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IMPACT OF DIFFERENT IRRIGATION WATER LEVELS ON YIELD AND SOME QUALITY PARAMETERS OF LETTUCE (*LACTUCA SATIVA L. VAR. LONGIFOLIA CV.*) UNDER UNHEATED GREENHOUSE CONDITION

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Summary

The experiment was carried out to determine the effects of different irrigation water levels on yield and some quality parameters of lettuce (Lactuca sativa L. Var. Longifolia cv.) under greenhouse conditions. Irrigation water was applied through drip irrigation method with 7 days interval during the total growing season. Irrigation treatments consisted of six different water levels (I1: non-irrigation, I2: 25 %, I3: 50 %, I4: 75 %, I5: 100 % and I6: 125 % of cumulative evaporation measured from Class A pan). The amount of irrigation water ranged between 0 and 106.3 mm among the treatments. Evapotranspiration (ET) values varied from 69.1 to 158.5 mm for the treatments. The highest yield was obtained from the I5 followed by I4. A significant polynomial relation (R^2=0.77) was obtained between the yield and irrigation water, and linear relation (R^2=0.99) was obtained between the yield and ET. This indicated that when irrigation water increased, yield also increased to a certain point. However, when the amount of irrigation water exceeded the plant water requirement, lettuce yield decreased. Yield response factor (Ky) was determined as 1.97. Since Ky > 1, lettuce was very sensitive to water deficiency. In addition, the highest water use efficiency (WUE) and irrigation water use efficiency (IWUE) values were calculated in the I5 with 0.60 t $ha.mm^{-1}$ and 0.96 t $ha.mm^{-1}$ respectively. The best plant quality parameters which were plant weight (239.11 g), plant height (26.30 cm), plant diameter (44.82 cm), root weight (17.31 g), root length (9.02 cm), root diameter (10.04 cm) and leaf number (49) were also obtained in I5. As a result, it was suggested that I5 can be the most appropriate irrigation water level for lettuce with higher WUE, IWUE, yield and quality under greenhouse conditions.

Key words: Lettuce, evapotranspiration, yield response factor, WUE, IWUE, Class A pan

INTRODUCTION

Lettuce is a vegetable that is widely cultivated due to the shortness of its vegetation time, the fact that it can be grown as a second product and the high consumption ratio along with economic return. Turkey is ranked number 7 in the world by supplying 1.8 % (438 thousand tons) of the total lettuce production (Faostat, 2011). Lettuce which is a winter vegetable is mostly grown out in field. However, the higher yield can be obtained in greenhouses or under protective covers where environmental conditions are under control. In addition, supplying fresh fruits and vegetables to markets and taking advantage of using labors all year long instead of seasonal is possible only by greenhouse cultivation (Yuksel, 1989). Greenhouse cultivation is also a cultivation method that makes it possible to grow plants outside of their seasons (Tuzel et al., 2005). Hence, lettuce is recently grown on high or low tunnels in order to obtain a higher market value for the products.

New irrigation methods have been developed because of a decrease in current water sources due to increased population and the pollution of water sources. The most ideal method in greenhouse cultivation is the drip irrigation system that requires the application of less amount of water each time in frequent intervals which keeps the soil moisture at a low tension (Yildirim, 1993). Water and nutrient elements can be supplied to the root area of plants by drip irrigation method without creating water stress (Phene and Howell, 1984). Class A evaporation pans can be used for the irrigation scheduling of the plants in the drip irrigation method in greenhouses (Casanova et al., 2009). In this condition, irrigation water as a specific percentage of the amount evaporated from the pan is applied regarding the irrigation interval considered (Yildirim and Madanoglu, 1985). In addition to the irrigation methods developed due to the decrease of water sources, new irrigation techniques are also developed. One of these is carried out by decreasing evapotranspiration (ET) by changing the irrigation programs and applying an approach known as deficit irrigation. In the aforementioned approach, the plant is faced with water deficiency during all the development season or at some periods and saving from irrigation water is made without significant losses in yield. Deficit irrigation technique can be defined as an optimization strategy in which the plant is faced with water deficiency in a certain level along with planned or known yield decreases (Kanber et al., 2007).

The objective of this study was to determine the effects of different irrigation water levels on the yield and some quality properties of lettuce grown under greenhouse conditions with using drip irrigation method in the region of Isparta. In addition, various water usage parameters such as evapotranspiration (ET), yield response factor (ky), water use efficiency (WUE), irrigation water use efficiency (IWUE) and the ratio of the irrigation water in ET (I_c) were examined.

