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THE EFFECTS OF DIFFERENT IRRIGATION LEVELS ON VEGETATIVE GROWTH OF YOUNG DWARF CHERRY TREES IN A SUB-HUMID CLIMATE

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Abstract

In this study, the effects of different irrigation treatments on evapotranspiration and vegetative growth parameters such as plant height, trunk cross-sectional area, volume of trees and branch cross-sectional area of 'Z-900'/Gisela-5 young dwarf cherry trees were investigated in a sub-humid climate during 2001-2002. Four irrigation treatments (T_1, T_2, T_3 and T_4) were applied based on different percentages of Class A Pan evaporation (50%, 75%, 100% and 125%). Seasonal crop evapotranspiration (ET_c) values at applied irrigation water levels varied from 327 to 656 mm and from 354 to 733 mm for 2001 and 2002, respectively. While the difference between water levels was 25%, the difference in evapotranspiration for water levels was found to be 21-30%. Maximum average values of vegetative growth parameters area were obtained in T_4 treatment in each experimental year. Although the amount of irrigation water for treatments increased, values of vegetative growth parameters didn't indicate a proportional change.

Introduction

Adequate water and nutrient supply are important factors affecting optimal plant growth and successful crop production (Ashraf *et al*., 2007). Accordingly, irrigation is one of the major agricultural activities and throughout the production season. Its importance increases as climate gets drier (Naor, 2006). The water requirements of temperate-zone fruit trees have been reviewed by Landsberg & Jones (1981) and Chalmers & Walker (1983). Although these studies don't cover cherry, in general, cherry trees are similar to apples and peaches which are stone fruits. Johnson *et al.,* (1992) studied the possibility of reducing the amount of irrigation water without affecting the tree performance in California. Similar studies with promising results have been reported on other fruit crops such as pear *(Pyrus communis* L.) (Brun *et al*., 1985), wine grapes (Matthews & Anderson, 1988) and apple *(Malus domestica* Borkh.) (Ebel & Proebsting, 1993).

Water deficit is one of the most important restricting factors in crop production in the world (Akram *et al*., 2007; Jabeen *et al*., 2008; Ashraf, 2010). Deficit irrigation is a strategy which could be applied to utilize water efficiently. As reported in English & Raja (1996), it is an optimizing strategy in which crops are deliberately allowed to sustain some degree of water deficit and yield reduction. The adoption of deficit irrigation implies appropriate knowledge of crop transpiration, crop responses to water deficits, yield reduction, its impact on water use efficiency and the economic impacts of yield reduction strategies (Pereira *et al*., 2002). Determining the optimal depletion levels for tree irrigation requires information on the effects of declining water supply on tree growth seasons. Long-term experiments suggest that soil water threshold levels for fruit trees shouldn't be much different from that of determined for herbaceous crops (Veimeyer, 1975).

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In a study for apricot trees in a sup-humid climate, Abrisqueta *et al.,* (2001) reported that average irrigation water for three years was 551 mm when the crop water needs were fully met and total amount of irrigation water in each treatment was taken as 76 % of pan evaporation. Dehghanisanij *et al*., (2007) reported that for mature cherry trees in a semi-arid climate, total amount of applied irrigation water was found as 876 mm under full irrigation treatment using a Class A Pan. Seasonal crop evapotranspiration was found as 1007 mm for mature cherry trees in a semi-arid climate under full irrigation treatment (Dehghanisanij *et al.*, 2007). Goldhamer & Viveros (1999) reported that evapotranspiration 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.

Dehghanisanij *et al.,* (2007) reported that there was a high correlation between the length of young branches and canopy volume on one hand and annual amount of irrigation water applied on the other in mature cherry trees. In another study, Elisea (2002) reported that irrigation to 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.

The goal of this study was (i) to evaluate the crop evapotranspiration and crop coefficients (k_c) of dwarf cherry trees (ii) to determine the effects of different irrigation levels on vegetative growth of dwarf cherry trees, irrigated by micro-sprinkler irrigation method in sub-humid climate.

