (Hillel and Guron, 1975; Kanber et al., 1996):

$$WUE = 100\left(\frac{Y}{ET}\right) \tag{4}$$

$$IWUE = 100\left(\frac{Y_I - Y_{nI}}{I}\right) \tag{5}$$

Where, *WUE* is the water use efficiency (kg $m^{-3}$), *Y* is the yield (kg $ha^{-1}$), *ET* is the evapotranspiration (mm), *IWUE* is the irrigation water use efficiency (kg $m^{-3}$), *YnI* is the yield obtained from the non-irrigation treatment (kg $ha^{-1}$) and *I* is the irrigation water (mm). Since yield was not obtained from non-irrigation treatment (S1), *YnI* was assumed as zero.

Eggplants were hand-harvested several times taking edge effects in the study plots into consideration and weighed in July and August. Amount of yield per unit area (tonnes $ha^{-1}$), number of fruit per unit area (number $ha^{-1}$) and some quality characteristics of eggplant fruit such as mean fruit weight, diameter, length, fruit firmness and amount of the soluble solids were determined. Statistical analyses were done applying the one way ANOVA analysis method. The Tukey test was used in determining the differences between the averages of the groups and the differences of the treatments were indicated with the latin letters in the test result. The non-irrigation treatment (S1) was not included in the statistical analysis, because yield was not obtained.

## RESULTS AND DISCUSSION

In relation with the period of study carried out, monthly mean temperature, humidity and duration of sunshine values ranged between 24.2 and 34.6℃, 53.7 and 58.4% and 8.3 and 13.5 h in the greenhouse, respectively (Table 3).

All plots were irrigated up to field capacity in the 0 to 120 cm soil depth prior to scheduled irrigation. Irrigation treatments were initiated at the beginning of June. During growing season, 529 mm evaporation occurred and treatments were irrigated 22 times (Table 4). The lowest irrigation water amount was applied to the S2 treatment as 95.2 mm and the highest irrigation was applied to the S5 treatment as 238.7 mm. ET values ranged from 93.1 (S1) to 466.3 mm (S5). ET increased the amount of irrigation water applied. The ET value obtained from the S1 treatment (non-irrigation) was calculated according to the soil water content in root zone soil profile when the

**Table 4.** Number of irrigation, amounts of irrigation water, evapotranspiration and cumulative evaporation.

| Treatments | Number of irrigation | Irrigation water amount (mm) | Evapotranspiration (mm) | Cumulative evaporation (CAP*, mm ) |
|---|---|---|---|---|
| S1 | - | - | 93.1 | 529 |
| S2 | 22 | 95.2 | 341.9 | |
| S3 | 22 | 143.1 | 391.5 | |
| S4 | 22 | 190.5 | 430.8 | |
| S5 | 22 | 238.7 | 466.3 | |

*Class A pan.

**Table 5**. Yield components related to treatments.

| Yield component | Treatments | | | | |
|---|---|---|---|---|---|
| | S1* | S2 | S3 | S4 | S5 |
| | $\bar{x} \pm S\bar{x}$ | $\bar{x} \pm S\bar{x}$ | $\bar{x} \pm S\bar{x}$ | $\bar{x} \pm S\bar{x}$ | $\bar{x} \pm S\bar{x}$ |
| Yield (ton ha$^{-1}$)* | - | 42.1 ± 0.9 b | 50.5 ± 1.7 a | 51.9 ± 1.1 a | 37.0 ± 2.5 b |
| Fruit number $^{ns}$ | - | 11.7 ± 0.9 | 13.7 ± 0.3 | 13.3 ± 0.3 | 11.3 ± 0.9 |
| Mean fruit weight (g)* | - | 196.6 ± 11.1 ab | 199.3 ± 1.9 ab | 210.5 ± 6.3 a | 176.7 ± 1.9 b |
| Fruit diameter (mm) $^{ns}$ | - | 44.0 ± 1.2 | 44.1 ± 1.4 | 43.8 ± 1.0 | 42.7 ± 1.3 |
| Fruit lenght (mm) $^{ns}$ | - | 180.6 ± 8.5 | 181.8 ± 4.8 | 182.6 ± 5.2 | 174.9 ± 5.4 |
| Fruit firmness (libre) $^{ns}$ | - | 14.3 ± 0.2 | 14.7 ± 0.2 | 14.3 ± 0.2 | 14.0 ± 0.6 |
| Soluble Solid (%) $^{ns}$ | - | 6.8 ± 0.1 | 6.8 ± 0.1 | 6.0 ± 0.3 | 6.3 ± 0.3 |

