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The Temporal Variation of Leaf Water Potential in Pistachio under Irrigated and Non-Irrigated Conditions

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Abstract: The present study was carried out in the experimental field of Pistachio Research Institute on pistachio trees which has uzun variety that was 30 years old. The aim of this research was to determine the Leaf Water Potential (LWP) of *Pistacia vera* L. under irrigated and non-irrigated conditions. In the study, the leaf water potential of pistachio was investigated under fully irrigated and non irrigated conditions. The leaf water potential values were measured one day before and after irrigation by using pressure chamber technique at the beginning, mid and end of irrigation season. According to the results obtained from measurements, the LWP value at the beginning of the irrigation season was -3.7 MPa at noon time due to relatively high temperature for both treatments. At the time of pre-dawn and sunset, this value increased and reached to -1.6 MPa due to relatively low temperature. In general, the LWP values during the mid of irrigation season, in the irrigated treatments, reached to almost -2.5 MPa in the non-irrigated treatment and the value was measured as -3.68 MPa.

Keywords: Pistachio, leaf water potential, pressure chamber technique

1. Introduction

Pistachio is the most important crop in the Southeastern Anatolia Region of Turkey due to production and export. The 88.87% of total pistachio production of Turkey has been grown in this area. Especially; Gaziantep, Şanlıurfa and Adıyaman provinces are the most important areas to grow pistachio (Ak et al., 1999). However, there are many problems faced by growers such as low yield and irregularity of the yield. The low yields can be attributed to factors such as inadequate pollination, periodicity, fertilization and prolonged periods of water stress due to low rainfall and lack of irrigation and primitive cultural practices of "no maintenance and no care" and harvesting methods.

The irregularity of the pistachio is the second important problem for growers. It is believed that the periodicity can be controlled genetically. On the other hand, there is a misconception of pistachio growers of Turkey that irrigation maybe harmfull to pistachio trees. These problems cause irregularity of the pistachio yield (Kanber et al., 1993). Pistachio has wide genotypic variability for water stress and salt tolerance. However, in order to have high yield available soil water content should only be allowed to drop to a minimum of 50% under irrigation practices, because irrigation influences the lenght of new branches, leaf area, nut size and weight (Sepaskhah and Maftoun, 1981). Goldhamer et al. (1985) showed that marketable yield following one year of severe water stress was only half that of unstressed trees. And also pistachio trees can use large amounts of water and that water stress can reduce shell splitting, harvestability and tree growth. Therefore irrigation should be considered amoung the most importand cultural practices to sustain high yields in pistachio orchards (Bilgen, 1982). Leaf size is also so important as indicator of tree water status. Leaf growth is more sensitive to water stress and appears to be influenced by only the current season's plant water status. Also LWP is one of the importand indicator of plant internal water status. For this reason, many researchers in the almonds (Goldhamer and Fereres, 2001) and pistachios (Goldhamer et al., 1985; De Palma and Novello, 1998; Monastra et al., 1998; Özmen, 2002; Testi et al., 2008) have conducted research projects.

The goal of this study is to determine the diurnal pattern of leaf water status before and after irrigation events.

2. Materials and Methods

2.1. Description of the study area

The study was carried out at the experimental field of the Pistachio Regional Research Institute near the city of Gaziantep between 1999 and 2002. The pistachio orchard is about 3.0 hectares and 26 kms far from Gaziantep. The orchard is placed at 37°28' East and 36°57' North longitude and latitude, respectively and 705 m altitude.

2.2. Soil characteristics

The soil in the experimental orchard is in the Gaziantep-Birecik sub-basin. The soils in this basin are the Karacaveran soil series, which is Calcaric Vertisol (Table 1).

Table 1. Some physical and chemical characteristics of the experimental soil

Soil depth	FC	PWP	Bulk density	pH	Salt content	Lime	Soil texture, %			Texture
Cm	%	%	g cm^{-3}		%	%	Clay	Sand	Silt	class
0-30	37.71	21.13	1.33	7.34	0.116	17.23	73.32	4.13	22.54	C
30-60	37.69	21.08	1.15	7.43	0.109	17.24	71.58	2.81	26.27	C
60-90	38.05	21.22	1.33	7.56	0.098	18.31	76.21	3.19	20.59	C
90-120	37.30	21.26	1.29	7.58	0.095	19.92	77.32	2.93	19.76	C
120-150	34.78	21.02	1.39	7.68	0.195	23.75	75.93	4.03	20.27	C