Materials and Methods

Experimental site: This study was carried out during 2001 and 2002 in Canakkale (North-West Turkey), located on latitude 39^o 48' N, longitude 26^o 37' E, and 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^{o}C, and 69 %, respectively (Anon., 1992). Precipitation is considerably low during the summer period. Meteorological data for the experimental years was measured on a daily basis at the Metos (Pessl Instruments GmbH) Meteorological Station located by the experimental area. Monthly average meteorological data for 2001, 2002 and long-term averages were given in Table 1.

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 0.60 m. The granulometric composition was determined according to Liu & Evet (1984). No vertical variability in the texture was observed. The samples were analyzed for soil texture, field capacity, wilting point, bulk density, total salt content and pH. The productivity level of the soil samples were calculated using the methods given in Hansen *et al.,* (1980). Soils in research area have silty clay and clayey loam texture. The main soil properties were given in Table 2.

Experimental design and irrigation treatments: The study material was sweet cherry trees (*Prunus cerasus* x *Prunus canescens,* grafted variety Z-900) on 2-3 years old Gisela-5 dwarf rootstocks. Gisela-5 rootstock produces a dwarf tree with very weak anchorage that is best compatible with sweet cherries. Z-900 grafted on Gisela-5 rootstock is a large, firm, juicy, and sweet variety with maroon color and adaptable to grow in different altitudes and climates.

Table 1. Meteorological data for 2001, 2002 and long-term averages.

Years	Months	Average temperature (°C)	Average humidity (%)	Average wind speed (m s^{-1})	Precipitation (mm)
2001	May	17.6	70.4	0.6	52.2
	June	22.7	54.8	0.5	14.2
	July	26.8	55.1	0.6	0.6
	Aug.	26.2	61.2	0.8	17.2
	Sept.	24.0	54.2	0.3	12.7
	Oct.	17.3	67.9	0.6	3.0
2002	May	17.4	69.5	0.5	49.0
	June	23.3	61.0	0.1	2.4
	July	26.6	60.9	0.0	2.8
	Aug.	24.9	65.5	0.0	8.2
	Sept.	20.8	74.7	0.0	36.4
	Oct.	15.7	82.8	0.0	35.2
Long-term averages [1]	May	17.3	66.0	1.0	38.2
	June	21.9	57.0	1.1	24.3
	July	24.3	54.0	1.4	8.6
	Aug.	23.6	56.0	1.4	8.3
	Sept.	19.8	62.0	1.2	24.1
	Oct.	14.7	72.0	1.3	35.8

1970-2000 Canakkale State Meteorological Station Records

Table 2. Physical and chemical properties of soils.

Soil depth (cm)	0-30	30-60
Field capacity (%)	28.59	29.27
Wilting point (%)	19.97	20.80
Bulk density (g cm^{3-1})	1.62	1.58
Clay (%)	36.76	38.38
Silt (%)	16.27	21.05
Sand (%)	46.96	40.57
Texture class	SC	CL
pH	7.35	7.77
Total salt (%)	0.078	0.073
Lime (%)	0.59	2.83
Organic matter (%)	0.35	0.52
Phosphorus (kg da^{-1})	0.01	0.01
Potassium (kg da^{-1})	58.26	36.58

The trees were planted in 1999, spaced 5 x 2.5 m apart. Each plot contained three plant rows and 30 trees. In order to prevent the irrigation in a plot 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 layout of the experiment was a completely randomized blocks design with three replications for each of the water treatments tested. However, replications have been distributed to the random blocks in a way that three blocks don't disturb the existing irrigation system. Micro-sprinkler irrigation was selected as the irrigation method, but plants were irrigated by traditional methods only from planting to first experimental year. The laterals with the micro-sprinklers were laid along the rows of the trees, one line at each row, with one micro-sprinkler per tree. Sprinklers were operated under 1.5 bar pressure head and 25.2 l h^{-1} discharge. Wetted diameter and sprinkling velocity were 2.0 m and 8.00 mm h^{-1}, respectively.

Four irrigation treatments were applied (T_1, T_2, T_3 and T_4). T_1 and T_2 treatments were programmed using two reduction percentages of the US Weather Bureau Class A Pan evaporation. T_3 was used as the control treatment. In this treatment, all of evaporated amount from Class A pan (100% of E_{pan}) was applied to the trees. The 25% difference between T_2 and T_3 treatments was considered to be water deficit. To determine the impact of excessive water application, T_4 (125% of E_{pan}) was selected and applied to the trees. Thus, irrigation treatments were as follows: $T_1 = 0.50\ E_{pan}$, $T_2 = 0.75\ E_{pan}$, $T_3 = 1.00\ E_{pan}$ and $T_4 = 1.25\ E_{pan}$.

