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GROWTH, YIELD AND PERIODICITY OF PISTACHIO UNDER DIFFERENT WATER AND NUTRITIONAL LEVELS: INVESTIGATION IN THE SOUTHEASTERN ANATOLIA PROJECT REGION (GAP)

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ABSTRACT

The effect of two irrigation intervals (I_1: 7 days and I_2: 14 days), four nitrogen doses (N_g, N_0, N_1, N_2 and N_3) and two crop coefficient (K_{pc}:0.60 and K_{pc}:0.90) on the pistachio nut fertigation was studied. The nitrogen levels were 0, 10, 15 and 20 ppm based on irrigation water concentration. In traditional treatment, each tree was given a 500/600/400 g of NPK fertilizer at the beginning of February. Other fertilizer doses were applied in the irrigation water through drip system. Irrigation water amount was calculated based on the pan-evapotranspiration. Wetted percentage in each irrigation was 30%. During the growing seasons extended from 29.05.2001 to 04.09.2001 at the first year and from 04.06.2002 to 10.09.2002 at the second year, experimental treatments were irrigated 15 or 8 times based on the irrigation intervals. Irrigation depth applied ranged from 324 to 906 mm in 2001 and 282 to 724 mm in 2002. In year of 2001, evapotranspiration varied from 518 to 345mm for plot area and 1152 to 572mm for the wetted area except in traditional treatments. Similarly, in 2002 the maximum evapotranspiration were varied from 1227mm for wetted area and 641mm for whole plot area, contrary, minimum values were 700mm (wetted area) and 482mm (plot area). Monthly values of K_c were calculated between 0.21 and 1.32 for 2001 and 0.19 and 1.56 for 2002 as minimum and maximum. All the experimental years have the highest K_c values in July when the highest evapotranspiration was measured.

The maximum nitrogen amount was applied to treatment with high nitrogen and high water ($I_{f1}N_3K_{pc2}$) with 18.1 g.m^{-2} (in 2001) and 15.9 g.m^{-2} (in 2002) among irrigated treatments. In 2001, all pistachio trees have received 4.9 and 3.2 g.m^{-2} phosphorous and potassium while in 2002 year these values decreased to 4.2 and 2.8 gram per square meter. The stomatal conductivity in the irrigated treatments ranged from 0.2 to 0.4 molm^{-2}s^{-1} while changing between 0.1 and 0.2 molm^{-2}s^{-1} in non-irrigated treatment. Net assimilation was recorded between 10 and 20 molm^{-2}s^{-1} in irrigated treatments. Corresponding figures for non irrigated treatment were between 5 and 15 molm^{-2}s^{-1}. The photosynthetic water use efficiency, however, was about 2 molmmol^{-1} in all treatments.

The maximum yields were taken from $I_{f2}N_3$ with average 11.7 kg per tree in 2001 and from $I_{f1}N_0$ with average 11.6 kg per tree in 2002.

Key Words: Fertigation, Drip Irrigation, Pistachio, Leaf Gas Exchange, Photosynthetic Water Use Efficiency, Yield

1. INTRODUCTION

Pistachio (*Pistacia vera L.*) is native of Anatolia, Syria, Iran, Afganistan, Baluchistan and some parts of Northern India (Kaºka, 1998a), as well as Lebanon, Palestine, Iraq, Southern Europe and the desert countries of Asia and Africa (Hendricks and Ferguson, 1995; Vargas, 1998). Pistachio is one of the most important crops in the Southeastern Anatolia Region of Turkey with respect to production and export. Although, it can be grown in many parts of Anatolia, it is most widely distributed in the Southeastern Provinces of Gaziantep, Sanliurfa, Adýyaman, Kahramanmaraþ, and Siirt. The first three cities of the Southeastern Region produce 87.88 % of the total pistachio in Turkey (Ak et al., 1999). However, there are many problems faced by growers, which mainly are: (i) Low Yield, and (ii) Irregularity of the yield.

