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Water use of walnut trees under different irrigation regimes

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Abstract

The experiment was conducted during the growing season 2014 and 2015 to evaluate the water use and vegetative growth parameters of walnut trees under different amount of irrigation water. The irrigation water was applied based on a ratio of Class A pan evaporation as 50, 75 and 100 % through drip irrigation. In the first year of the study, in all treatments, water was applied 8 times amounting between 58.30 and 116.59 mm irrigation water. In the second year, irrigation was applied 15 times and 95.26 and 190.47 mm of irrigation water was applied. Results revealed that the seasonal evapotranspiration in the treatments during the measurement period varied from 264.41 and 304.77 mm in 2014 and from 346.49 and 418.76 mm in 2015 depending on the irrigation treatment. The effects of different irrigation practices on the vegetative growth parameters of walnut trees were also studied. The study revealed that the amount of irrigation water applied to the walnut trees had no significant effect on vegetative growth parameters.

Key words: Walnut, evapotranspiration, vegetative growth parameters

Introduction

Walnut is one of the important nut crops and the annual consumption per capita in Turkey is 2-3 kg. In addition, Turkey's annual walnut production is around 180000 tons while the import amounts about 40000 tons. The Ministry of Forestry and Water Affairs has put emphasis on walnut in afforestation work in recent years to increase the walnut production of Turkey. Approximately 110 thousand ha of the special walnut afforestation plan has been completed within 983 projects in Turkey so far and 2 million walnut trees have been planted (Anonymous, 2012).

When new walnut areas were planted, the low yields obtained from the old areas were examined and it was stated that necessary researches should be conducted to overcome this. It has been proposed that these surveys concentrate on the standard walnut varieties as well as technical and cultural practices such as irrigation, fertilization, diseases and pests tolerance and making producers more aware along with improving the cultural practices (Unver and Sakar, 2011; Anonymous, 2012). In this approach, irrigation is important both in terms of plant productivity and conservation of natural resources. Şen (2011) stated that walnut trees are a common branching type of fruit species mostly in need of water because of large leaf surface area. It explained that although walnut trees are partially dependent on natural rainfall, irrigation practices are important in terms of initial plant development. Previous studies indicated that irrigation for walnut trees were important at different vegetative phases, and affected yield and quality parameters (Şen, 2011; Huabing *et al.*, 2014). Also, the drip irrigation method gave better results in walnut trees (Hu *et al.*, 2010; Li *et al.*, 2013).

The objectives of this research were to evaluate the effect of different irrigation regimes of drip irrigated walnut trees on water use and vegetative growth parameters under Tekirdag-Turkey conditions.

Materials and methods

The study was conducted in 2014 and 2015 growing seasons at the Işıklar Village, Tekirdag-Turkey (northwestern part of Turkey) at 40º51´N latitude, 27º 21´E longitudes, 166 m altitude. The research field is classified as semi-arid and the average annual temperature, relative humidity, wind speed, sunshine duration per day and total precipitation were 13.9 ºC, 78 %, 2.7 m s^{-1}, 6.5 h and 585.1 mm, respectively. Additionally, the climatic parameters for experimental periods are given in Table 1.

The soil type in the experimental area was loam for upper 60 cm depth and sandy-clay-loam for 60-90 cm depth. The bulk density varied from 1.65 g cm^{-3} to 1.77 g cm^{-3}. The available water holding capacity within 90 cm of the soil profile was 166.5 mm. There were no salinity and alkalinity problems. Some physical and chemical properties of the experimental field soil related to irrigation are shown in Table 2. Irrigation water quality was classified as C_1S_1 with 2.6 sodium absorption ratio (SAR) and 0.54 dS m^{-1} electrical conductivity (EC). The infiltration rate was measured as 11 mm h^{-1}.

Trees of the walnut cultivar "Chandler" were planted in 2012 at spacing of 8.0 x 8.0 m in the experimental area. The experiment was arranged in randomized block design with three replications. Each plot covered an area of 432 m^2 (24.0 m x 32.0 m) and contained 12 trees. The irrigation regime treatments consisted of three irrigation levels of cumulative pan evaporation (E_p) and water quantities applied were 0.50 (I_1), 0.75 (I_2) and 1.00 (I_3) times of pan evaporation measured at 7 days interval by Class A pan located in the experimental area.

