Current Trends in Natural Sciences Vol. 5, Issue 9, pp. 145-151, 2016

Current Trends in Natural Sciences (on-line)
ISSN: 2284-953X
ISSN-L: 2284-9521

Current Trends in Natural Sciences (CD-Rom)
ISSN: 2284-9521
ISSN-L: 2284-9521

EFFECTS OF DIFFERENT IRRIGATION LEVELS ON YIELD OF LETTUCE GROWN IN AN UNHEATED GREENHOUSE

Halil Kirnak*, Ismail Taş, Zeki Gökalp***, Sedat Karaman******

* Erciyes Univ. Agricultural Fac. Biosystems Engineering Dept., Kayseri, Turkey
E-mail: hkirnak@yahoo.com
** Canakkale Onsekiz Mart Univ. Agricultural Fac. Agricultural Structures and Irrigation Dept. Canakkale, Turkey
E-mail: tas_ismail@yahoo.com
*** Erciyes Univ. Agricultural Fac. Biosystem Engineering Dept., Kayseri, Turkey
E-mail: zekigokalp@yahoo.com
**** Gaziosmanpasa Univ. Agricultural Fac. Biosystem Engineering Dept., Tokat, Turkey
E-mail: sedat.karaman@gop.edu.tr

Abstract
This study was carried out in an unheated greenhouse in order to determine effects of different irrigation levels on lettuce yield (cv. Hazar*) grown from December to February in Şanlıurfa, Turkey. Different irrigation water amounts based on Class-A-Pan evaporation were applied to the plants by drip irrigation system at four irrigation levels (Kp_1= 1.0, Kp_2=0.75, Kp_3=0.50, Kp_4=0.25) in one week irrigation interval. Applied irrigation water and evapotranspiration of Kp_1 treatment were 118 and 125 mm, respectively. The highest average lettuce yield of 7.8 ton da^{-1} was obtained from the full-irrigation treatment (Kp_1). Significant differences were not observed between Kp_1 and Kp_2 treatments in terms of lettuce yield. Maximum irrigation water use efficiency and total water use efficiency were obtained from Kp_4 treatment respectively with 0.117 and 0.074 ton da^{-1} mm^{-1}. Yield response factor (ky) was found to be 0.88. The research results showed that a 7 day irrigation interval with Kp_2 treatment could be used for irrigating lettuce under the unheated greenhouse conditions without any significant yield loss but increased water use efficiencies.*

Keywords: Drip irrigation, greenhouse, water stress, class A-pan evaporation

1. INTRODUCTION

Water is fast becoming an economically scarce resource in many areas of the world, especially in arid and semi-arid regions. The need for more-efficient agricultural use of irrigation water arises out of increased competition for water resources and rising environmental anxiety that irrigation practice in some cases is facilitating a degradation in the quality of those ground and surface waters that receive leachates from the root zone of irrigated fields (James, 1993). The low water use efficiency can occur when soil evaporation is high in relation to crop evapotranspiration, water application does not correspond to crop demand, and when shallow roots are unable to utilize deep water in the profile. All these mentioned problems are especially important in vegetable production in arid and semi-arid regions. Many vegetable species are shallow-rooted and sensitive to mild water stress. In lettuce production, where the harvested part of the plant is the photosynthetic leaf area, it is especially important to maintain optimal growth through a well-scheduled irrigation program (Casanova et al., 2009; Ahmed et al., 2000).

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Greenhouse grown agricultural crops takes an important place in Turkey especially in Mediterranean region lately due to increases in crop prices, higher quality and global warming. The most important key factor in the greenhouse crop production is forming an optimal irrigation scheduling strategy which avoiding excessive irrigation and optimizing water use. Crop responses to different rates of applied water have been used for many vegetable crops to determine irrigation strategies for optimal yield and maximum water use efficiency (e.g., Hanson et al., 1997).

The objectives of this study were to determine the water production functions, water use efficiency and water requirements via class A pan evaporation for lettuce under unheated greenhouse conditions.

2. MATERIALS AND METHODS

Plant material and culture conditions

The experiment was conducted in an unheated greenhouse at the Regional Directory of Agricultural Institute of Şanlıurfa Province from December to February. The total growing area of the greenhouse was 500 m^2 and the greenhouse was steel structured covered with a PE plastic. The plastic greenhouse had a manual operated natural ventilating system. The top 30 cm soil layer in the greenhouse was clay-textured (62.5% clay, 8.90% sand, 28.69% silt). Readings for field capacity, permanent wilting point, dry bulk density, pH, and EC of the greenhouse soil at the site for 0-30 cm soil depth were 32.38%, 21.53%, 1.31 g cm^{-3}, 7.40, and 1.25 dSm^{-1} respectively. Irrigation water was of good quality (C_2S_1) with EC_w of 0.258 dSm^{-1}, containing (meq l^{-1}) 1.1 Ca^{2+}, 0.85 Mg^{2+}, 0.22 Na^+, 0.01 K^+, 0.70 SO_4^{2-}, 0.95 HCO_3^-, 0.53 Cl^- and a pH of 7.0.