MATERIALS AND METHODS

The study was carried out between February and April of 2011 in plastic covered greenhouse which had 96 m^2 surface area and the long axis placed in the east-west direction in Agricultural Research and Experimental Center at the Campus of Süleyman Demirel University, Isparta, Turkey. The study area was between 37° $50^{I}\,23^{II}$ N latitude and 30° 32^{I} 02^{II} E longitude and 1010 m altitude. The Isparta 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, wind speed and precipitation are 12 °C, 61%, 1.9 m s^{-1} and 520 mm, respectively [TSMS, 2008]. Automatic recorders [Hobo, Bourne, MA, U.S.A.] was used in order to determine the monthly values of iner greenhouse average temperature and relative humidity during the growing season (Figure 1).

The greenhouse soil was clay-loam, and the dry soil bulk density average was 1.47 g cm^{-3} throughout the 0.60 m depth in soil profile. The total available soil water content within top 0.60 m of soil profile was 104.1 mm and no water problem was found. Some soil characteristics related to irrigation are presented in Table 1.

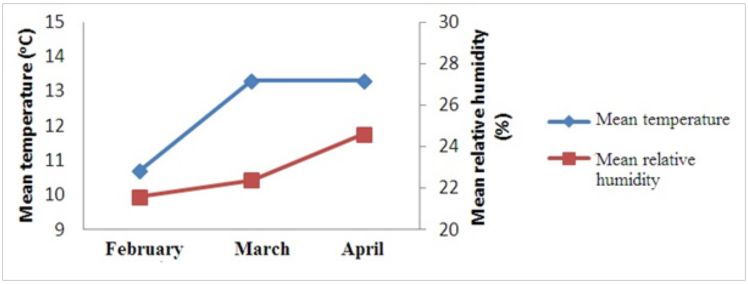

Figure 1. Mean temperature and relative humidity in greenhouse

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

Soil depth (cm)	Structure	Bulk density (gr cm^{-3})	Field capacity		Wilting point		Available soil water content	
			%	mm	%	mm	%	mm
0-30	CL	1.51	28.0	127.0	14.0	63.4	14.0	63.6
30-60	CL	1.42	27.0	115.0	17.5	74.6	9.5	40.5

In the experiment, Yedikule lettuce (*Lactuca sativa L. Var. Longifolia cv.*) variety was used as the plant material. The seeds were first planted in viols and then 33 days after planting (February 7, 2011) when they reached an average of 5-6 leaves they were planted on parcels inside the greenhouse with dimensions of 2.4 x 0.4 m at distance of 0.20x0.20 m and following the 90 day growth period harvesting was carried out. Same amounts of fertilizer which consisted of 0.1 tonnes ha^{-1} P_2O_5, 0.2 tonnes ha^{-1} K_2O and 0.15 tonnes ha^{-1} N were applied using drip fertigation to all the treatments. After the harvesting, the yield per unit area (t ha^{-1}), weight (g), plant height (cm), plant diameter (cm), root weight (cm), root diameter (cm) and leaf number (units) were determined. Scale was used to determine the weights of the plant and the root whereas digital caliper was used to measure the height and diameters of the plant and root. In the study, the treatments were formed in accordance with randomized plot design with 3 replications. There are a total of 390 plants in the study area, 65 in each parcel and 12 in the harvest parcel.

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}. Electrical conductivity of irrigation water was 0.81 ds m^{-1} and C_3S_1 qualified. Engineering characteristics and working principles related to the drip irrigation method were determined on the fundamentals given in Yildirim [2008]. Drip irrigation system consisted of PE laterals of Φ16 mm in diameter inline type drippers with pressure regulators at 0.20 m distance. The drippers had a discharge rate of 2 L h^{-1} under an operational pressure of 1 atm. One lateral was placed in each plant row. All treatments were irrigated prior to the experiment until the current moisture reached the field capacity at 0-60 cm soil depth. Class A Pan was used to determine the amounts of irrigation water applied to the treatments. In the study, experimental treatments were used consisting of six different irrigation water levels (no irrigation water (I1), 25 % of the cumulative evaporation amount measured in Class A Pan (I2), 50 % of the same amount (I3), 75 % of the same amount (I4), 100 % of the same amount (I5) and 125 % of the same amount (I6)) selected according to the cumulative evaporation that occurred in the Class A Pan during the seven day irrigation interval. Irrigation water volume was calculated by equation 1 described by Doorenbos and Pruitt [1977] and Kanber [1984].

$$V = A \; x \; k_{cp} \; x \; E_p \; x \; P \tag{1}$$

Where, V is the volume of irrigation water applied (L), A is the pilot area (m^2), kcp is the plant-pan coefficient, Ep is the cumulative evaporation at Class A pan in the 7 days irrigation intervals (mm) and P is the wetted area percentage (100 %).