*S1 (Non-irrigation) was not included in the statistical analyses, because yield was not obtained.

plants dried. The obtained values related to the amount of the irrigation water and ET was similar to the findings of Elliades (1992), Chartzoulakis and Drosos (1995) and Lovelli et al. (2007). However, less irrigation water was applied in this study as compared to studies the described earlier which may be explained by the wetting percentage (36%) of the drip irrigation method used.

Values regarding the average fruit number, yield and quality parameters of all the treatments are presented in the Table 5. It was shown that irrigation treatments had a significant effect on the eggplant yield ($p < 0.05$). While the highest yield was obtained from the S4 treatment, S3 and S4 treatments were in the same class in terms of yield values. The lowest yield was obtained from the S5 treatment to which the highest irrigation was applied and, no yield was obtained from the S1 treatment (non-irrigation). Controlled irrigation is a vital importance regarding the plants which are sensitive to excessive or deficient irrigation water (FAO, 2004). Despite the highest irrigation water and plant water consumption, it was observed that the more vegetative growth of the plants affected the fruit yield negatively in the S5 treatment. This indicated that irrigation may decrease the eggplant yield when irrigation water exceeded plant water requirement.

In addition, significant polynomial correlations between the yield and irrigation water and the yield and ET were obtained as shown in Figure 1 ($p < 0.01$). It was observed that when irrigation water and ET increased, yield also increased to a certain point, however, irrigation had a slightly ($R^2 = 0.99^{**}$) more positive-effect on yield than ET ($R^2 = 0.94^{**}$). The obtained results are similar with the results found by Cevik et al. (1996) and Ertek et al. (2006). In these studies, the researchers concluded that there was a linear relationship between amount of irrigation water and the yield for the eggplant to a certain level, but after a certain level, the excessive water applied did not provide a significant increase, and on the contrary, caused a decrease in the yield.

In terms of the measured fruit weight, the highest fruit weight was obtained from the S4 treatment as 210.5 g, while the lowest fruit weight was obtained from the S5 treatment as 176.7 g ($p < 0.05$). Nonetheless, significant differences were not observed in the fruit number and the other quality parameters such as fruit diameter, fruit length, fruit flesh firmness and soluble solids values of the eggplant among the irrigation treatments.

The relationship between relative decreases in yield ($1-Y/Y_m$) and relative decreases in evapotranspiration ($1-ET/ET_m$) is shown in Figure 2. The coefficient $K_y$, calculated according to Equation 3 for irrigation treatments, was determined as 0.81. In this sense, 0.81 unit yield decrease can be expected for per unit water

