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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 9 (1): 39-44, 2006
ISSN 1828-8880

Evapotranspiration for Young Cherry Trees (*Prunus avium*) and Growth Responses to Irrigation

[1]Senih Yazgan, [2]Hakan Buyukcangaz, [2]Cigdem Demirtas and [2]Burak Nazmi Candogan
[1]Department of Agricultural Engineering, Faculty of Agriculture, University of Uludag, 16059, Bursa, Turkey
[2]Department of Agricultural Engineering, Faculty of Agricultural, 16059, Bursa, Turkey

Abstract: The goal of this research was to determine the water requirements and effects of different irrigation water application levels on vegetative growth of sweet cherry trees irrigated by a micro-sprinkler system. Evapotranspiration and vegetative growth parameters (tree height, trunk cross-sectional area, volume of trees and branch cross sectional area) of 3-4 years old sweet cherry trees (*Prunus avium*) were determined during the growing season of 2001 and 2002. The trees were subjected to four irrigation treatments based on adjusted coefficients of Class A pan evaporation (0.50 E_{pan}, 0.75 E_{pan}, 1.00 E_{pan} and 1.25 E_{pan}). Calculated evapotranspiration (ET_c) values for irrigation treatments were found as 365-839 mm and 418-840 mm for 2001 and 2002, respectively. The effect of irrigation treatments on total height of tree, trunk cross-sectional area 30 cm above the grafting point, volume of trees and branch cross sectional area were statistically significant at 1% level of probability. When considering the average values of 2001 and 2002, maximum tree height, trunk cross-sectional area, volume of trees and branch cross sectional area were observed at T_3 (1.00 E_{pan}) and T_4 (1.25 E_{pan}) treatments.

Key words: Evapotranspiration, vegetative growth parameters, sweet cherry trees, micro-sprinkler irrigation

INTRODUCTION

Cherry is relatively diverse and broadly distributed fruit around the world, being found in Asia, Europe and North America. Germany has the largest harvested area of cherry (8.79%) followed by Spain (7.99%), USA (7.73%), Italy (7.67%), Russia Federation (7.20%), Turkey (6.77%) and Iran (6.66%). In terms of cherry production, Turkey is the principal producer (13.4%) followed by Iran (11.6%) and USA (11.6%)[1]. Most Turkish production is concentrated in the Marmara and Aegean Region. Despite a considerable increase in cherry export, crop quality is far below market expectations. Crop quality and yield per tree are relatively low due to inappropriate agricultural practices such as rootstock selection, fertilizing, pruning and irrigation.

There are very few studies on response of cherry to irrigation in global scale. The water requirements of temperate-zone fruit trees have been reviewed[2,3] and although these reviews do not cover cherries specifically, on the broad scale cherry trees are elaborate to apples and peaches. The objective of well-regulated deficit irrigation is to save water by subjecting crops to periods of moisture stress with minimal effects on yields. The water stress results in less evapotranspiration by closure of the stomata, reduced assimilation of carbon and decreased biomass production[4]. Timing of water deficits has important effects on productivity of fruit trees, since it has observed that are not always detrimental[5-7]. In fact, Regulated Deficit Irrigation (RDI) strategies are based on the beneficial effects of applying a water deficit at a certain developmental stage[8,9]. Determining optimal depletion levels for fruit tree irrigation requires information on the effects of declining water supply on tree processes. Long-term experiments with fruit trees tend to suggest that soil water threshold levels for fruit trees should not be very different from those determined for herbaceous crops[10].

In a study on determination of irrigation water requirement and irrigation scheduling for cherry, reported that irrigating the replace 25 or 50% of pan evaporation has reduced vegetative vigor of young Lapins/Mazzard trees by at least 25% in relation to control trees irrigated by replacing 100% of evaporation rate[11].

Cherry species grafted on Mazzard rootstock yield after 7 years after plantation time. Applied amount of irrigation and its affects on vegetative growth and evapotranspiration are not exactly known during in this period. The goal of this research was to determine the water requirements and effects of different irrigation water application levels on vegetative growth of sweet cherry trees irrigated by a micro-sprinkler system.