All treatment received the same amounts of total N (200 kg ha^{-1}), P (100 kg ha^{-1}) and K (150 kg ha^{-1}) fertiliser. All of the P, K and 40% of the N fertiliser were applied prior to planting and thoroughly mixed into the soil. The remaining 60% of N was added equally at weekly intervals through the drip irrigation system starting one week after transplanting until two weeks before the harvest. Lettuce cv. *Hazar* , widely cultivated in this region, was selected for the study. Seeds were germinated in fine sand in the last week of October. After germination, at the first true leaf stage (15 days), seedlings were transplanted into a plastic tubs containing mixture of turf and soil. When the fourth true leaves appeared, similar sized seedlings were again selected and transplanted into the greenhouse on 5 of December. After transplanting, all treatments were given uniform optimal irrigation for two weeks to promote root system establishment without water stress. In order to measure temperature inside the greenhouse, a thermometer was placed in the center of the greenhouse.

Irrigation

Plants were planted in rows with an inter-plant spacing of 0.30 m and an inter-row spacing of 0.40 m. A single drip irrigation tube was placed on the centre of each rows. Spacing of the drippers with a constant discharge of 2.0 L h^{-1} at 100 kPa for both irrigation systems was 0.33 m. The 4 rows, 6 m long, were prepared for each replication. There were 1 m space between treatments in order to prevent water movements among treatments. All measurements related to plant analysis were taken from the central rows. Each plot had a separate flow meter to monitor water input. There were four different pan coefficients (Kp_1=1.0, Kp_2=0.75, Kp_3=0.50, Kp_4=0.25) in the experiment and irrigation interval was constant as 7 days. A randomised complete block design was used and data were analyzed using a Minitab computer program. Means were separated by Duncan's multiple range test. The amount of irrigation water was calculated based on the following equation:

$$I = A \times E_{pan} \times K_p \times P \qquad (1)$$

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Where: I = amount of irrigation water (mm), A = growing area (m^2), E_{pan} = cumulative class-A-pan evaporation, K_p = pan coefficient, P = canopy cover percentage.

Evaporation was calculated from a standard class A pan located in the center of the greenhouse. In order to monitor soil moisture changes in the root zone, a tensiometer per plot was replaced to 20 cm soil depth. Evapotranspiration for each treatment was calculated according to the water balance approach. Soil moisture content to a depth of 60 cm was determined gravimetrically (Doorenbos and Kassam, 1988). Total water use efficiency (TWUE) was calculated as the ratio of lettuce yield to water use. Irrigation water use efficiency (IWUE) was computed as the ratio of lettuce yield to applied irrigation water for each treatment.

Growth measurements

Plant measurements and observations were started three weeks after transplanting, and continued till end of harvest. Shoot dry matter was determined four times during the experimental period by harvesting 3 heads at surface level per plot at 15 day intervals till harvest. Plant samples were dried at 70 °C for 48 hours to constant weight. Measurements of plant height and canopy diameter from ten randomly selected plants in each plot were also taken 10-day intervals till harvest. Yield components (g per plant) were determined from fresh weight of plants. Harvesting was done one on 28rd of February.

3. RESULTS AND DISCUSSIONS

The total irrigation water applied during the experimental period and water use of lettuce were given for each irrigation treatment (Table 1). Drip-irrigated plots receiving irrigation water varying from a low of 30 mm in Kp_4 to a high of 118 mm in Kp_1 treatment. Seasonal cumulative ET of lettuce varied from a low of 50 mm to a high of 125 mm based on water stress level. Schulbach (1995) using a Bowen ratio energy balance system, estimated values of 100-190 mm for lettuce from planting to harvest at nearby sites in the central coast region of California under out-door conditions. Ciolkosz et al. (1998) determined the water use of lettuce as 150 g per plant in greenhouse condition. Hanson et al. (1997) applied an average of 200 mm irrigation water to lettuce via surface drip irrigation system.