The plots were irrigated by drip irrigation. Irrigation water was taken by a pump pool at the highest point of the experimental area. Polyethylene (PE) tube was used for 50 mm main and manifolds of the irrigation system. The diameters of the laterals were 16 mm and each row trees was irrigated by two lateral lines. Pressure compensating drippers were used to supply uniform water

Table 1. Some climatic data of the experimental area

Year	Period	T* (°C)	RH (%)	W (m s^{-1})	n (h)	E_p (mm day^{-1})	R (mm)
2014	June 29-July 5	22.9	69.2	3.2	9.1	6.9	-
	July 6-July 12	24.7	66.4	2.2	8.7	7.5	17.2
	July 13-July 19	24.4	75.4	2.4	7.7	7.7	35.6
	July 20-July 26	25.5	74.7	2.4	6.9	7.4	33.1
	July 27- August 2	26.0	80.5	2.6	8.9	7.1	-
	August 3- August 9	25.7	74.6	2.5	8.8	7.2	0.1
	August 10- August 16	26.4	77.2	1.9	10.7	5.5	-
	August 17-August 23	24.4	74.9	2.6	9.8	6.9	4.1
	August 24- August 30	24.9	70.4	3.6	8.8	6.8	-
2015	May 29-June 4	20.5	73.1	2.5	8.9	4.9	-
	June 5-June 11	20.4	79.0	3.3	8.1	5.3	22
	June 12-June 18	22.9	74.3	2.6	9.8	6.1	25.5
	June 19-June 25	21.0	71.9	2.8	9.7	4.4	0.3
	June 26-July 2	22.1	66.9	2.6	8.3	5.0	6.4
	July 3-July 9	23.7	72.5	2.8	8.6	5.1	0.5
	July 10-July 16	24.0	70.0	2.9	9.7	6.8	-
	July 17-July 23	25.1	67.6	3.9	10.6	7.1	-
	July 24- July 30	26.7	73.0	2.2	10.5	6.6	-
	July 31- August 6	26.9	72.2	3.4	8.9	6.2	-
	August 7- August.13	26.6	70.6	3.4	8.8	6.7	-
	August. 14- August 20	26.9	72.9	2.9	9.7	6.6	-
	August 21- August 27	24.6	63.6	3.9	7.4	6.9	-
	August 28-September 3	25.4	66.5	2.6	10.7	6.6	-
	September 4-September10	24.5	69.4	3.4	6.9	6.4	1.4
	September 11-September18	22.4	76.9	3.0	6.6	6.1	5.0

*T: average temperature; RH: average relative humidity; W: average wind speed at 2 m; n: sunshine duration; E_p: class-A pan evaporation; R: rainfall.

distribution. A total of 8 drippers were placed at intervals of 50 cm under each tree, 4 each in the lateral lines. Dripper discharge rate was 4 L h^{-1} above 10 m operating pressure. The amount of irrigation water was calculated by using the equation given below (Yıldırım, 2003):

$$I = E_p \times k_p \times P$$

Where, E_p is the cumulative pan evaporation for the 7 day irrigation interval (mm), k_p is the coefficient of pan evaporation and P is the percentage of wetted area. P value was accepted as 30 %. Soil water content in the plots was gravimetrically measured every week and before irrigation applications in the 30 cm depth increments to 0.90 m, by using the hand sampler. Evapotranspiration was estimated using the soil water balance equation (Allen *et al.*, 1998). Evapotranspiration measurements were conducted in the first year of the experiment between June 29 and August 31 and in the second year between May 29 and September 18. The equation can be written as:

$$ET = I + P \pm DSW - DP - RO$$

Where, ET is the evapotranpiration (mm), I is the irrigation water (mm), P is the precipitation (mm), DSW is the change in the soil water storage in the 90 cm soil profile (mm), DP is the deep percolation (mm) and RO is the amount of runoff (mm). Since, the amount of irrigation water was controlled, run off was assumed to be zero.

The height of canopy tree, shoot length, the cross-sectional area of trunk and canopy volume was evaluated for vegetative growth parameters. The cross-section area of trunk was determined by measuring trunk diameter at the height 15 cm above the graft union. The height of the canopy and shoot length were measured at the end of the vegetative growth period (Köksal *et al.*, 1996). Data on effects on the walnut vegetative growth parameters were analyzed using Analysis of variance (ANOVA). Differences were indicated significant at $P < 0.05$ and 0.01 (Gomez and Gomez, 1984).