Corresponding Author: Dr. Senih Yazgan, Department of Agricultural Engineering, Faculty of Agriculture, University of Uludag, 16059, Bursa, Turkey Tel: +90 224 4428970 Fax: +90 224 4428775

MATERIALS AND METHODS

This study was carried out during the growing season of 2001 and 2002, on the experimental field, located in Bayramic-Canakkale (western part of Turkey), latitude 39° 48' N, longitude 26° 37' E and at altitude 70 m above sea level.

The local climate is temperate, summers are hot and dry and winters are mild and rainy. Annual mean rainfall, temperature and relative humidity are 624.3 mm, 14.0°C and 69%, respectively[12]. Rainfall amounts are extremely low in the summer period. Meteorological data of trial years (in 2001-2002) was measured on a daily basis at the Metos (Pessl Instruments GmbH) meteorological station nearby the experimental area. Soil texture characterization was carried out from 12 profiles. Samples were taken with an auger at 0.30 m intervals and with maximum depth to 0.90 m. The granulometric composition was determined according to Liu and Evet[13]. No vertical variability in the texture could be observed. The samples were analyzed for soil texture, gravel content, field capacity, wilting point, bulk density, total salt content, pH and productivity level of the soil samples were found according to methods given by Hasen *et al.*[14]. Soils in research area have clayey loam texture.

Plant material studied was sweet cherry trees (*Prunus avium,* variety Z-900) on 3-4 years old Mazzard rootstocks. Mazzard rootstock produces a vigorous tree with very good anchorage and best compatible with sweet cherries. Z-900 grafted on Mazzard rootstock is large, firm, juicy, sweet variety with bordeaux color and is adaptable to grow in different altitudes and different climates.

The trees were planted in 1998, spaced 6×6 m apart. Each plot contained three plant rows and 39 trees, each block consists of 156 trees and total number of trees is 468 on the trial plot. In order to prevent the water in any one plot from affecting its neighboring plots, the two rows on the outer edges of each plot were left untouched and only the one middle row was monitored. On the tree rows, five trees with almost same height representing the plots have been selected for phenological observations.

The experimental plots were fertilized with mineral nitrogen (1.5 kg/tree $(NH_4)_2SO_4$), potassium (1.2 kg/tree K_2SO_4), MAP (1.6 kg da^{-1}) and magnesium (7 kg da^{-1}) in two experimental years. A routine pesticide program was maintained. The alleyway was kept under grass with herbicide stripe (3 m broad) along the tree rows.

The layout of the experiment was a Completely Randomized Block Design with three replications for each of water treatments tested. However, replications have been distributed to the random blocks in such a way that following same range in three blocks not to disturb the existing irrigation system. Micro-sprinkler irrigation was selected as the irrigation method. The laterals with the micro-sprinklers are laid along the rows of the trees, one line at each row; with one micro-sprinkler per tree. Sprinkler are operated under 1.4 bar pressure head and discharge of each is 35.8 L h^{-1} and sprinklers wetted diameter is 4.2 m. Water application efficiency (E_a) was taken as 85%[15,16]. To determine the applied irrigation water along a lateral, water measurement devices were used for each lateral.

The trees were subjected to four micro-sprinkler irrigation treatments (T_1, T_2, T_3 and T_4). T_1 and T_2 were programmed using two reduction percentages of the US Weather Bureau Class A pan evaporation. The water applied in treatment T_2 was considered sufficient to satisfy fully needs of the crop (100% of ET_c) and to allow good rooting and tree growth.

The Total amount of Irrigation Water (TIW) applied in treatment T_2 was calculated from[17]:

$$TIW = \frac{K_p.K_c.K_t}{E_a.E_u} E_{pan}$$

Where, K_p is the pan coefficient 0.70[18]; K_c the crop coefficient 0.85[17]; K_t the shade coefficient 0.97[19]; taking into account that the estimated mean shade surface provided by the tree canopies was 85% of the total surface of the orchard, E_a water application efficiency 0.85[15]; E_u the coefficient of uniformity of emitters (0.9)[16].