Table 1. Applied irrigation water (I mm), Evapotranspiration (ET, mm), Yield (ton da^{-1}), IWUE (ton da^{-1} mm^{-1}), TWUE (ton da^{-1} mm^{-1}) of drip irrigated lettuce under greenhouse conditions

Treatments	I	ET	Yield	IWUE	TWUE
Kp_1	118	125	7.8 a*	0.066	0.062
Kp_2	88	110	7.2 a	0.085	0.065
Kp_3	59	78	5.4 b	0.095	0.069
Kp_4	30	51	3.8 c	0.117	0.074

*Note.**: Differences among the means with the same letter are insignificant based on Duncan's test ($p<0.05$)

The yield, IWUE and TWUE values of drip-irrigated lettuce treatments were also summarized in Table 1 for two growing seasons. The highest yield was obtained as 7.8 ton da^{-1} in Kp_1 treatment. However, there was no significant difference in yield between Kp_1 and Kp_2. These suggest that lettuce under greenhouse conditions can be grown without significant yield loss with a seasonal water application of average 110 mm. The lowest yield was in Kp_4 treatment as 3.8 ton da^{-1}. Table 1 shows that as the amount of irrigation water applied decreases, lettuce yield also diminishes.

The heights IWUE and TWUE, 0.117 ton da^{-1} mm^{-1} and 0.074 ton da^{-1} mm^{-1}, respectively, were obtained from Kp_4 treatment. Table 1 indicates that IWUE and TWUE increase with decreased

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amount of irrigation water applied. Although yield was similar in Kp_1 and Kp_2 treatment, IWUE and TWUE were significantly increased in Kp_2 treatment compared to Kp_1 treatment. Based on Table 1, it can be said that Kp_2 treatment can be suggested for lettuce crop in Harran plain under unheated greenhouse conditions. The values of IWUE and TWUE for lettuce obtained in this experiment were a little bit lower to those for lettuce in field studies (Gallardo et al., 1996; Sale, 1966). These changes may be explained because of different environmental conditions and agricultural management strategies followed in the studies carried out. According to Gallardo et al. (1996), the major constraint on efficient water use in lettuce is its shallow root system.

Figures 1 and 2 show that there was a good relationship among yield, applied irrigation water and water use of lettuce. The relationship between applied irrigation water and yield was defined as y = 0.047 I + 2.5822 (R^2 = 0.96). On the other hand, relationship between water use and yield was as y = 0.0547 ET + 1.0708 (R^2 = 0.98).

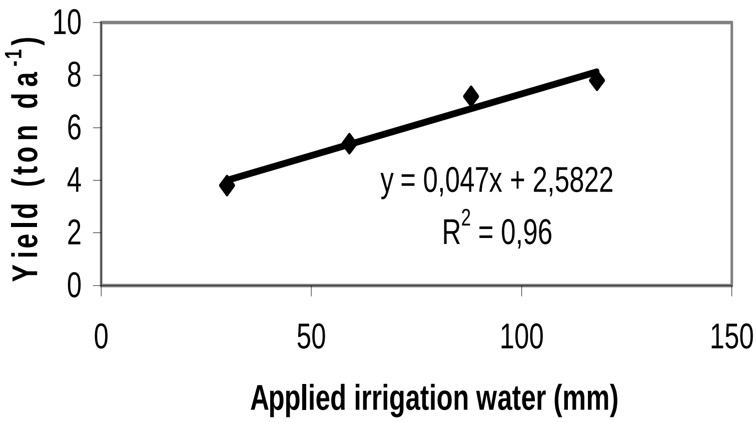

Figure 1. The relationship between yield and applied irrigation water for drip irrigated lettuce under greenhouse

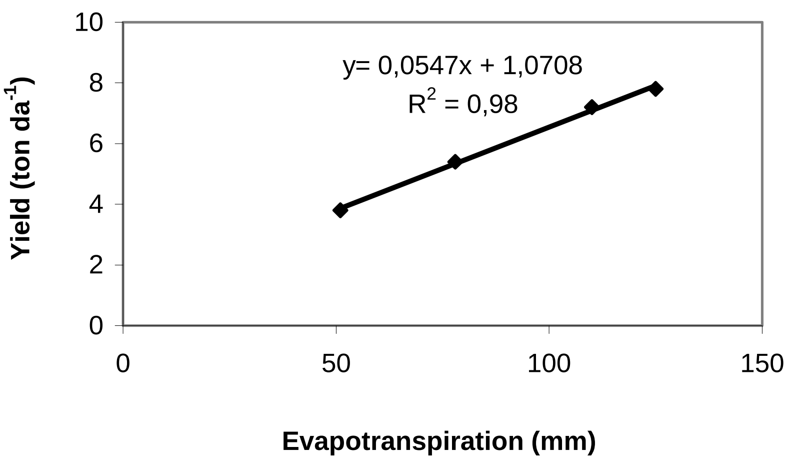

Figure 2. The relationship between yield and water use for drip irrigated lettuce under greenhouse