The amount of irrigation water to be applied during a particular week was calculated from the weekly evaporation values (E_{pan}) measured in the Class A Pan during the preceding week.

The experimental plots were fertilized with mineral nitrogen (1.5 kg $tree^{-1}$ $(NH_4)_2SO_4$), potassium (1.2 kg $tree^{-1}$ 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 an herbicide stripe along the tree rows.

Measurements: 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 to 29 October 2001 and from 27 May to 29 September 2002. Elisea (2002) reported that the young cherry trees irrigated with micro-sprinklers developed a bulk root system at 40-50 cm soil depth. Since the study trees were young and rootstocks were dwarf, the efficient root depth was taken as 0.60 m. The soil water content was determined using the gravimetric method. The soil samples were taken at 0.30 m intervals. For each treatment, samples were taken from the points which were 0.50, 1.0 and 1.5 m far from stem under tree crown. Abrisqueta *et al.* (2001) reported that it is essential to determine the areas and volumes of soil in which water moves or is stored. It is usual to relate the water balance to the plantation spacing (Sharples *et al.*, 1985), down to a depth slightly below that is reached by the roots.

The water balance in the soil was estimated by means of the mass conservation equation (James, 1988);

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

where ET_c is the crop evapotranspiration (mm), I is the amount of applied irrigation water (mm), P is the precipitation (mm) and ΔS is soil water content variation in crop root depth (mm for 60 cm soil depth), D is drainage below the root zone and R is the runoff. Runoff was assumed to be negligible.

Crop coefficient (k_c): In this study, evaporation values were measured weekly. Thus, reference crop evapotranspiration (ET_o) was calculated by FAO Penman-Monteith Method using Cropwat 4 Windows (Version 4.3) software package. Monthly average temperature, relative humidity, wind speed and precipitation values (Table 1) were used to estimate ET_o and the crop coefficient was calculated from (Allen *et al.*, 1998) as following:

$$k_c = \frac{ET_c}{ET_o}$$

where k_c is crop coefficient, ET_c is the crop evapotranspiration (mm), ET_o is the reference crop evapotranspiration (mm).

Vegetative growth: In order to determine the effects of different water application levels on vegetative growth, the following measurements were taken (before than 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 surveyor's 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 using the following equation given by Westwood (1993). VT for a prolote spheroid shaped tree is as follows,

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

where VT is the volume of tree in m^3, a is 1/2 the major axis in m, b is 1/2 the minor axis in m.

Statistical analyses: The data obtained from the experiments were subjected to analysis of variance (ANOVA) and LSD test (Least Significant Difference Test) according to Steel & Torrie (1980) using MINITAB (University of Texas at Austin) and MSTAT-C (Michigan State University) statistical analysis software package, respectively.

Results

Applied irrigation water and evapotranspiration: Irrigation was initiated after the completion of flowering with a ratio of 70 %. Trees were irrigated from 26 June to 23 October 2001 in the first year and from 28 May to 24 September 2002 in the second year. The amounts of applied water were 238, 356, 475 and 594 mm in the first year and 276, 414, 552 and 690 mm in the second year for T_1, T_2, T_3 and T_4 treatments, respectively. Maximum amount of weekly irrigation water for T_3 (1.00 E_{pan}) treatment was 48 mm in 23 August and 44 mm in 25 June for the first and second years (Table 3). The rainfall observed during the monitoring of soil moisture was 33.3 mm in first year, and 66.0 mm in second year.

Seasonal evapotranspiration values were found as 327, 427, 518 and 656 mm and 354, 481, 599 and 733 mm for T_1, T_2, T_3 and T_4 treatments in the first and second year, respectively. Highest monthly ET_c values for treatment T_3 were estimated as 184 and 189 in July of each year, respectively (Table 3).