T_3 which is applied water amount in farm was selected as the control. In this treatment, full of evaporated amount from Class A pan (100% of E_{pan}) was applied to the trees. The difference at 25% level between T_2 and T_3 was considered as deficit amount and T_1 was defined according to this difference. To determine the impact of excessive water application on cherry trees, another treatment (T_4) with the same amount of difference was selected and applied to the trees. Thus, irrigation treatments were as follows:

$$TIW (T_1) = 0.50\ E_{pan}$$
$$TIW (T_2) = 0.75\ E_{pan}$$
$$TIW (T_3) = 1.00\ E_{pan}$$
$$TIW (T_4) = 1.25\ E_{pan}$$

The amount of irrigation water to be applied during a particular week was calculated from the weekly evaporation values measured in the Class A pan during the preceding week. Irrigation water was supplied weekly.

Measurements of soil water content were initiated immediately after the completion of the flowering period with the ratio of 70% and ended with first frost appearance. The soil water content was measured every

7 days from 25 June 2001 to 29 October 2001 and from 27 May 2002 to 29 September 2002 (i.e., during the irrigation season) on 2 trees root zone. The young cherry trees irrigated with micro-sprinklers shows that the bulk of the root system is located at 40-50 cm soil depth[11]. Since the trees are young, efficient root depth was taken as 0.90 m. The soil water content was determined by gravimetrical method and soil samples were taken at 0.30 m intervals and with a maximum depth of 0.90 m. For each treatment, samples were taken from the points which are 0.50, 1.0, 2.0 and 3.0 m far from stem under tree crown. The three-dimensional aspect of water flow in the soil-plant-atmosphere system means that it is essential to determine the areas and volumes of soil in which water moves or is stored[20]. It is customary to relate the water balance to the plantation spacing[21], down to a depth slightly below that reached by the roots.

The water balance in the soil is estimated by means of the mass conservation equation by[22];

$$Et_c = I + P \pm \Delta S - D - R$$

Where, ET_c is the evapotranspiration (mm), I is the applied irrigation water amount (mm), P is the precipitation (mm) and ΔS is soil water content variation in crop root depth (mm/90 cm), D is drainage below the root zone and R is the runoff. Since the clayey loam soil characteristics are fully dominant in the field and lower sprinkling velocity of sprinkler (I_{sp} = 5.81 mm h^{-1}) than soil infiltration (I_s = 8.00 mm h^{-1}), runoff and drainage (deep percolation) were assumed to be negligible.

In order to determine the effects of different water application levels on vegetative growth of sweet cherry trees, the following measurements were taken (in between before bud development and fall of leaves); total height of tree, trunk cross-sectional area 30 cm above the grafting point and branch cross sectional area on 5 trees. In this study, a rod has been used to measure total height of the trees. Trunk cross-sectional area and the branch cross sectional area were measured in both east-west and north-south directions and were calculated as the average of measured values.

Volume of Tree (VT) was determined following the equation given by Westwood[23]. For a tree that is taller than wide (prolote spheroid);

$$VT = \frac{4}{3}\pi . b^2 . a$$

Where, VT the volume of tree in m^3, a is ½ the major axis in m, b is ½ the minor axis in m.

The data obtained from the experiments were analysed with analysis of variance (ANOVA) and Duncan's Multiple Range Tests using MINITAB (University of Texas at Austin)[24] and MSTAT-C (Michigan State University) statistical analysis software package, respectively

RESULTS AND DISCUSSION

Irrigation was initiated firstly after the completion of flowering with the ratio of 70%. Cherry trees were irrigated from 26 June 2001 to 23 October 2001 at the first year and from 28 May 2002 to 24 September 2003 at the second trial year. Irrigation periods for both years were differentiated more likely due to flowering time based on climatologic conditions.