To obtain an evaluation of the sensivity of lettuce to soil water deficit, yield response factor ky (Doorenbos and Pruitt, 1992) was calculated as the regression of relative yield decrease (1-Ya/Ym) on relative evapotranspiration deficit (1-ETa/ETm), where Ya and ETa are the actual yield and water use, respectively; and again Ym and ETm are the maximum yield and water use, respectively. The seasonal ky value of lettuce for the total growing period was 0.88 (Figure 3). It implies that one

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unit decrease in water use causes 0.88 unit yield loss. The average tension readings showed that Kp_1 and Kp_2 plots were in the range of 10 and 18 kPa while Kp_3 and Kp_4 plots were in between 22-42 and 35-68 kPa, respectively. The results showed that irrigation should be initiated when the tension reading was not more than 20 kPa.

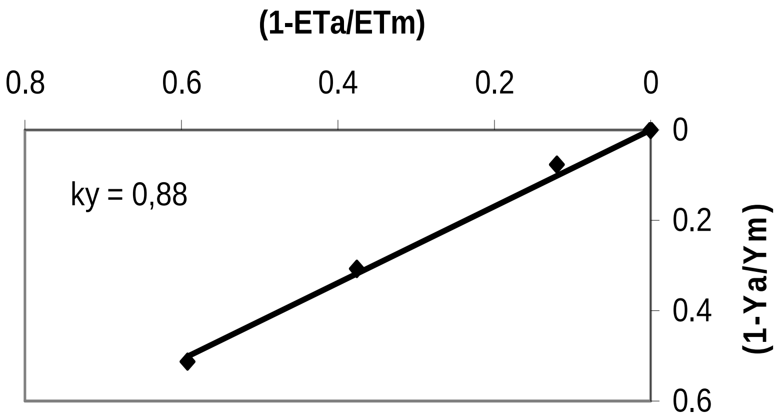

Figure 3. Relative yield reduction vs. relative ET deficit for drip irrigated lettuce under greenhouse

Table 2 shows that plant vegetative growth significantly influenced by the irrigation treatments. The average canopy diameter, plant height and shoot dry matter were obtained from Kp_1 treatment as 25.8 cm, 36.2 cm and 26.3 g plant^{-1}, respectively. Plant vegetative growth parameters increased with increasing I and ET as with lettuce yield. The lowest growth parameters were obtained from the Kp_4 treatment. However, as in yield, there was no significant changes between Kp_1 and Kp_2 treatments in terms of vegetative growth parameters. Shoot dry matter decreased with decreasing water use and water applications (Table 1 & 2). The decreases in shoot dry matter in Kp_4 compared to Kp_1 was 34.6%. Our results were in agreement with findings of Sammis et al. (1988) and Yazgan et al. (2008) who concluded that limited irrigation resulted in reduced growth and yield in lettuce.

Changes of growth parameters (plant height, diameter, and shoot dry matter) during the growing season were also shown in Figure 4. Figure 4 shows that the highest increase in shoot dry matter was in the last four weeks of lettuce (January 30-February 28). There was a linear tendency between shoot dry matter and water use during the experimental period. Shoot dry matter and vegetative growth were very low rate during the first 30 days of growing season after transplanting to greenhouse and then increased linearly till harvest.

Table 2. Influence of different amounts of applied irrigation water on canopy diameter (cm), plant height (cm) and shoot dry matter (g/plant) of greenhouse grown lettuce

Treatments	Canopy diameter	Plant height	Shoot dry matter
Kp1	25.8 a*	36.2 a	26.3 a
Kp2	25.1 a	35.1 a	25.7 a
Kp3	21.9 b	27.4 b	21.3 b
Kp4	18.6 c	23.0 c	17.2 c

*Note.**: Differences among the means with the same letter are insignificant based on Duncan's test ($p<0.05$).