Results and discussion

The amount of total irrigation water, rainfall and measured evapotranspiration for all treatments during the measurement period are presented in Table 3. Rainfall during the measurement period was 90.10 mm in 2014 and 61.10 mm in 2015. The total amount of open water surface evaporation measured in 2014 was 388.50 mm, while in 2015 it was 634.9 mm. In addition, the measured open water surface evaporation for 7 days in the first year of experiment ranged from 38.5 to 52.5 mm, while in the second year it ranged from 30.8 to 49.7 mm. In 2014, a total of 58.30 mm, 87.46 mm and 116.59 mm of irrigation water was applied eight times through I_1, I_2 and I_3 treatments, respectively. While 95.26 mm, 142.87 mm and 190.47 mm of irrigation water was applied fifteen times in 2015. The reason for the difference between the two years can be explained as the start of irrigation applications in 2014 was about one month later. During the measurement periods, the evapotranspiration recorded in the experimental area varied between 264.41 mm and 304.77 mm for the year

Table 2. Some soil properties of the experimental area

Soil depth (cm)	pH	EC (ds m^{-1})	Organic matter (%)	Sand (%)	Silt (%)	Clay (%)	Texture class	Field capacity (%)	Wilting point (%)	Bulk density (g cm^{-3})
0-30	8.1	0.5	0.68	41.7	33.3	25.0	L	20.71	48.35	1.70
30-60	8.0	0.6	0.65	31.3	41.6	27.1	L	18.22	46.88	1.65
60-90	8.1	0.4	0.49	56.2	18.8	25.0	SCL	19.88	39.67	1.77

Table 3. Applied irrigation water and measured seasonal evapotranspiration for treatments

Year	Treatments	Soil water depletion (mm)	Rainfall (mm)	Irrigation water use (mm)	Seasonal evapotranspiration (mm)
2014	I_1	116.01	90.10	58.30	264.41
	I_2	105.05		87.46	282.61
	I_3	98.08		116.59	304.77
2015	I_1	190.13	61.10	95.26	346.49
	I_2	181.21		142.87	385.18
	I_3	167.19		190.47	418.76

Table 4. The walnut vegetative growth parameters for treatments

Treatments	Height of the canopy tree (m)	Shoot length (cm)	Cross-sectional area of trunk (m^2)	Canopy volume (m^3)
I_1	3.82	123.3	146.51	26.08
I_2	4.02	133.3	148.50	38.81
I_3	3.80	106.7	113.30	28.26
LSD	ns*	ns	ns	ns

ns: not significant

2014 and between 346.49 mm and 418.76 mm for the year 2015. In general, low evapotranspiration recorded in the first year was due to more of rainy days in first year and consequently less irrigation water was applied. As the amount of applied irrigation water increased with the increasing evapotranspiration values. In I_3 trial, 100 % of the evaporation was recorded by the Class A pan. The evapotranspiration was measured as 304.77 mm in the first year and 418.76 mm in the second year. In the present experiment, in I_1 treatment, irrigation water was restricted to 50 %. The evapotranspiration was measured as 264.41 mm in the first year and 346.49 mm in the second year. In the same way, for the I_2 trial in which 75 % of the evaporation amount measured 25 % irrigation water was applied. The evapotranspiration was calculated to be 282.61 mm in the first year and 385.18 mm in the second year. When the monthly evapotranspiration values were examined (Fig. 1), July and August in the first year of experiment had the highest evapotranspiration. In the second year of the study, evapotranspiration values were higher in June, July, August and September and highest in July followed by June. When the average evapotranspiration calculated for the treatments was examined, values ranged between 2.55 and 6.63 mm day^{-1} in 2014 and between 1.52 and 4.43 mm day^{-1} in 2015 for the I_1 treatment. In I_2 treatment, daily evapotranspiration values ranged from 2.55 to 6.58 mm day^{-1} in the first year and 1.98 to 5.01 mm day^{-1} in the second year. On the other hand, for the I_3 treatment, the daily evapotranspiration values ranged from 2.55 to 6.55 mm day^{-1} in the first year and 2.23 to 5.43 mm day^{-1} in the second year. The maximum daily evapotranspiration values for all three treatments was found to be in July of each year. Although the results on studies on evapotranspiration of walnut trees in Turkey are not available, it can be said that the obtained results are corresponding to reports from elsewhere. Hu *et al.* (2010) observed in the study conducted in China that the average daily evapotranspiration for walnut trees was 2.9 mm day^{-1} for flowering period, 3.97 mm day^{-1} for fruit formation period, 5.55 mm day^{-1} for shell formation and 3.39 mm day^{-1} for ripening period with drip irrigation method. In another study, conducted in China, the total seasonal evapotranspiration of walnut trees was measured between 585.6 and 840.3 mm in under-tree sprinkler irrigation method conditions (Zhao *et al.*, 2010).

