Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. VI, 2017
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

WATER-YIELD RELATIONSHIP OF ZIVZIK POMEGRANATE UNDER DEFICIT IRRIGATION CONDITIONS

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Abstract

The Southeastern Anatolia Region meets approximately 10% of Turkey's pomegranate production. Siirt region pomegranate cultivation has a great importance within the region. The production of Zivzik pomegranate, a local variety of the region, was significantly increased in the last 10 years with projects and public contributions. Although there are many problems encountered in pomegranate cultivation, irregularity in irrigation programs that causes cracking in them has a significant value. In this study it was aimed to achieve the irrigation program of Zivzik pomegranate which is especially cultivated in Siirt region. The experiment was carried out in the experimental design of split plots in randomised block design with three replications, the irrigation interval was placed in the main plots, and the irrigation levels were placed in the sub-plots. Each experimental treatment was composed of 4-year-old 15 trees planted at 3x3.5 m intervals, measurements and observations were obtained from 3 trees in the middle of the block. In this study, the inline drip irrigation system was used. In the study carried out, parameters such as yield, irrigation water, plant water consumption and yield response factor were examined, and an attempt to determine the irrigation program was made. The average yield values obtained from the experiment varied between 20.5 kg/subject and 53.7 kg/subject, and no significant difference was found between the treatments as a result of the statistical analysis performed. In the subjects examined, the plant water consumption values varied between 601.5 mm and 902.9 mm, and the amount of irrigation water was determined as 292.6 mm and 585.2 mm. The yield response (Ky) showing the sensitivity of pomegranate to water deficiency was calculated as 1.59.

Key words: *deficit irrigation, irrigation program, pomegranate, yield response factor.*

INTRODUCTION

The amounts of production and consumption of pomegranate, that can also grow in regions with warm and temperate climate although it is known to be a tropical and subtropical climate fruit, in the world and in our country are increasing even more with each passing day.

The Southeastern Anatolia Region has a share of 10.5% of Turkey's pomegranate production. Although pomegranate is grown in all provinces of the Southeastern Anatolia Region, it is mainly produced in Gaziantep, Şanlıurfa, Siirt and Adıyaman. Zivzik variety of pomegranate with a significant economic value is mostly produced in Pervari and Şirvan districts. The production of Zivzik pomegranate in Siirt significantly increased in the last 10 years in parallel with the significant increase in pomegranate production in Turkey. While 5981 tonnes of product were obtained from the pomegranate production area of 398.7 ha in 2002, these values increased to 8544 tonnes of product from the pomegranate production area of 569.6 ha in 2012 and showed a very rapid development (Anonymous, 2013).

There are significant problems that are encountered during the cultivation of pomegranate which is not very selective in terms of soil and climatic conditions, that cause damages to the fruits and that lead to the losses of product and quality. One of these problems is the cracking of fruit which is a physiological formation. In other words, fruit cracking is a very common physiological disease in pomegranate growing. It generally appears at the maturity stage, the amount of cracked fruit is also increasing in parallel with the progress of maturity and thus it can cause yield loss in half. It is possible to talk about a great number of factors that cause fruit cracking in pomegranate. However, the most important of these is the irregular and inadequate irrigation during the maturity stage of the fruit. Since pomegranate fruit consists of a large number of fruit seeds containing water, there is a high osmotic pressure at the time of water stress, and the grains get swollen because of receiving large amounts of water when it is irrigated immediately after it, and the internal pressure on the peel increases. Therefore, the fruit becomes susceptible to cracking. For that reason it is important that the irrigations are regular and programmed (Yılmaz and Özgüven, 2003).

Coşkun (2006), who states that the sufficient soil moisture should be provided during the maturation period of the fruit, points out that the presence of the sufficient soil moisture especially in summer and at the beginning of autumn will also decrease the rate of fruit cracking.

The region is usually under the influence of dry and hot air masses during summer. The daytime maximum temperature rises above 40^{o}C. In addition, dry and hot winds called "simum" increase evaporation and also cause dust storms in this period. During the winter season, the region falls under the influence of rainy fronts until April. According to the results of the measurement performed in the experimental area during the period 1960-2013, the annual average temperature value was determined to be 16.1ºC. The average temperature values falling to the lowest level in winter months tend to increase rapidly as of March and rise above 25ºC in May and June (Table 1). In the experimental area, it is seen that the average temperatures do not fall below 26ºC during the summer period (June, July, August) and below -2.7ºC during the winter period (December, January, February).

As a consequence of the continental climate observed in the study, the temperature difference between the seasons is quite high. While the average temperature of summer months in the central district of Siirt is 28.8˚C, the average temperature of winter months is 3.8˚C.