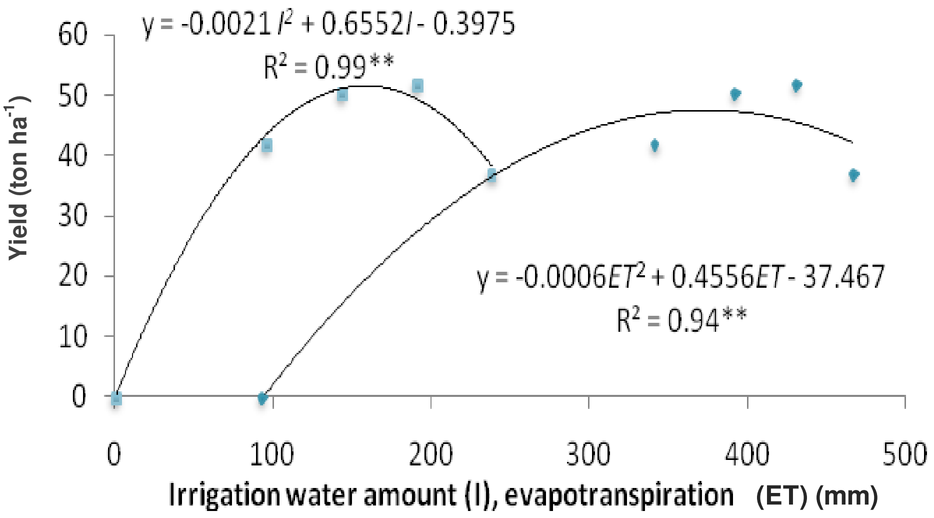

**Figure 1.** Relationships between yield and irrigation water amount or evapotranspiration.

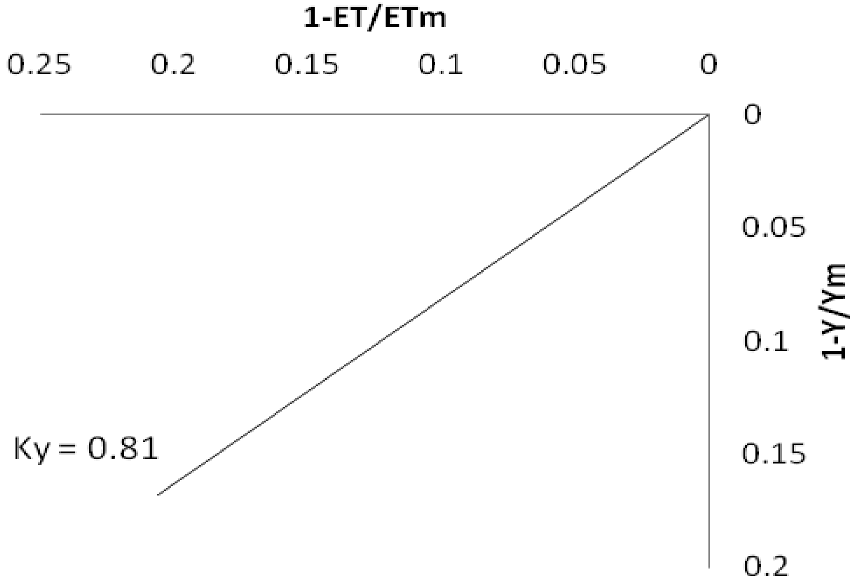

**Figure 2**. Relationships between relative yield decrease and relative evapotranspiration deficit for eggplant.

deficiency. This means $K_y < 1$ and therefore, shows that eggplant is not sensitive to water deficit. The yield response factor ($K_y$) was determined as 0.60 by Ertek et al. (2006) and as 1.37 by Lovelli et al. (2007). The value obtained in this study differed from the referred researchers' values which may be caused by the greenhouse conditions carried out in this study and total yield values used in the Equation 3 instead of marketable yield values.

The WUE and IWUE values related to the irrigation treatments are presented in Figure 3. The highest WUE and IWUE values were calculated in the S3 (12.9 kgm$^{-3}$) and S2 (44.2 kgm$^{-3}$) treatments, while the lowest WUE and IWUE values were calculated in the S5 (7.9 and 15.5 kgm$^{-3}$) treatment where the highest irrigation water was applied. In other words, it was seen that WUE and IWUE values decreased with the increasing irrigation water and evapotranspiration. The results obtained in this study are parallel with the studies of Lovelli et al. (2007) and Ertek et al. (2006) in the eggplant, Xuesen et al. (2003) in cucumber, and Costa and Gianquinto (2002) in pepper.