Evapotranspiration related to the treatments were estimated using the water balance method in 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 ΔS is the change in the soil water content determined by the gravimetrical method in the 60 cm soil depth (mm). In the experiment area, since there was no capillary water entrance from the water table, runoff loss due to the drip irrigation method and precipitation due to greenhouse, C_p, R_f and P 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, D_p values were neglected

[Kanber et al., 1993].

The relationship between relative decrease in evapotranspiration and relative decrease in yield was determined by equation 3 as described by Doorenbos and Kassam [1986].

$$(1-Y_a/Y_{max}) = k_y(1-ET_a/ET_{max}) \tag{3}$$

where, Y_a and Y_m are actual and maximum yields (tonnes ha^{-1}), respectively, K_y is yield response factor and ET_a and ET_m are actual and maximum evapotranspiration (mm), respectively.

Water use efficiency (WUE) and irrigation water use efficiency (IWUE) in the treatments were calculated using equations 4 and 5 (Howell et al., 1990; Kanber et al., 1996).

$$WUE = 100\ (Y/\ ET) \tag{4}$$

$$IWUE = 100\ (Y - Y_{NI})\ /\ I \tag{5}$$

Where, *WUE* is the water use efficiency (tonnes ha.mm^{-1}), *Y* is the yield (tonnes mm^{-1}), *IWUE* is the irrigation water use efficiency (tonnes ha.mm^{-1}) and Y_{NI} is the yield obtained from the non-irrigation treatment (tonnes mm^{-1}).

The amount of yield per unit area and some quality characteristics of lettuce such as mean plant weight, length, diameter, root weight, length, diameter and leaf number 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.

RESULTS AND DISCUSSION

The total amounts of irrigation water applied to the treatments were calculated respectively as 0 (I_1), 21.3 (I_2), 42.5 (I_3), 63.8 (I_4), 85.0 (I_5), 106.3 (I_6) mm. The evapotranspiration values (ET) varied among to treatments and the highest ET value was determined for I_6 as 158.5 mm for which the highest amount of irrigation water was used, whereas the lowest ET value was obtained for I_1 as 69.1 on which no irrigation water was used. Whereas in general, the ET values for treatments increased along with the increase of the irrigation water and these increase trends were similar to previous studies (Bozkurt and Mansuroglu, 2011; Kadayıfçı, 2004), the total amount of irrigation water applied was determined to be lower than the values found in other studies (Yazgan et al., 2008; Bozkurt and Mansuroglu, 2011). The values of yield (Y), evapotranspiration (ET), water use efficiency (WUE) and irrigation water use efficiency (IWUE) are presented in Table 2. The highest yield was obtained for the I5 on which the irrigation water amount according to total evaporation amount measured from Class A Pan was given, this was followed by I4 for which a 25 % deficit irrigation was applied. There was no statistically significant difference between the yield values obtained for the I6 on which a 25 % water excess was applied and I3 on which 50 % deficit irrigation was applied. In other words, even though evapotranspiration increased during excessive water application, a similar increase was not observed in the yield. The highest WUE and IWUE values were obtained respectively as 0.60 t $ha.mm^{-1}$ and 0.96 t $ha.mm^{-1}$ from the I5, whereas the lowest values were obtained from I2 and I6 (without considering the non-irrigated treatment I1). Whereas the obtained values were lower in deficit irrigation treatments as different with those determined by Bozkurt and Mansuroglu [2011] in greenhouse conditions and Nagaz et al. [2013] in field conditions, the yield values found in this study were similar with Acharya et al. [2013].

Relationships between irrigation water with evapotranspiration and yield can be seen in Figure 2. A linear relationship was determined between evapotranspiration and yield (R^2=0.99), whereas a polynomial relationship was determined between irrigation water and yield (R^2=0.77). The yield response factor (ky) was determined as 1.97 in the study (Figure 3). This value shows that the lettuce plant was very sensitive to water deficiency in the soil. Accordingly, it was observed that lettuce cultivation cannot be carried out under greenhouse conditions without irrigation.

Some quality parameters related to treatments are presented in Table 3. The obtained quality parameters were varied according to the amounts of the applied irrigation water. The plant weights were observed to vary between 18.4 and 345.3 g, plant heights between 11.5 and 31.5 cm, plant diameters between 5.1 and 64.9 cm, root weight between 7.7 and 21.1 g, root height between 4.3 and 9.0, root diameter between 2.2 and 10.0 cm and leaf number between 13 and 49. The best plant growth was observed in the I5 followed by the I4. The values obtained were similar to those obtained by Yazgan et al. [2008] and Bozkurt and Mansuroglu [2011] but different than those obtained by Duman [2007], Kaymak [2007] and Guvenc et al. [2004]. Differences between our study and previous studies may be due to differences in the plant variety used, region and cultivation periods.