The temperature values of the experimental area are higher compared to many regions of Turkey. There are some factors that affect this situation. One of them is the latitude, and the other one is continentally. As it is known, the weather becomes warmer rapidly and excessively in places where the continental climate is observed. Therefore, summer is very hot, and winter is cold.

Table 1. Some Meteorological Data of Experimental Area for Long Term Period (1960-2013)

Months	January	February	March	April	May	June	July	August	Septembe r	Novembe r	October	December	Average
Ave. Max. Temp. ^{o}C	6.7	8.8	13.8	19.3	25.3	32.3	37.2	37.0	32.4	24.7	15.4	8.7	21.8
Ave. Min. Temp. ^{o}C	-0.5	0.6	4.5	9.3	13.7	19.2	23.5	23.2	18.9	12.9	6.3	1.6	11.1
Ave. Temp. ^{o}C	-2.7	4.2	8.6	13.9	19.4	26.0	30.5	30.0	25.1	18.1	10.2	4.7	16.1
Min. Temp.^{o}C	-11	-9.5	-7.2	-3.8	2.0	5.4	13.7	19.7	8.5	3.8	-4.3	-11.7	-3.5
Max. Temp. ^{o}C	15.2	17.3	28.5	32.9	36.1	40.2	44	43.4	39.5	33.6	18.6	14.3	33.6
Ave. Wind Speed (m/s)	0.3	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.3	0.3	0.3
Max. Wind Speed (m/s)	4.2	3.4	2.4	2.6	2.6	4.2	3.8	4.7	4.7	5.8	5.2	2.4	4.2

Many important studies on pomegranate irrigation have been carried out until today. However, no study on Siirt region and Zivzikpomegranate, in particular, has been encountered. Such a study has been required to solve the problems arising from irrigation of Zivzik pomegranate, which has an economic value and is cultivated in the region.

In this study, an attempt to achieve the most appropriate irrigation programs in Zivzik pomegranate variety, which is widely cultivated and has an economic value in Siirt region, was made, and the tree fruit yield and plant-water relationships were examined. It was aimed to minimise the yield losses due to irrigation, which is one of the most important problems of pomegranate cultivation and is shown as the cause of fruit cracking, by applying the appropriate irrigation programs.

MATERIALS AND METHODS

The study was carried out in a garden of 7200 m^2, which was established with Zivzik variety of pomegranate at 3.0 x 3.5 m intervals in 2011, at 37°57'17" Northern and 41°51'07" Eastern coordinates, in Kezer region of the central district of Siirt.

Soil Properties of the Experimental Area

Some physical and chemical properties of the soils of the experimental area are presented in Table 2. Accordingly, the soils of the experimental area have a clayey texture and are included in the class of soils with a low organic matter.

Table 2. Some physical and chemical properties of the soils of the experimental area

Soil depth (cm)	Texture	Sand %	Loam %	Clay %	FC %	PWP %	Bulk Density g/cm^3	pH	EC dS/m	Lime ($CaCO_3$) %	OM %
0-30	C	20.04	32	47.06	33.16	21.35	1.24	7.17	0.02	7.6	2.04
30-60	C	20.04	32	47.06	32.15	20.95	1.46	7.54	0.57	7.9	1.74
60-90	C	22.04	34	43.06	28.85	18.57	1.48	7.59	0.53	12.9	1.63
90-120	C	22.04	36	41.06	28.94	18.02	1.44	7.48	0.57	11.0	1.38

Irrigation water

The irrigation water used in the study was provided from the drilling well in the experimental area, and the results of the irrigation water analysis performed in the samples taken from there are presented in Table 3. Accordingly, the irrigation water with a quality that does not cause problems in terms of salinity was used in the experiment.

Table 3. Irrigation Water Analysis of the Well in the Experimental Area

			Cations (me/l)				Anions (me/l)					
Source	ECdS/m	pH	Ca	Na (%)	Mg	K	CO_3	HCO_3	Cl	SO_4	SAR	Class
Well	0.494	7.43	3.57	8.67	1.52	0.028	0	4.38	0.19	1.034	0.305	C_2S_1

Irrigation treatments

The amount of irrigation water was designed based on the fact that 50%, 75% and 100% (I) of the open water surface evaporation values (D), obtained from the Class A Pan evaporation vessel placed in the experimental area, were applied as irrigation water when they reached 80 mm and 120 mm.

The irrigation intervals were placed in the main plots (D), and the irrigation levels (I) were placed in the sub-plots, and Equation 1 was used in the calculation of irrigation water.

$$IR = I \times E_0 \times A \times C \qquad (1)$$

In the equation, IR, E_0, A and C represent the irrigation water, the cumulative amount of evaporation (CAP) in the irrigation interval, mm, the area (m^2) and the area covered by trees (%), respectively.