FC: Field capacity, PWP: Permanent wilting point, C: Clay

2.3. Climate

Gaziantep district has a typical transient climate zone between Mediterranean and desert. The hot and dry summer and rainy spring and autumn and snowy and cold winter prevail in that zone. Some meteorological observations of the treatment years were given in Table 2. As it has been seen in Table 2; the average rainfall of the area in the last 45 years is about 544 mm. During the experimental year, the total rainfall receiving in the growing period of pistachio are the almost same of the value occured in the long-term period. Despite that fact, the distrubution of rainfall was not homogeneous in the experimental year (Figure 1). About 90% of total rainfall was in the winter time. The average relative humidity for long-term period was about 61.5%. These values decreased to low levels in the summer months due to high temperature and increased to high levels in the winter mounths in comparison to other months.

Table 2. Some meteorological observations for the experimental area

Meteorological parameters	Years	January	February	March	April	May	June	July	August	September	October	November	December
Average temperature (°C)	2001	6.1	5.8	12.7	14.5	17.4	25.5	29.4	28.2				
	2002	5.6	8.9	11.1	13.2	18.7	25.0	29.6	28.4				
	LTP	3.5	4.3	8.0	13.4	18.3	24.0	27.8	27.3	23.1	16.1	9.2	5.0
Maximum temperature (°C)	2001	19.0	19.0	26.6	288	39.5	42.6	40.0	38.8				
	2002	8.7	13.7	16.7	18.1	25.4	32.0	37.0	35.3				
	LTP	19.0	20.4	26.6	32.8	37.8	39.6	44.0	41.8	37.7	34.2	26.9	21.2
Minimum temperature (°C)	2001	-2.0	-5.5	3.8	4.4	6.0	14.2	19.0	17.2				
	2002	2.6	2.4	5.4	7.5	11.9	17.9	22.2	21.5				
	LTP	-9.6	-11.7	-7.2	-2.5	3.2	7.1	11.8	12.7	6.4	0.3	-6.7	-7.6
Average RH (%)	2001	74.2	73.3	67.3	62.7	61.2	36.5	30.0	45.9				
	2002	68.3	61.8	63.9	67.0	54.4	40.9	35.4	44.3				
	LTP	75.2	71.8	67.5	64.0	57.8	48.7	45.7	48.7	50.3	61.2	71.8	75.1
Rainfall (mm)	2001	35.6	103.6	82.1	57.9	52.6	0.0	0.0	2.2	1.4	24.5		
	2002	93.9	50.4	92.5	45.0	33.8	1.4	0.1	25.5				
	LTP	89.7	83.3	76.4	50.2	29.8	7.5	1.6	0.6	6.0	40.9	78.2	99.0
Evaporation CAP, (mm)	2001					102.6[a]	290.4	346.1	274.8	133[b]			
	2002					153.9	260.9	301.7	260.0	153.0	70.4		

LTP: Long term period (1979-2000), RH: Relative humidity, CAP: Class A Pan, [a]: Cumulative evaporation measured between 19th and 31st of May 2001, [b]: Cumulative evaporation measured between 01th and 18st of September 2001

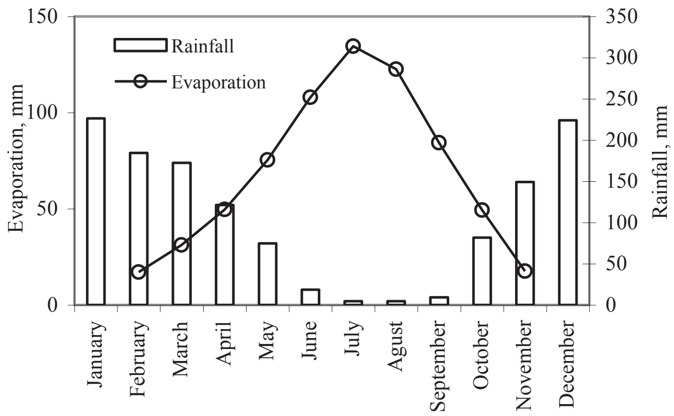

Figure 1. Relation between free water surface evaporation measured by class A pan and rainfall in Gaziantep province

2.4. Treatments description

Irrigation water was suplied from two deep wells located within the orchard with a depth of almost 252 m. Water has electrical conductivity (EC) within the range 0.0-0.25 dS m^{-1} and a sodium adsorption ratio (SAR) within the range 0-10 (C_1S_1 class, Table 3). The irrigation water was supplied by drip irrigation system, which contains a control unit (pump, injection equipments, filters, flow and pressure measuring devices etc.) and a pipe network. Two pipe lines were used for each tree row.