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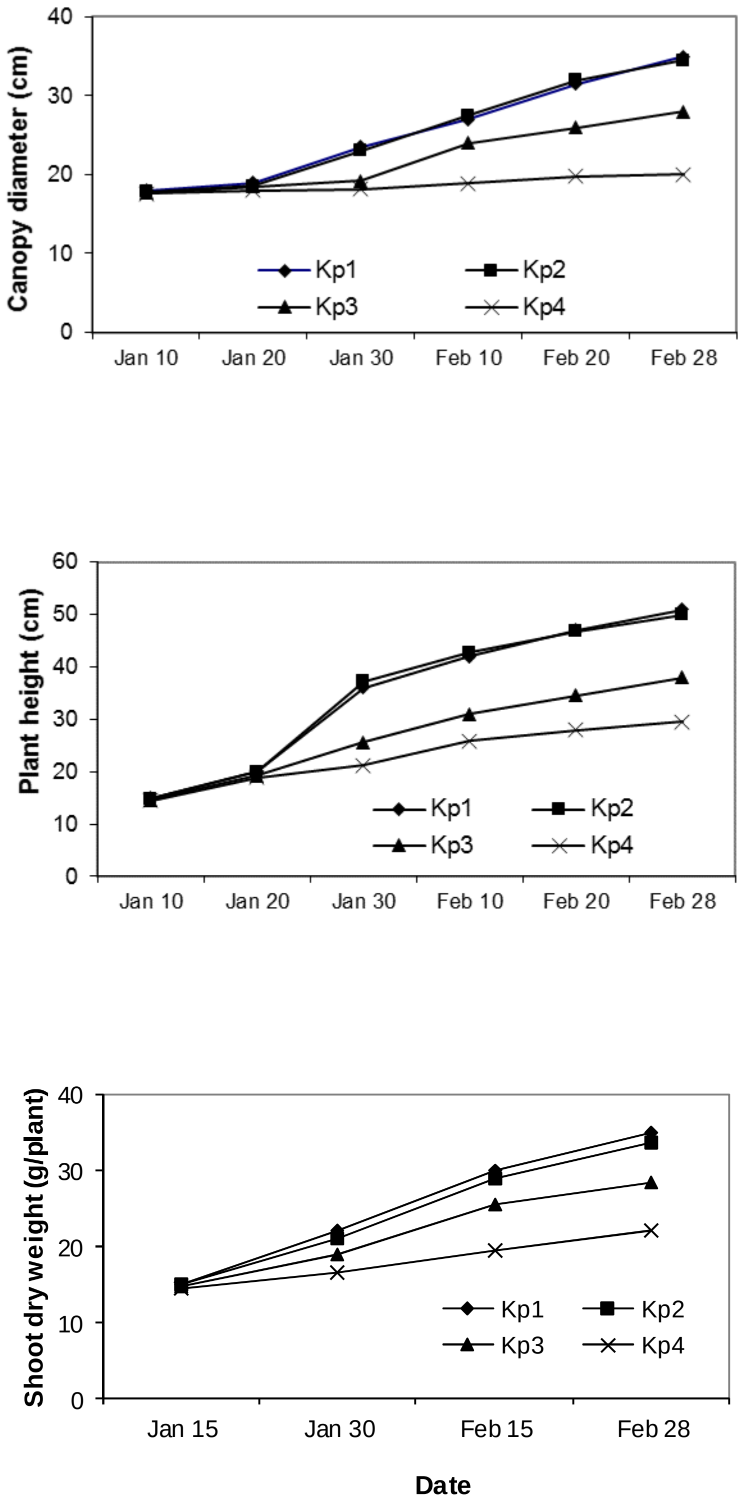

Figure 4. Influence of different amounts of applied irrigation water on canopy diameter, plant height and shoot dry weight

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The seasonal development of canopy diameter (ground cover) was similar to that for dry matter accumulation (Figure 4). Very little ground cover was observed during the first 30 days of the season and a rapid increase in ground cover occurred later. The percentage of ground cover at the end of the experiment reached to a maximum value of 52%. These results suggest that lettuce growers should be cautions in the irrigation of lettuce especially in the last 4 weeks before harvesting because the lettuce growth is most sensitive to water supply during these period. The relative difference in yield and shoot dry weight between the highest and lowest irrigation treatments indicated that yield of lettuce (fresh weight of lettuce) was a more sensitive parameter under mild water stress conditions. This observation are in agreement with the findings of Bar-Yosef and Sagiv (1982); Sutton and Merit (1993) and Wheeler et al., (1994).

4. CONCLUSIONS

The study demonstrated that a moderate deficit irrigation, which is replenishment up to 75% Class A Pan, can be successfully used to improve WUE in semi-arid climatic conditions under the unheated greenhouse. Yield response factor (ky) was found to be 0.88. The lettuce growers in the region should be aware of crop sensitivity to applied amount of irrigation in the last 4 weeks of the season. The study showed that irrigation should be initiated as the tension reading was not more than 20 kPa for clay-textured soils.

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