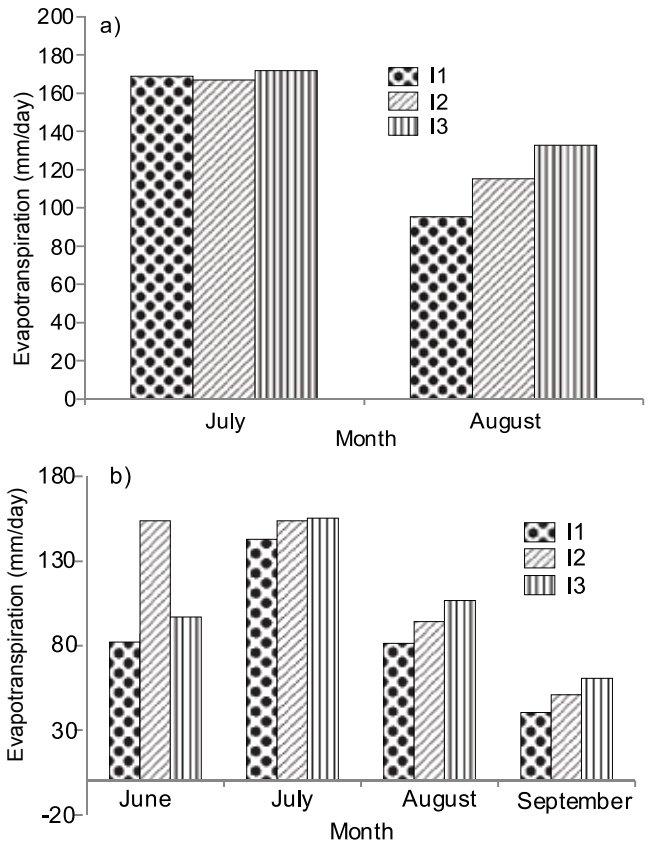

Fig. 1. Variations of monthly evapotranspiration for treatments a) 2014 and b) 2015 years

The height of canopy tree, shoot length, the cross-sectional area of trunk and canopy volume of walnut trees obtained from each treatment and results are presented in Table 4. These parameters were measured only in the second year (2015). The height of canopy tree obtained in the experimental areas varied between 3.40 m and 4.30 m in 2015. When we analyzed the results of variance analysis on the height of canopy tree, there were no statistically significant differences between treatments. In the second year of the experiment, the average shoot lengths ranged from 95 cm to 140 cm. Among the irrigation applications, the shoot length values were highest in the second year of the I_2 treatment but difference were statistically non significant. In the second year of the experiment, the average canopy volume between experiment subjects ranged from 24.54 m^3 to 48.74 m^3. Although the canopy volume values were obtained from the I_2 treatment in the research year, no significant differences were observed between the experimental subjects. This result shows that the application of different irrigation water does not make a significant difference on the canopy volume of walnut trees under the conditions of experimental conditions of Turkey. As can be seen from the Table 4, the mean trunk cross-sectional area between treatment experimental subjects during the second year of the experiment varied from 94.99 cm^2 to 176.63 cm^2. In the second year of the experiment, the highest trunk cross-sectional area values were obtained from the I_2 treatment with 148.50 cm^2. In addition, there were no statistically significant differences between the treatments. This result shows that the application of different irrigation water does not make a significant difference on the trunk cross-sectional area of walnut trees for said conditions.

The research on the determination of evapotranspiration of walnut trees in walnut producer area in 2014 and 2015 with three different irrigation water applications applied at 50, 75 and 100 % of the evaporation values indicate that the amount of irrigation water applied between treatments varied according to the evaporation values measured from class A pan. The highest irrigation water application was 100 % of the evaporation values based on class A pan. Growth parameters, height of canopy tree, shoot length, the cross-sectional area of trunk and canopy volume were not affected by the amount of irrigation water during initial 2 years of planting.

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