Applied amounts of seasonal irrigation water were 346.0, 518.8, 691.6 and 864.7 mm in the first year and 313.3, 470.0, 626.6 and 783.3 mm in the second year for T_1, T_2, T_3 and T_4, respectively (Table 1). Despite the age and vegetative growth of trees at the second year were more than those of first year, the amount of irrigation water applied to the trees was lower with the ratio of 10% at the second year than the first year. The main reason for that the evaporation amounts based on climatological conditions were relatively low in the second trial year. The differences on the amounts of irrigation water may be attributed to the rainfall occurred in the irrigation season (33.3 mm for 2001 and 66.0 mm for 2002).

The average water applied in T_2 was found as 518.8 and 470.0 mm for 2001 and 2002, respectively. In a parallel study for apricot trees in the same climate conditions, Abrisqueta *et al.*[20] reported that average of irrigation water amounts for three years is 550.5 mm when crop water needs were fully met and total amount of irrigation water in each treatment was taken as 76 % of pan evaporation. Maximum amount of irrigation water was 61.2 mm for T_3 (1.0 E_{pan}) treatment at 23 August for the first trial year. In the second trial year, applied water as a maximum in T_3 treatment was 50.4 mm at 25 June.

The soil water content was firstly measured on 25 June in 2001 and 27 May for 2002 to determine the crop water requirements. Daily measurements of the evaporation from the Class A pan were started at 26 June for first experimental year and 28 May for second year. Total evaporation from Class A pan were 691.6 mm and 626.6 mm for 2001 and 2002, respectively. According to those values, applied irrigation amounts were realized as 346, 518.8, 691.6, 864.7 mm and 313.3, 470, 626.6, 783.3 mm and the seasonal evapotranspiration were found as 365, 495, 649 and 839 mm and 418, 547, 691 and 840 mm for T_1, T_2, T_3 and T_4 treatments at the first and second year, respectively (Table 1). Monthly ET_c has reached to the peak in August, July and September in 2001 and in July, June and August in 2002, respectively.

Table 1: Monthly and seasonal evapotranspiration (ET_c, mm) and amount of water applied

	3-years old sweet cherry tree (2001)					Seasonal	
Treatments	June[a]	July	August	September	October[b]	Et_c (mm)	Applied water (mm)
T_1	21	81	128	79	56	365	346.0
T_2	26	131	156	103	79	495	518.8
T_3	38	151	217	136	107	649	691.6
T_4	25	198	264	184	168	839	864.7
	4-years old sweet cherry tree (2002)						
T_1	12	115	120	98	73	418	313.3
T_2	21	166	152	119	89	547	470.0
T_3	19	194	225	158	95	691	626.6
T_4	13	230	280	198	119	840	783.3

[a]June 2001: ET_c values in between 25-30 June, [b]October 2001: ET_c values in between 01-29 October, [c]May 2002: ET_c values in between 27-31 May, [d]September 2002: ET_c values in between 01-29 September

Table 2: Effects of different irrigation treatments on vegetative growth parameters

	Plant height (m)		Trunk cross sec. area (cm^2)		Volume of trees (m^3)		Branch cross sec. area (m^2)	
Treatments	2001	2002	2001	2002	2001	2002	2001	2002
T_1	2.620^{b}	3.270^{b}	22.36^{c}	35.99^{c}	1.800^{b}	6.140^{c}	1.320^{b}	3.190^{c}
T_2	2.870^{b}	3.480^{ab}	25.26^{bc}	42.15^{b}	2.130^{b}	7.080^{b}	1.340^{b}	3.590^{b}
T_3	3.240^{a}	3.610^{a}	27.23^{ab}	49.36^{a}	2.870^{a}	7.470^{ab}	1.650^{a}	3.670^{ab}
T_4	3.180^{a}	3.670^{a}	28.82^{a}	44.60^{a}	2.480^{a}	8.110^{a}	1.680^{a}	3.940^{a}
Replication (R)	**	ns	ns	ns	**	**	ns	**
Treatments (T)	**	**	**	**	**	**	**	**
RxT	*	ns	ns	ns	ns	**	*	**
Error	ns	ns	ns	ns	ns	ns	ns	ns

Column have letter (s) are significantly different by $Duncan_{0.01}$, ns: non-significant, ** $p<0.01$ * $p<0.05$

Evapotranspiration and applied irrigation water amount at treatment in which crop needs are fully met was found as 833 mm in between 16 May and 15 October in a study for almond trees[25]. These values are nearly one and half fold of applied values for T_2 in this study. This difference may be attributed to different type and age of fruit trees (almond trees with 14 years old) and climatological conditions.