The low yields can be attributed to factors such as periodicity, inadequate pollination, fertilization and prolonged periods of water stress due to low rainfall and lack of irrigation, and primitive traditional cultural practices such as planting, maintenance, fertilization, and harvesting (Kanber et al., 1986). Although pistachio production in Turkey goes back to very old times, today's production has not increased to the anticipated levels since pistachio are grown in dry and unproductive lands and thus yield per tree is very low. For instance, the average yield is only 1.4 kg per tree in Turkey, whereas U.S.A where modern production and management techniques such as irrigation and fertigation practices were used has 16-18 kg per tree even though they started to grow pistachio after 1960's (Tekin et al., 1990, Ak et al., 1999). Even though it is very drought resistant, its growth rate is very slow. Therefore, Turkey like other countries is not in favor of growing pistachio nut in fertile soils and they devote only marginal areas to pistachio (Kaºka, 2001).

The irregularity of the yield is the biggest problem in Turkey for pistachio production. There are 33 million pistachio trees, but according to the agricultural survey, total pistachio production in Turkey varies from 15000 metric tons in off-yielding years to 40000 metric tons in on-yielding years. This irregularity is caused by periodicity (Kanber et al., 1993). Using modern production and management techniques such as irrigation and fertigation practices can decrease the effect of periodicity. The effects of irrigation, fertigation and nutrient deficiencies as well as the soil on pistachio are not known sufficiently in Turkey (Ayfer, 1990). There are a few studies done in Turkey and other countries on irrigation and fertilization of pistachio. The first study of irrigation on pistachio in Turkey was started in 1973 at the Pistachio Research Institute in Gaziantep (Bilgen, 1973; Kuru, 1992). Those studies show that irrigation is one of the most important preventive cares, which need to be considered to reduce the yield decline due to periodicity. On the other hand, various researchers indicated that both lack of irrigation and inadequate accumulation of nitrogen in plant tissues cause the periodicity. Nowadays, irrigation and fertigation studies on pistachio trees are being done at the same institute since pistachio are grown in dry and unproductive lands and thus the yield per tree is very low (Kanber et al., 1993).

The main purposes of this study are (1) to investigate the water relations of pistachio and (2) to examine the most appropriate irrigation/fertigation practices of pistachio orchards (3) to introduce the new irrigation technology consisting of trickle irrigation system and fertigation techniques.

2. LITERATURE REWIEV

Pistachio is one of the most important crops in the Southeastern Anatolia Region (GAP) of Turkey (Kanber et al., 1992; Kaºka, 1998a), but also in U.S.A (Callifornia), Iran (Kerman Province), Italy, Greece, Syria and Australia (Sheibani, 1994; Vargas, 1998). Althoug it can be grown in many parts of Anatolia, it is most widely distributed in the Southeastern Provinces of Kahramanmaraþ, Gaziantep, Þanlýurfa, Adýyaman, Siirt (Ak, et al., 1999; Kaþka, 1998a, b) Pistachio nuts are grown in steppes areas of Southeastern Anatolia where the winters are cold and summers are long dry and hot annual precipitation is between 200 to 400 mm (Kaºka, 1998a).

There is severe irregularity in pistachio production and it is respected as the major problem faced by the growers in the region. The observed irregularity in yield is caused by periodicity inadequate pollination and fertilization prolonged periods of water stress due to low annual rainfall and no irrigation primitiveness of the existing harvesting methods and the traditional cultural practice of "no maintenance and no care" (Geurts 1982). It is believed that the periodicity is genetically controlled. However the factors mentioned above must significantly enhance the effects of periodicity and cause low yields. This has led us to believe that improved cultural practices especially irrigation may suppress the effect of periodicity and therefore high yields can be attained even in the off-yielding years. Bilgen (1979) indicated that irrigation is among the most important preventive cares, which need to be considered to reduce the yield decline due to periodicity. On the other hand a majority of the pistachio growers in Turkey have a misconception that irrigation may be harmful to pistachio trees.