Reference crop evapotranspiration and crop coefficient (k_c): Changes in the crop coefficients (k_c), daily crop evapotranspiration and calculated reference crop evapotranspiration values for T_3 treatment are given in Table 4 for both years. In the first year, reference crop evapotranspiration values were found as 5.5, 5.8, 5.3, 3.4, 2.1 mm day^{-1} from June to October, respectively. The same values for the second year in May-September period were calculated as 4.7, 5.4, 5.6, 4.8, 3.4 mm day^{-1}.

K_c values were found as 0.81 in June, 1.02 in July, 1.04 in August, 0.95 in September, 0.69 in October for 2001, 0.79 in May, 0.86 in June, 1.09 in July, 1.08 in August, and 0.92 in September for 2002.

Table 3. Applied irrigation water, rainfall, monthly and seasonal evapotranspiration (ET_c) for irrigation treatments in two years (mm).

Treatments	2- years old dwarf cherry tree, 2001						
	June[1]	July	Aug.	Sep.	Oct.[2]	Seasonal ET_c	Applied water
T_1	12	121	106	60	28	327	238
T_2	17	155	141	81	33	427	356
T_3	22	184	170	97	45	518	475
T_4	25	220	223	128	60	656	594
	3- years old dwarf cherry tree, 2002						
Treatments	**May[3]**	**June**	**Jul.**	**Aug.**	**Sep.[4]**	**Seasonal ET_c**	**Applied water**
T_1	8	79	110	101	56	354	276
T_2	13	116	155	126	71	481	414
T_3	15	139	189	162	94	599	552
T_4	18	180	220	195	120	733	690

[1] June 2001: ET_c values in between 25-30 June
[2] October 2001: ET_c values in between 01-29 October
[3] May 2002: ET_c values in between 27-31 May
[4] September 2002: ET_c values in between 01-29 September

Table 4. Crop coefficients (k_c) for treatments and months in 2001 and 2002.

2001		T_3	2002		T_3
June	ET_c[1]	4.42	May	ET_c	3.67
	ET_o[2]	5.46		ET_o	4.67
	k_c	0.81		k_c	0.79
July	ET_c	5.92	June	ET_c	4.63
	ET_o	5.80		ET_o	5.36
	k_c	1.02		k_c	0.86
August	ET_c	5.48	July	ET_c	6.09
	ET_o	5.26		ET_o	5.61
	k_c	1.04		k_c	1.09
September	ET_c	3.23	August	ET_c	5.24
	ET_o	3.41		ET_o	4.83
	k_c	0.95		k_c	1.08
October	ET_c	1.45	September	ET_c	3.12
	ET_o	2.09		ET_o	3.40
	k_c	0.69		k_c	0.92

[1] Daily average crop evapotranspiration, mm day^{-1}
[2] Reference crop evapotranspiration, mm day^{-1}

Water-vegetative growth relations: The differences between irrigation treatments were statistically significant ($p<0.01$) for plant height in the first year and trunk cross-sectional area 30 cm above the grafting point in 2001 and 2002. In addition, the effects of irrigation treatments on branch cross-sectional area in first year and volume of trees for both years were statistically significant ($p<0.05$). Effects of different irrigation treatments on plant height and branch cross-sectional area were not statistically significant in 2002 (Table 5).

Table 5. Effects of different irrigation treatments on vegetative growth parameters.

Treatments	Plant height (m)		Trunk cross sec. area (cm^2)	
	2001	2002	2001	2002
T_1	2.38a	2.64	13.55b	17.42bc
T_2	2.03b	2.51	11.17c	16.60c
T_3	2.27a	2.59	14.39ab	19.57b
T_4	2.46a	2.70	16.47a	23.52a
LSD (0.05)	0.19	ns	2.13	2.64
Replication (R)	ns	ns	ns	ns
Treatments (T)	**	ns	**	**
RxT	ns	ns	ns	ns
Treatments	**Volume of trees (m^3)**		**Branch cross sec. area (m^2)**	
	2001	**2002**	**2001**	**2002**
T_1	1.65a	2.50b	1.36a	1.80
T_2	0.89b	2.49b	0.85b	1.86
T_3	1.51ab	2.32b	1.32a	1.76
T_4	1.85a	3.34a	1.42a	2.32
LSD (0.05)	0.64	0.82	0.46	ns
Replication (R)	ns	ns	ns	ns
Treatments (T)	*	*	*	ns
RxT	ns	ns	ns	ns