The "Water Budget" approach (Howell et al., 1986) was used (Equation 2) in calculating the water consumption (ETc) values for each experimental treatment.

$$ET_c = I + P + C_p - D_p \pm R_f \pm \Delta S \qquad (2)$$

In the equation, P value, C_p, D_p, R_f and ΔS represent the rainfall, the amount of water entering the root zone with the capillary rise, deeper percolation losses occurring after irrigation or rainfall, the surface flow quantities entering or leaving experimental parcels and the soil water exchange in the root zone, respectively.

All units in the equation are in mm size. The capillary rise was taken as zero as the study was carried out in the area where underground water is low.

The soil water exchange was determined by the gravimetric method in 30 cm layers of soil profile at depth of 90 cm in each subject. The drip irrigation system was used in irrigation.

Experimental Design
The treatments were located on the land by the experimental design of split plots in randomised block design with three replications. In the study, main plots constitute the irrigation interval, and the sub-plots constitute the irrigation level. Each experimental plot was arranged in blocks of 15 trees, and measurements and observations were obtained from 3 trees in the middle of the block to remove the side effects.

Determination of the yield response factor (K_y)
The relationships between fruit yield and water consumption were also investigated in this study, which was carried out for obtaining the irrigation program in pomegranate. For this purpose, the yield response factor explaining the relationship between Zivzik pomegranate's Proportional Evapotranspiration Deficit and Proportional Yield Decreases was predicted using the approaches presented by Köksal et al. (2001).

$$(1 - Y/Y_m) = K_y (1 - ET/ET_m) \quad (3)$$

In the equation, Y and Y_m, ET and ET_m, and K_y represent the real and maximum yields, the real and maximum water consumptions and the yield response factor, respectively.

RESULTS AND DISCUSSIONS

Plant Water Consumption
The soil water exchange in the root zone of the plant, the amounts of irrigation water applied and the amount of rainfall were taken into account while calculating the plant water consumption values of the treatments, and the calculated plant water consumption values are presented in Table 4.
In the calculation, the whole rainfall falling during the growth season was accepted as the effective rainfall due to the amount and frequency.
The water consumption values of the treatments varied between 601.5 mm and 902.9 mm.
The realisation of the ET value in higher amounts was due to the higher amount of rainfall during the vegetation period. According to the report of Sener (1993), Cooper et al. (1987) stated that plant water consumption was almost equal to rainfall in arid and semi-arid regions where there was little rainfall and the soil thickness was high under conditions where there was no irrigation.
Therefore, the difference and height in water consumption values in the study are due to the fluctuations in the rainfall regime.

Table 4. Water consumption values of the treatments

Treatments	Soil water (ΔS), mm	Rainfall (P), mm	Irrigation water (IR), mm	ETc, mm
D_1I_1	37.1	271.9	292.6	601.5
D_1I_2	42.1	271.9	438.9	752.8
D_1I_3	42.8	271.9	585.2	899.9
D_2I_1	47.3	271.9	292.6	611.8
D_2I_2	50.3	271.9	438.8	761.0
D_2I_3	45.9	271.9	585.2	902.9

Plant water consumption-yield relationship
In the comparison made between the plant water consumptions and yield values of the treatments, it was found out that there was a second-degree polynomial relationship between the irrigation water and yield (R=0.97, n=6) (Figure 1).
However, the difference between the treatment averages was not found to be statistically significant when the results of the analysis of variance were examined.
This is attributed to the small number of study treatments that were observed and measured and to the average of which was taken.

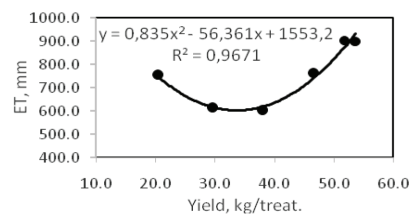

Figure 1. Plant water consumption-yield relationship in Zivzik pomegranate

Yield

The yield obtained from the experiment is presented in Table 5.

The yield values were treatment to the analysis of variance according to the experimental design of split plots in randomized blocks.

The applications that were found to be statistically significant according to the results of the variance analysis were compared with the LSD test. All applications that were not found to be significant were not grouped.

According to the results of the analysis of variance presented in Table 6, no statistically significant difference was found between the cumulative evaporation amounts (D) and irrigation levels (I), between cumulative evaporation amounts and irrigation levels interactions (D*I), and therefore, grouping was not performed. In this case, (I_3) treatment (D_2I_3) with the irrigation interval (D_2) in which the amount of cumulative evaporation reaches 120 mm, using 50% of the amount of evaporation can be suggested as the irrigation interval.