Sykes (1975) indicates that extreme temperatures both low and high and low annual rainfalls are between the two major constraints, which limit the extension of the pistachio plantations in Turkey. It is reported that the leaf abscission of pistachio occurs as a result of prolonged periods of water stress during dry years when annual rainfall is below 400 mm. The leaf abscission occurring in a given year hinders the bud development in the subsequent year and thereby decreases the fruit yield. Sepaskhah and Maftoun (1981) demonstrated that pistachio has wide genotypic variability for water stress and salt tolerance. However in order to have high yields available soil water content should only be allowed to drop to a minimum of 50% under irrigation practices. Irrigation influences length of new branches leaf area and nut size and weight. The studies by Goldhamer, et al. (1985) showed that marketable yield following one year of severe water stress was only half that of unstressed trees. Therefore irrigation should be considered among the most important cultural practices to sustain high yields in the pistachio orchards (Bilgen, 1982).

The pistachio trees are very drought tolerant and their roots may go as deep as 2.5 m in search of moist soil layers. In the extreme dry years when available soil water content is below wilting point root activity may completely cease for a 4 to 5 week period in all soil layers. This implies that irrigation can significantly improve pistachio fruit yield (Spiegel-Roy et al. 1977). Firuzeh and Ludders (1978) have reported that pistachio is quite salt tolerant but very sensitive to frost and water stress when they are young (up to 5 to 7 years). It is questionable however whether irrigation practices can benefit very old (30 to 40 years) pistachio trees, which are well adapted to long periods of drought. Trees with extended rooting systems may effectively extract soil water from deeper moist soil layers.

There are a few studies done in Turkey and other countries on irrigation and fertilization of pistachio (Kanber, et al., 1990). In some desert and transitional areas pistachio trees are irrigated. Iran and some parts of Syria, Greece, and South part of Italy, Tarragona areas in Spain are the examples for such areas (Kaºka, 1998a).

Pistachio can be grown dry condition in Turkey whereas, pistachio is grown under irrigating condition in some countries such as California (U.S.A.) and Iran (Ak, et al., 1999). Pistachio trees have a reputation of being drought tolerant, for being able to survive and even produce modest crops with very little water. However, drought tolerance doesn't mean that pistachio trees require little water optimal performance (Goldhamer, 1995).

The drought tolerance of pistachio trees refers to its ability to survive under severe waters stress conditions (Goldhamer, 1995; Kanber, et al., 1990). Michailied, et al. (1996) observed that avoiding water stressing of pistachio trees during mid-May (at a time when the shell is growing fast) decreases significantly the incidence of early splits and thus reduces the incidence of aflatoxin contamination.

Kanber, et al. (1990) has investigated relationship of pistachio and irrigation with applying different type of flood irrigation system between 1974-85 years in Turkey (GAP). Irrigation practices in pistachio trees increases fruit yield especially in “on” year trees. The irrigation at 20 days interval was 57.1 kg/tree during the “on” year trees; whereas, the control treatment of no irrigation gave only 34.5 (kg / tree) during the same period. During the “off ” year tree, the non-irrigated treatment was 17.3 kg/tree, whereas the irrigated treatment gave higher fruit yield of 40.3 (kg/tree). Irrigation treatments had no effect on yield quality. Seasonal evapotranspiration during the normal yielding years was 803 mm. The highest monthly evapotranspiration was obtained in August with 205 mm and 6.6 mm per day.

Fertigation is the common term for injecting fertilizers through the irrigation system. Micro-irrigation systems are well suited to fertigation because of the frequency of operation and because water application can be easily controlled by the manager (Schwankl, 1995).

3. MATERIAL AND METHODS

3.1. Site Description

The study is carried out at the experimental garden of the Pistachio Regional Research Institute near the city of Gaziantep. The pistachio orchard is about 3.0 hectares and 26 km far from Gaziantep. The orchard is 37°28'east and 36°57'north longitude and latitude respectively and 705m altitude.