The values with the same letter are statistically homogeneous in LSD test
ns: Non-significant
**Significant at the 1% probability ($p<0.01$)
*Significant at the 5% probability ($p<0.05$)

Maximum values in terms of plant height, trunk cross-sectional area, volume of trees and branch cross-sectional area were found in T_4 treatment. In each individual year, T_4 treatment produced the largest trunk cross-sectional area (16.47 and 23.52 cm^2). The smallest trunk cross-sectional area was obtained from T_2 irrigation treatment (11.17 and 16.60 cm^2) in both years. Irrigation treatment T_4 and T_1 produced the highest volume of trees (1.85 m and 1.65 m^3, respectively) in 2001. The highest volume of tree was obtained from T_4 (3.34 m^3) treatment, followed by T_1, T_2 and T_3 (2.50, 2.49 and 2.32 m^3) in 2002. Also, T_4, T_1 and T_3 treatments produced the tallest plants (2.46, 2.38 and 2.27 m, respectively) in first year. Irrigation treatments had no significant effect on plant height and their average values varied from 2.64-2.70 m in all treatments of second year. The largest branch cross-sectional area was obtained from T_4, T_1 and T_3 (1.42-1.32 m^2) while the smallest by T_2 treatment (0.85 m^2) in 2001. Irrigation treatments statistically had no effects on branch cross-sectional area and their average values varied from 1.80-2.32 m^2 in all treatments in second year (Table 5).

Discussion

Irrigation periods for both years were different due to the flowering time based on climatologic conditions. The amount of water applied to trees in second year was 15% higher than the first year. The main reason was the occurrence of both irrigation seasons in different time periods.

Applied irrigation water in T_3 (1.00 E_{pan}) were calculated as 475 and 552 mm in first and second year, respectively. These values were in agreement with the results reported by Abrisqueta *et al.,* (2001), but our findings were not in agreement with results of study conducted by Dehghanisanij *et al.,* (2007) in a semi arid region. This disagreement could be based on different climate conditions in both regions.

Seasonal ET_c values of T_3 treatment were found as 518 and 599 mm in first and second year, respectively. These findings were lower than evapotranspiration values reported by Dehghanisanij *et al.,* (2007) and Goldhamer & Viveros (1999). These differences may be attributed to different type and age of fruit trees (almond trees with 14 years old), and climatic conditions.

Maximum mid-season crop coefficients (based on Penman ET_o) range from 0.90-0.95 for apricot, peach, pear and plum and 0.95 - 1.00 for apple and cherry under clean cultivated conditions (Fereres & Goldhamer, 1990). Allen *et al.,* (1998) reported that mid-season crop coefficients (for use with the FAO Penman-Monteith ET_o) range from 0.90-1.15 for apples, cherries, pears for non-stressed, well-managed crops in sub-humid climates. In this study, crop coefficients for T_3 (Table 5) were found close to the reported values by Allen *et al.,* (1998).

Many researchers reported that vegetative growth significantly increased as the irrigation water applied in different stone fruit trees (Micke *et al.*, 1972; Veimeyer, 1975; Fereres & Goldhamer, 1990; Dehghanisanij *et al.*, 2007). In this study, the relation between vegetative growth and applied irrigation water for T_4 in both years was in agreement with findings of those researches. But, according to LSD test results, in spite of increasing the applied water, average values of vegetative growth parameters didn't indicate a systematical increase (Table 5). Effects of irrigation treatments on plant height and branch cross-sectional area were statistically significant in first year. These results are contrary to those of second year. These disagreements may be attributed to non-complete adaptation process of plant, soil conditions in the root zone. On the other hand, a homogeneous growth for the plant for different irrigation levels was observed in second year. The reason may be due to adaptation ability of young plants to the root zone and plant characteristics such as shallow root development and dwarf rootstock. In addition, these plants with shallow root development may fulfill water requirements at low irrigation levels in non-bearing period.

Irrigation treatment T_3 may be recommended as optimum irrigation treatment for irrigation of 'Z-900'/Gisela-5 young cherry trees in the sup-humid conditions. On the other hand, these irrigation treatments must be re-considered in different conditions and T_3 irrigation level should be verified with yield parameters.

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