## Conclusions

In this study, it was observed that different irrigation

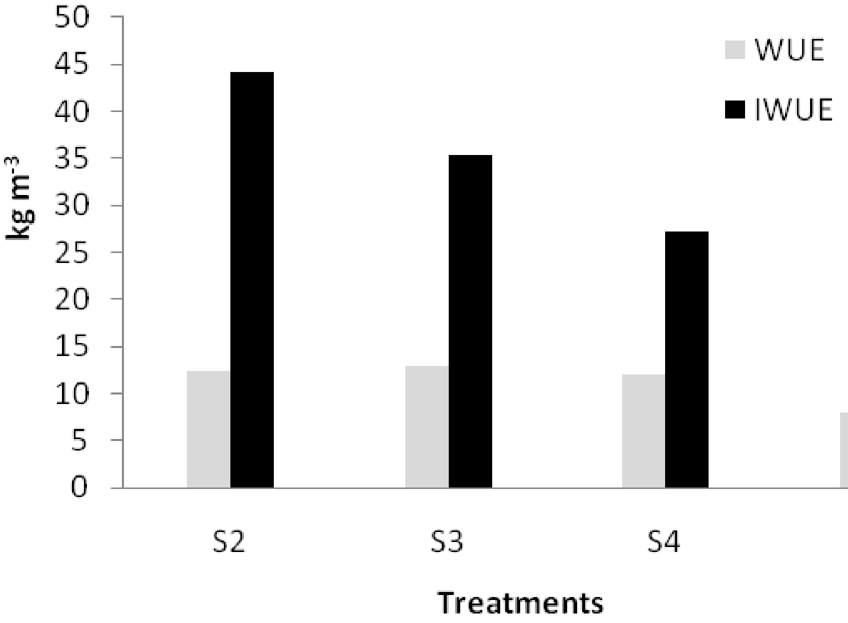

**Figure 3.** Water use efficiency (WUE) and irrigation water use efficiency (IWUE) related to the treatments.

programs with plant-pan coefficients had a significant effect on the yield and fruit weight ($p < 0.05$). The highest eggplant yields were obtained from the S4 (51.9 tonnes ha$^{-1}$) and S3 (50.5 tonnes ha$^{-1}$) treatments. A significant polynomial correlation between the yield and irrigation water and between the yield and ET were obtained. It was shown that there was a linear relation between irrigation water amount and the yield for the eggplant to a certain level, but after a certain level, the excessive water applied did not provide a significant increase, and on the contrary, caused a decrease in the yield. The seasonal yield response factor ($K_y$), which is a crucial parameter in the determination of the plant's resistance against the water stress and the appropriate irrigation program was obtained as 0.81 in this study. This value indicated that the eggplant was not sensitive to water deficiency and was more adapted to the irrigation program where the water deficit was applied. In conclusion, for similar greenhouse conditions, S3 ($k_{cp}$ = 0.75) treatment for eggplant can be suggested as the most appropriate irrigation program with higher yield and higher WUE (12.9 kgm$^{-3}$).

## REFERENCES

Aujla MS, Thind HS, Buttar GS (2007). Fruit yield and water use efficiency of eggplant (*Solanum melongema L.)* as influenced by different quantities of nitrogen and water applied through drip and furrow irrigation. Sci Hortic., 112: 142–148.

Antony E, Singandhupe RB (2004). Impact of drip and surface irrigation on growth, yield and WUE of capsicum (*Capsicum annum L.*). Agric. Water Manage., 65: 121–132.

Boyacı HF (2007). Resistance resources and its inheritance against to *fusarium* wilt in eggplants, Cukurova University, Ph D Thesis, Natural and Applied Sciences. 108 p.

Chartzoulakis K, Drosos N (1995). Water use and yield of greenhouse grown eggplant under drip irrigation. Agric. Water Manage., 28: 113-120.

Costa LD, Gianquinto G (2002). Water stress and water- depth influence yield, water use efficiency, and nitrogen recovery in bell pepper: Lysimeter studies. Aust. J. Agric. Res., 53: 201–210.

Cevik B, Baytorun N, Tanriverdi C, Abak K, Sari N (1996). Farklı sulama suyu uygulamalarının serada yetiştirilen patlıcanın verim ve kalitesine etkileri. Ankara TÜBİTAK, Turkish J. Agric. For., 2: 175-181 (in Turkish press).

Doorenbos J, Pruitt WO (1977). Guidelines for predict of water requirement. Irrigation and Drainage Paper. Rome FAO. 24: 144.

Doorenbos J, Kassam AH (1986). Yield response to water. Irrigation and Drainage Paper. Rome FAO. 33: 193 p.

Elliades G (1988). Irrigation of greenhouse-grown cucumbers. J. Hort. Sci., 63: 235–239.

Elliades G (1992). Irrigation of eggplants grown in greenhouse. J. Hort. Sci., 67: 143-147.

Ertek A, Sensoy S, Yildiz M, Kabay T (2002). Determination of the irrigation interval and amount of application water in eggplant by using the free surface evaporation values in greenhouse conditions, KSU J. Sci. Eng., 5: 57-67

Ertek A, Sensoy S, Kucukyumuk C, Gedik I (2006). Determination of plant-pan coefficients for field-grown eggplant (*Solanum melongena L.)* using class A pan evaporation values. Agric.Water Manage., 85: 58–66.