3.2. Variety

Trees of pistachio *(Pistachio Vera L.) Uzun* variety planted with 10x10 m spacing was used for this experiment. This variety is grown widely in all of the country especially in Gaziantep Adýyaman Þanlýurfa and Kahramanmaraþ provinces. Trees have semi upright habitus. Chilling requirement is less than other pistachio varieties such as Halebi and Kýrmýzý, which can be grown in the other places of the GAP region. Since this variety matures 15-20 days earlier than the others it is being recommended for high elevation places. The experimental orchard is 27 years old and was in the off-yielding year in 2001 and on-yielding year in 2002.

3.3. Soils

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. The Profiles represent widely distributed soils developed on calcretes. The main crops, which are pistachio and olive, grow under rain fed condition due to the suitable soil properties. However, irrigation has started at some parts under the Southeastern Anatolia Project (GAP).

The irrigation characteristics of the experimental soil are determined by disturbed and undisturbed soil samples taken from representative places in the orchard using the systematic sampled methods given by Peters and Calvin (1965). Soil samples with 30 cm layers in the 150 cm profile depth were used. For undisturbed soil samples, values of field capacity, bulk density, were analyzed. Soil texture, percentage of $CaCO_3$, clay, silt and sand contents, pH, and permanent wilting point were analyzed using the disturbed soil samples. All analysis was done by methods given by USSLS (1954) and Tüzüner (1990) and the results were in Table 1.

Table 1. Some Physical and Chemical Characteristics of the experimental soil

Soil Depth cm	Soil Type	F.C gr/gr	PWP gr/gr	Bulk density	pH	Salt Content %	Lime %	Clay %	Sand %	Silt %
0-30	C	37.71	21.13	1.33	7.34	0.116	17.23	73.32	4.13	22.54
30-60	C	37.69	21.08	1.15	7.43	0.109	17.24	71.58	2.81	26.27
60-90	C	38.05	21.22	1.33	7.56	0.098	18.31	76.21	3.19	20.59
90-120	C	37.30	21.26	1.29	7.58	0.095	19.92	77.32	2.93	19.76
120-150	C	34.78	21.02	1.39	7.68	0.195	23.75	75.93	4.03	20.27

3.4. Climate

Climatic characteristics of Gaziantep district show the typical transient zone between Mediterranean and desert climates. The hot and dry summer and rainy spring and autumn and snowy and cold winter prevail in that zone. The average rainfall of the zone in the last 45 years is about 531mm. During the experimental years, the total rainfall received in the growing period of pistachio are the almost same of the value occurred in the long-term period.

3.5. Irrigation System

Irrigation water is supplied from two deep wells with almost 220m depth located within the orchard. Water has EC within the range 0.25-0.75 dS m^{-1} and a SAR within the range 0-10 (C_2S_1 class).

The irrigation water is applied by the drip irrigation system, which contains a control unit (pump injection equipments, filters flow and pressure measuring devices etc.) and pipe network. As it is known that trickle irrigation system has high irrigation efficiency therefore it can be considered as a new irrigation technology and a potential tool under water scarce conditions that can arise in places where traditional irrigation methods are used.

3.6. Treatments Description

Different irrigation and fertilization programs were used. Different irrigation intervals (I_{f1}=7; I_{f2}=14 days) pan coefficients (Kpc_1=0.60; Kpc_2=0.90) and nitrogen concentrations (Ng; N_0=0 ppm; N_1=10 ppm; N_2=15 ppm; N_3=20 ppm) were considered in the experiment (Figure 1).

The treatment, Ng, shows the traditional fertilization program 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. However, these trees are not irrigated. The phosphorus and potassium fertilizers were injected at same concentrations of 15 and 10 ppm respectively to all treatments at the two weeks intervals except for the traditional treatment. For the treatment of N_0 only the phosphorus and potassium were injected to irrigation water.

The experiment has been planned as split-split block design with two replications. The nitrogen contents, irrigation intervals and crop-pan coefficients were placed in the main plots, sub-plots, and sub-sub (mini) plots, respectively. The every mini plots have 8 to 10 trees with 813 square meters area.