Table 5. Yield Values Obtained from the Treatments in the Application Year (kg/treatment)

Treatments	R_1	R_2	R_3	TOTAL	AVERAGE	Yield kg/tree	Yield kg/da.
D_1I_1	24.7	51.2	38.3	**114.2**	**38.1**	2.5	241.6
D_1I_2	17.8	37.8	6.0	**61.6**	**20.5**	1.4	130.3
D_1I_3	39.0	46.7	75.3	**161.0**	**53.7**	3.6	340.6
D_2I_1	24.0	24.5	40.5	**89.0**	**29.7**	2.0	188.3
D_2I_2	39.8	40.4	60.0	**140.2**	**46.7**	3.1	296.6
D_2I_3	47.6	65.0	42.5	**155.1**	**51.7**	3.4	328.1
Total	**192.9**	**265.6**	**262.6**	**707.7**			

Table 6. The analysis of variance table

Source of variation	Sum of squares	SD	Average of Squares	F value	F table value
Irrigation interval (D)	125.347	1	125.347	2.080	0.286
Block	564.021	2	282.011	4.680	0.176
$Error_{(1)}$	120.521	2	60.261		
Irrigation level (I)	1434.048	2	717.024	3.511	0.080
D*I	1015.954	2	507.977	2.487	0.145
$Error_{(2)}$	1633.831	8	204.229		

Yield-Irrigation Water Relationship

The existence and the level of the relationship between the yield values obtained from the treatments in the year of study and irrigation water were also investigated. For this purpose, the covariance between the yield values of the treatments and the irrigation water was examined, and the chart of the relationship obtained is presented in Figure 2. As it is seen in the figure, it is possible to talk about the existence of a nonlinear relationship between the yield and irrigation water (R=0.75, n=6).

However, a small number of the relationship level and the measured value (n) indicate that this relationship is not statistically significant.

This can be associated with the fact that the data are only for one year. Repetition of the study in successive years and increasing the numbers of parameters measured will contribute to the fact that the relationship will be found to be more significant.

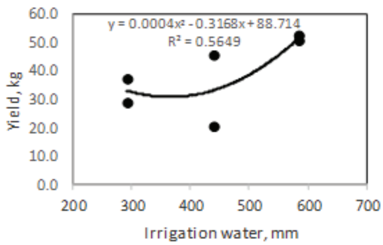

Figure 2. Yield-Irrigation water relationship

Determination of the Yield Response Factor

The relationship between the Proportional Evapotranspiration Deficit and Proportional Yield Reduction in Zivzik pomegranate was also examined. For this purpose, the relationship between the yields and water consumption values of the treatments was firstly obtained; then, the yield response related to Zivzik pomegranate was predicted. As a result of these operations, the following equation was obtained.

$(1 - Y/Ym) = 1.5907 (1 - ET/ETm) - 0.0068$;
$R = 0.95$

Accordingly, it can be said that the yield response factor of Zivzik pomegranate during the growth period is Ky = 1.59 (Figure 3).

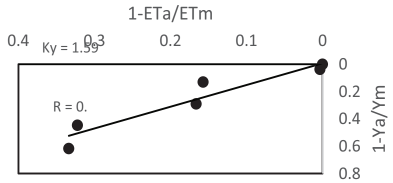

Figure 3. Yield response factor of Zivzik var. of pomegranate

According to the results obtained, it can be said that yield can be significantly affected by the lack of one unit of water under conditions where irrigation water is limited. Consequently, it can be said that Zivzik pomegranate is very sensitive to water and that there will be adecrease in yield in case of lack of water.

CONCLUSIONS

The study was carried out with the farmer garden established in 2011 with Zivzik variety. It was aimed to decrease the damage of fruit cracking, which is one of the most important problems in pomegranate and is stated to result from irregular irrigation and to achieve the irrigation program by applying different water levels under the limited irrigation conditions.
In the statistical analysis performed among the yield values obtained from the treatments, while the treatments were not found to be statistically significant, the lowest and highest yield values were obtained from 130.3 kg/da (D1I2) and 340.6 kg/da (D1I3), respectively. In the study carried out by Dinç et al. (2012) for obtaining the irrigation program, the best yield value, 1265 kg/da, was obtained from the treatment for which 6 days irrigation interval was applied. The noncompliance with the research findings can be associated with the variety of the experimental material and the regional conditions. In this case, (I3) treatment (D2I3) with the irrigation interval (D2) in which the amount of cumulative evaporation reaches 120 mm, using 50% of the amount of evaporation can be suggested as the irrigation interval. While the plant water consumptions in the experimental treatments were calculated to be between 601.5 mm (D1I1) and 902.9 mm (D2I3), the amounts of irrigation water applied to the treatments were between 292.6 mm (D1I1) and 585.2 mm (D1I3-D2I3). In the statistical analysis performed, the difference between the treatments was not found to be significant.

ACKNOWLEDGEMENT

This study was financially supported by Siirt University of Turkey, BAP unit under project number 2014-SİÜZİR-11.

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