Fabeiro C, Martin SF, Juan JA (2001). Yield and size of deficit irrigated potatoes. Agric. Water Manage., 48: 255–266.

FAO (2004). Crop water management. Eggplant. AGLW water Management Group. http://www.fao.org/ag/agl/aglw/cropwater/eggplant.gtm

FAO (2010). Food and Agriculture Organization of The United Nations. http://www.fao.org

Hillel D, Guron Y (1975). Relation between evapotranspiration rate and maize yield. Water Res., 9: 743-748.

James LG (1988). Principles of farm irrigation system design. John Wiley and Sons. Inc., New York. 543 p.

Kanber R (2010). Farm Irrigation Systems. CU Agriculture Faculty Press, 575 p.

Kanber R, Yazar A, Onder S, Koksal H (1993). Irrigation response of pistachio (*Pistacia vera L.*). Irrig. Sci., 14: 1–14.

Kanber R, Koksal H, Onder S, Unlu M, Sezen SM, Ozekinci B, Yazar A, Pakyurek Y (1996). Bazı Kışlık Sebze Türlerinin Sulama Olanaklarının Araştırılması. Ç.Ü.Z.F. Adana., 154(195): 83 (in Turkish press).

Kirda C (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit Irrigation Practise. Water Rep. Rome FAO, 22: 3-10.

Li F, Yan X, Li F, Guo A (2001). Effects of different water supply regimes on water use and yield performance of spring wheat in a simulated semi-arid environment. Agric. Water Manage., 47: 25–35.

Lovelli S, Perniola M, Ferrara A, Di Tommaso T (2007). Yield response factor to water ($K_y$) and water use efficiency of *Carthamus tinctorius L*. and *Solanum melongena L.* Agric. Water Manage., 92: 73–80.

Mannini P, Gallina D (1996). Effects of different irrigation regimes on two tomato cultivars grown in a cold greenhouse. Hortic. Abstr., 61: 64-650.

Mendezr FJ (1987). Effect of applying different irrigation frequencies into tomato production in San Juan de Lagunillas merid state. Acta Hortic., 22: 383–386.

Motilva M, Tovar MJ, Romero MP, Alegre S, Girona J (2000). Influence of regulated deficit irrigation strategies applied to olive trees (*Arbequina cultivar*) on oil yield and oil composition during the fruit ripening period. J. Sci. Food Agric., 80: 2037–2043.

Oweis T, Zhang H, Pala M (2000). Water use efficiency of rainfed and irrigated bread wheat in a Mediterranean environment. Agron. J., 92: 231–238.

Pandey RK, Maranville JW, Admou A (2000). Deficit irrigation and nitrogen effect on maize in a Sahelian environment. Agric. Water Manage., 46: 1–13.

Sezen SM, Yazar A, Eker S (2006). Effect of drip irrigation regimes on yield and quality of field grown bell pepper. Agric. Water Manage., 81: 115–131.

Stewart JI, Cuenca RH, Pruitt WO, Hagan RM, Tosso J (1977). Determination and utilization of water production functions for principal California crops. W-67 CA Contributing Project Report. University of California, Davis, USA.

TSI (2010). Turkish Statistical Institute. Population Statistics. http://www. tuik.gov.tr

TSMS (2008). Turkish State Meteorological Service, http://www.dmi.gov.tr/en-US

Van OS EA (1994). Closed growing system for more efficient and environmental friendly production. Acta Hortic., 396: 25-32.

Xuesen M, Mengyu L, Xinyuan W, Changming L, Zhimin H, Jinzhi S (2003). Effects of deficit irrigation on yield and water use of greenhouse grown cucumber in the North China Plain. Agric. Water Manage., 61: 219-228

Yuan BZ, Sun J, Kang Y, Nishiyama S (2006). Response of cucumber to drip irrigation water under a rainshelter. Agric.Water Manage., 81: 145–158.

Zhang H, Wang X, You M, Liu C (1999). Water-yield relations and water-use efficiency of winter wheat in the North China Plain. Irrig. Sci., 19: 37–45.