Vegetative growth significantly increased as the irrigation water applied in different stone fruit trees[10,27-31]. In this study, a linear relationship was found between irrigation water applied and vegetative growth in both years in close agreement with findings of those researches. This positive linear response suggested that common vegetative growth parameters response would be positive to irrigation water amount higher than in this experiment under similar conditions.

The effect of irrigation treatments on total height of tree, trunk cross-sectional area 30 cm above the grafting point, volume of trees and branch cross sectional area were statistically significant at 1% level of probability (Table 2).

In the first experimental year, T_3 and T_4 and T_1 and T_2 were placed in the same statistical groups in terms of impacts of treatments on tree height. Despite the impacts of irrigation treatments on tree heights were anticipated to be evident in the second trial year, T_2 was placed in the same statistical group with T_3 and T_4 However, the relationship between irrigation level and total height of trees was found lower (R^2 = 0.84) at the first year than those of second trial year (R^2 = 0.94).

In a parallel study which aimed to determine the effect of different irrigation treatments on the vegetative development of three different almond cultivars grafted onto `Pestaneta' rootstock, the tree height for Cartagenera cultivar did not show significant differences between irrigation treatments in any year of the experiment, while difference between different treatments were statistically significant for Ramillete and Atocha cultivars in terms of tree height[26].

The highest (28.82 cm^2) and the lowest (22.36 cm^2) trunk cross sectional, area were obtained in T_4 and T_1 in the first year, respectively. Trunk cross sectional area results in T_2 and T_3 were placed in the same group. In the second trial year, T_3 gave the highest trunk cross sectional area (49.36 cm^2), T_4 and T_2 followed this result. The relationship between irrigation treatment level and trunk cross sectional area was found higher (R^2 = 0.98) at the first year, compared with the second year (R^2=0.94). In the study of Franco *et al.*[26], similar relationship was also found for trunk cross sectional area.

When considering the irrigation impact on volume of trees, T_3 and T_4 and T_1 and T_2 were placed in the same statistical group at the first year. Since impacts of irrigation treatments has become evident, the highest and the lowest volume of trees were obtained at T_4 (8.110 m^3) and T_1 (6.140 m^3) treatments at the second trial year, respectively. The relationship between irrigation treatments and volume of trees was found nearly the same and as high as $R^2 = 0.97$ in both years.

In terms of irrigation effects on branch cross sectional area, similar results were obtained with those of volume of trees. The relationship between irrigation treatment level and branch cross sectional area at the first year was found lower ($R^2 = 0.86$) than the relation for the second year ($R^2 = 0.94$).

According to results of two years study; vegetative growth was positively affected from the increase of applied irrigation water amount. The results indicate that the highest total height of tree, trunk cross-sectional area, volume of trees, branch cross sectional area were obtained from T_3 and T_4. In statistical manner, there was no significant difference between two treatments. On the other hand, the T_2 which was considered sufficient to satisfy fully needs of the crop was placed in the same statistical group of T_3 in terms of total height of tree and trunk cross sectional area. Since the number of flower bud was mostly related to volume of trees or branch cross sectional area, applied water amount in T_2 may be assumed as inadequate for vegetative growth. Vegetative growth parameters at T_1 were remained at the lowest level compared to other treatments. When considering irrigation treatments and vegetative growth parameters as a whole, the best developments were obtained at T_3 and T_4. When considering irrigation labour costs and water fees and T_3 and T_4 were placed in the same statistical group for all vegetative parameters, T_3 can be considered as appropriate preharvest irrigation level for sweet cherry tress. Since the improvement of fruit quality is the main purpose of cherry production, water application levels should be tested with yield and quality.

ACKNOWLEDGMENTS

The authors are grateful to The Research Fund of Uludag University of Turkey for financial support. We also special thanks to Alara Co., Bursa, Turkey for the supply of experimental area.

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