In this treatment Uzun varieaty was used grafted on *Pistacia vera* L. which has been grown in Gaziantep, Şanlıurfa, Kahramanmaraş and Adıyaman provinces widely. The pistachio trees were planted as 10x10 m. distance and were 30 years old. These trees were under non-irrigated conditions untill this research project and irrigation system was installed in 1999 firstly in this area. However, LWP measurement were taken in 2002 and it was the forth years of treatment and on yielding year.

Different irrigation and fertilization programme were used in this treatment. Two irrigation intervals (I_1= 7 days and I_2= 14 days) and 2 plant-pan coefficients (K_{cp1}= 0.60 and K_{cp2}= 0.90) and four nitrogen concentrations (Ng, No= 0 ppm, N_1= 10 pmm, N_2= 15 ppm and N_3= 20 ppm) were considered in this treatment. The treatment Ng shows the traditional fertilization programme in which 500 g N, 600 g P_2O_5 and 400 g K_2O per tree was applied at the projection of tree crown in February and these trees were not irrigated.

The experiment has been planned as split-split block design with 2 replications. Leaf water potential measurements were made by Pressure Chamber (Baştuğ and Kanber, 1989) in the well-irrigated (7 days intervals and N_3= 20 ppm nitrogen and K_{cp2}= 0.90) and non-irrigated treatments. The measurements were taken one day before and after irrigations from pre-down to sunset with 2 hours interval. Also early leaf water potential were measured from pre-dawn to maximum 8:00 am and at noon time one day before and after irrigation events. In addition the diurnal pattern of leaf water potential was also measured at the sunrise, noon time and sunset between consecutive irrigations. In each measurement, full exposed leaf samples were taken four direction of tree canopy which includes 2 or 3 main branches. Four leaves taken from inside the canopy as close to trunk as possible were cut from each tree for every measurement and put in a pressure chamber immediately after cutting. The latest leaf water potential measurement was taken at harvest time after irrigation event.

Table 3. Irrigation water analyzes for two wells

Source	EC (dS m^{-1})	pH	Cations (me L^{-1})				Anions (me L^{-1})				SAR	Class*
			Ca	Na	Mg	K	CO_3	HCO_3	Cl	SO_4		
Two wells	0.117	6.5	3.16	2.0	0.4	0.03	0.0	4.22	0.76	0.61	0.25	C_1S_1

*: Classification of irrigation water, C_1S_1: Low salinity-low sodium water

3. Results

Leaf water potential measurements were taken on irrigated and non-irrigated treatments. The results obtained from the measurements are shown in Figures 2-4 as MPa. In these Figures, LWP values showed some change on both of the treatments at the beginning of irrigation season. The LWP values for both treatments were decreased down to -3.7 MPa with increasing weather temperature at noon time. At times of pre-down and sunset, the LWP values were started to increase again with decreasing temperature and reached to -1.6 MPa (Figure 2).

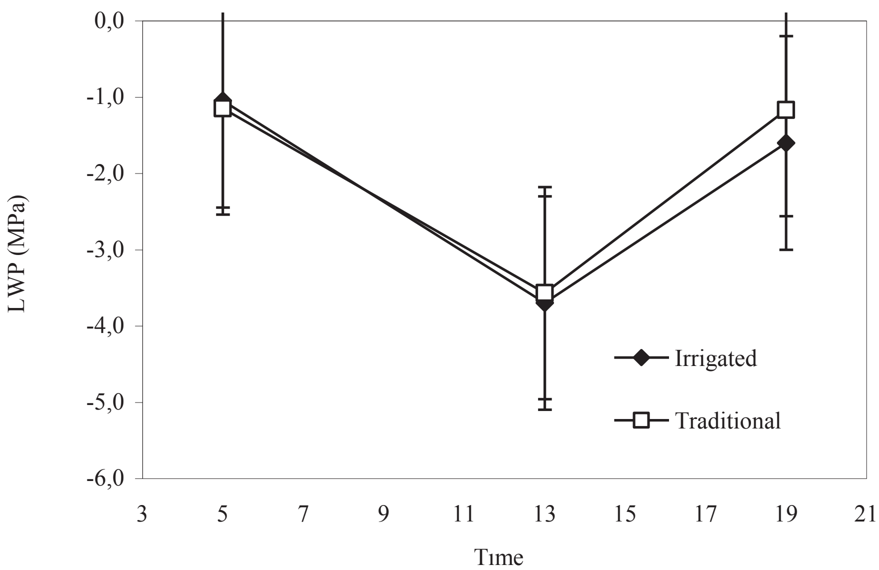

Figure 2. Typical diurnal trend of leaf water potential of Pistachio for the traditional and irrigated treatments in the beginning of irrigation season [The data are shown to hourly average (n=4), and vertical bars ± standart deviations]