Table 2. The values of yield (Y), irrigation water amount (IR), evapotranspiration (ET), water use efficiency (WUE) and irrigation water use efficiency (IWUE) for the treatments

Treatments	Y ($t\ ha^{-1}$)	IR (mm)	ET (mm)	WUE ($t\ ha.mm^{-1}$)	IWUE ($t\ ha.mm^{-1}$)
I_1	4.6 d	0.0	69.1	0.07	0.00
I_2	19.3 c	21.3	87.6	0.22	0.69
I_3	43.1 bc	42.5	114.9	0.38	0.91
I_4	59.8 b	63.8	122.2	0.49	0.87
I_5	86.3 a	85.0	142.4	0.60	0.96
I_6	45.5 bc	106.3	158.5	0.29	0.38

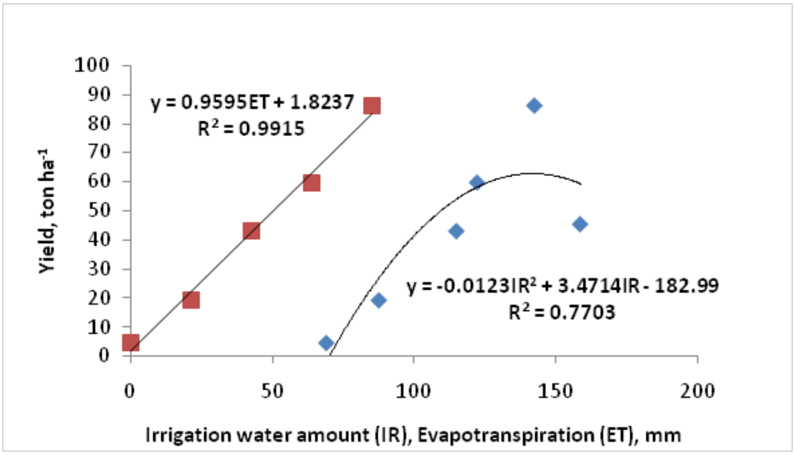

Figure 2. Relationships between yield and irrigation water amount with evapotranspiration

In conclusion, it was determined that the lettuce plant grown under greenhouse conditions at the region of Isparta and irrigated by drip irrigation method was very sensitive to water deficiency and it cannot be grown under greenhouse conditions without irrigation. According to the results obtained from this study, the most suitable irrigation water level to get the highest yield, quality and water use efficiencies was suggested as total cumulative evaporation amount (100 %) measured in the Class A Pan. In addition, even though a certain amount of decrease in yield and quality can be faced, the irrigation level with 75 % of the cumulative evaporation amount can also be suggested for conditions with water shortage.

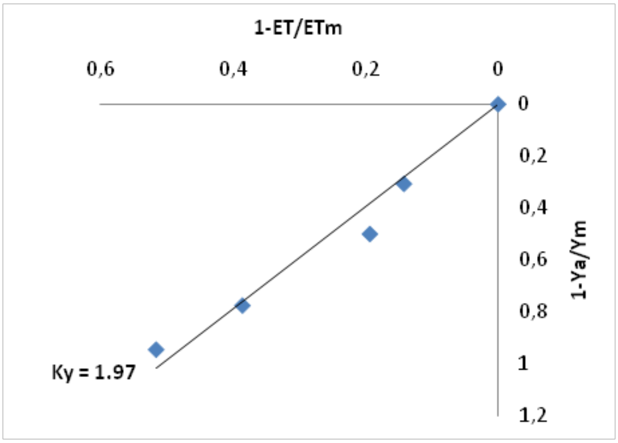

Figure 3. Relationships between relative yield decrease and relative evapotranspiration deficit for lettuce

Table 3. Yield quality parameters for the treatments

Konular	Plant weight (g)	Plant lenght (cm)	Plant diameter (cm)	Root weight (g)	Root lenght (cm)	Root diameter (cm)	Leaf number
I1	18.4 d	11.5 d	5.1 e	7.7 c	4.3 c	2.2 e	13 d
I2	77.3 c	16.6 c	10.2 de	8.4 c	5.4 bc	4.0 d	16 c
I3	172.3 bc	23.5 b	17.9 d	14.3 b	6.0 b	6.0 c	25 bc
I4	239.1 b	26.3 ab	44.8 b	17.3 ab	8.3 a	8.1 b	34 b
I5	345.3 a	31.5 a	64.9 a	21.1 a	9.0 a	10.0 a	49 a
I6	182.1 bc	21.4 bc	30.1 c	13.2 b	5.6 bc	6.6 c	24 bc

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