In the mid of irrigation season (August, 12, 2002), the LWP measurements were taken before and after irrigation on both treatments with two hours interval, consecutively. Although LWP values were changing between 1.1-1.4 MPa in the morning, it decreased to -2.47 MPa with increasing weather temperature (9:00 am approximately) in the traditional treatment (Figure 3a). By the time, it continued to decrease and reached the value of -2.67 MPa at 11:00 am. After that time, it was stabilized with only mild fluctuations and started to increase again after a certain time. Curves of potentials were substituted between each other in the morning hours with decreasing of LWP and continioued up to sunset as parallel and in the irrigation treatment were reached to -2.03 MPa. Starting to increase of LWP on traditional in the morning hours, it can be attributed to prevent of evaporation losses. Similarly, the measurements of LWP were taken on the same treatments after irrigation event (Figure 3b).

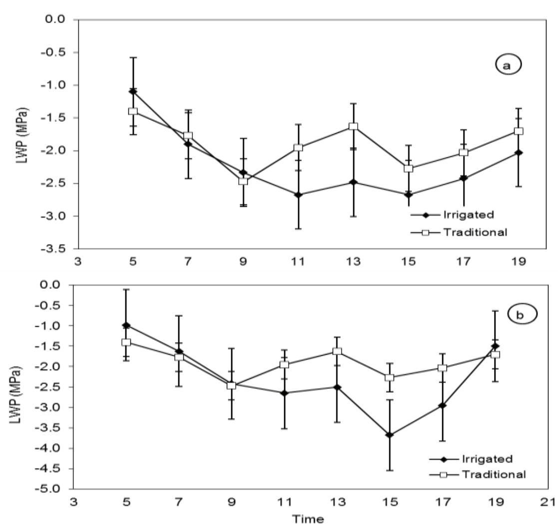

Figure 3. Typical diurnal trend of leaf water potential of Pistachio for the traditional and irrigated treatments in the irrigation season (a) before (upper plot) and (b) after (lower plot) irrigation [The data are shown to hourly average (n=4), and vertical bars ± standart deviations]

On the irrigated and non irrigated treatments the LWP values decreased as parallel to each other and the traditional treatment was reached to 2.47 MPa in the morning time (9:00 am). After this point, it was started to increase again.

On the other hand, as it has been on the before irrigation, it was gone on to decreasing in the traditional treatment due to high weather temperature and solar radiation and the lowest value was measured as -3.68 MPa. After this point, the LWP curve started to increase again. LWP value just has been reached to -1.5 MPa at the sunset time with weather temperature.

The LWP measurements were taken as diurnal pattern on the same treatments after finished irrigation events (October, 03, 2002) similarly within the irrigation season (Figure 4). When the LWP value in the irrigated treatment started to increase in early hours this time, in the traditional one, it was too late. The highest (-2.17 MPa and -1.40 MPa) and the lowest (-3.88 MPa and -2.67 MPa) LWP values were obtained, respectively in the both treatments after irrigation season.

In general, it was observed that the LWP values in irrigated treatment decreased when compared to the traditional one. Its also can be attributed that the roots and leaves are well responded to the irrigated conditions rather than the traditional.

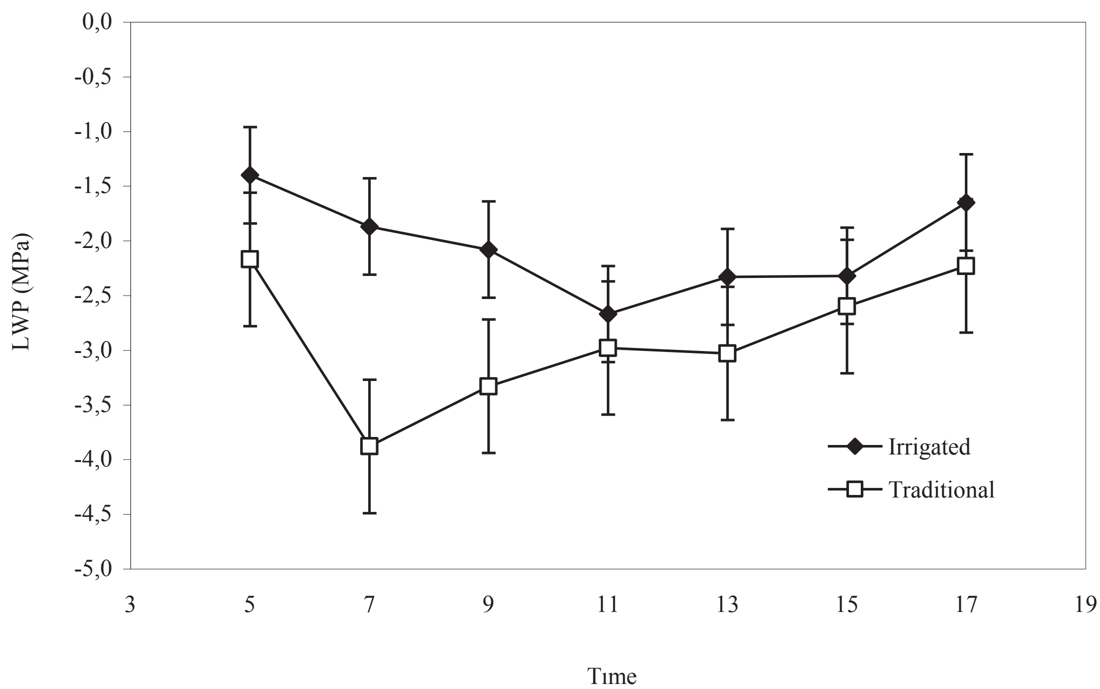

Figure 4. Typical diurnal trend of leaf water potential of Pistachio for the traditional and irrigated treatments in the end of irrigation season [The data are shown to hourly average (n=4), and vertical bars ± standart deviations]

4. Discussion

Goldhamer et al. (1986), has been measured the LWP on different irrigation levels and reported that the opposite of this situation. They were measured to LWP values -1.54 MPa in the irrigated treatment and -3.59 MPa in the traditional with 11 years aged Kerman variety and young and infertile pistachio trees budded on *Pistacia atlantica*. However, these values submitted here were measured on Uzun variety pistachio trees which is 30 years aged and in the optimum yielding time budded *Pistacia vera* L. It can be attributed that the results differences may spring from such as the climate and variety, tree crown growing, tree age, heavy nut load and the long-term water stress factors. Özmen (2002) has been reported on his study which was carried on the on-yielding year trees that the lowest LWP values were found -3.2 and -2.9 MPa in the irrigated and non irrigated treatments, respectively. Goldhamer et al. (1985) explained that the water losses occured by transpiration of plant leaves have been controlled by stomatas placed on leaves. De Palma and

Novello (1998), have showed that the stem water potential of irrigated and non-irrigated pistachio trees have same alterations. And also the researchers have reported that this situation has been springed from changing of climate measured in term as in the plant growing as. Monastra et al. (1998) have also reported that the pistachio leaves are more resistant to drought conditions due to stomatas placed on both sides of leaves and to be open or closed them are controlled by relative humudity on air. According to the results of this study, the stomatas on leaves are closed due to high temperature in the warm hours and LWP values have started to decrease as negatively. Oke (1987), reported that the transpiration rate of trees has been controlled by atmospheric conditions such as air temperature, relative humidity, solar radiation absorbed by tree crown and wind speed.

The leaf water potential of pistachio depended on irrigable conditions as changing of the climate as. The high air temperature occured in the measuring time has decreased to leaf water potential.

5. Conclusions

Leaf water potential measurements were taken on irrigated and non-irrigated treatments in the beginning, mid and after irrigation season of 2002 which was the last year of study.

In the beginning of irrigation season, the leaf water potential values have decreased on the noon time due to high air temperature and measured as -3.7 MPa. However, at the pre-dawn and sunset have started to increase as negatively due to low temperature and reached up to -1.6 MPa.

Generally, the LWP values have reached -2.5 MPa approximately on irrigated treatment in the mid of irrigation season. And then LWP has tendenced to prevent transpiration by stomatal closure. However, in the non-irrigated treatment, this value was found as -3.68 MPa. It was observed that the LWP value has shown continuosly decreasing as negatively on the irrigated treatment on rate to non-irrigated one. This situation can be attributed that the leaves of irrigated trees have been well adapted and to become conditioned to irrigable.

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