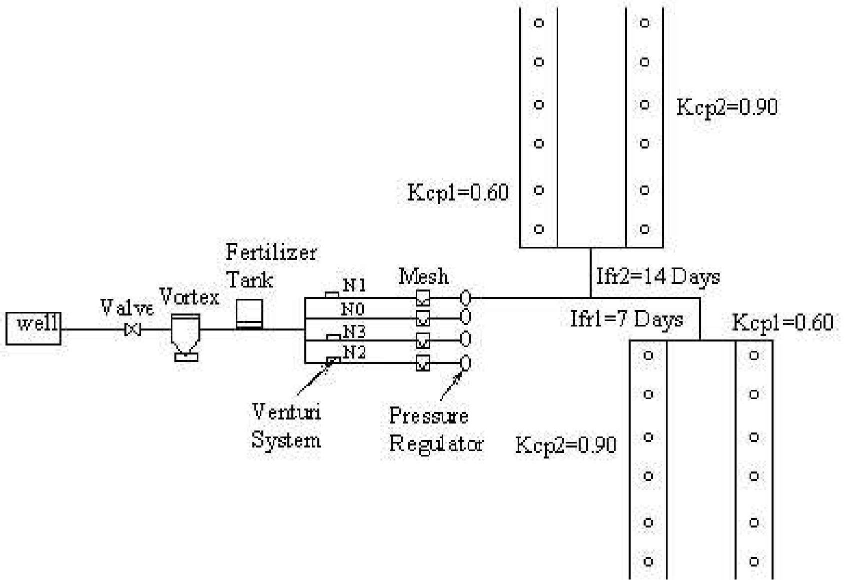

Fig. 1. The fertigation system used in the pistachio experiment

3.7. Amount of Irrigation Water

Amount of irrigation water to be applied to the plots is calculated according to the free water surface evaporation measured from class A pan during irrigation intervals with using as the following equation. Evaporation pan is placed on the bare soil at central point of the four trees in the experimental orchard.

$$I = K_{pc}\ E_o\ C \qquad (1)$$

Where K_{pc} is the coefficient related to crop and pan type; E_o is the cumulative evaporation and C is the wetting percent (30% is used). The wetted area was measured after irrigation events to control wetting percent.

Nitrogen concentrations were prepared and applied using fertigation control units. Water with nitrogen is given directly to the trickle lateral lines that are placed in both sides of the trees.

3.8. Actual Evapotranspiration

Actual evapotranspiration (crop ET) of the treatments was calculated using water balance approach as plot basis using Equation 2 (James 1988).

$$ETa = IR + P + Cp - Dp\ R_f\ S \qquad (2)$$

Where, ETa is the actual evapotranspiration which is calculated for wetted area; IR is the irrigation water applied to the plots; P is the rainfall; Cp is the capillary rise; Dp is the deep percolation R_f is the runoff going into or out of the plots; S shows the change of moisture content in the root depth. Irrigation water, rainfall and moisture content are measured and other components are assumed to be zero.

3.9. Reference Evapotranspiration

Crop ET data were used to develop K_c values based on estimates grass reference evapotranspiration using the Penman-Monteith (Allen et al. 1998; Steduto 1999) FAO-Blaney-Criddle and Pan Evaporation methods (Doorenbos and Kassam 1986) and Jensen Pan Evaporation method (Kanber 1999) with daily weather values. ET estimations were made for pistachio growing season assumed to extend from the end of February when the buds opened to the mid of the November when leaves shed.

3.10. Crop Coefficient (K_c)

The equation given by Koumanov et al. (1997) was used for calculating the Kc values. That equation was changed according to wetting percent used for calculating irrigation water amount.

$ET_c = K_c K_r ET_o$ (3)

Where ET_c is crop evapotranspiration, which is estimated by reference ET approach; K_c denotes the crop coefficient; K_r shows the percentage of soil surface covered by the crop canopy as compared with the total surface area ET_o is the grass-reference evapotranspiration estimated using FAO-methods. The actual evapotranspiration for whole plot area was calculated by multiplying 0.30 and put instead of ET_c in the Equation 3 for calculating K_c values.

3.11. Measurement of Soil Moisture Content

Moisture content of soil profile in the treatments were measured before and one day after irrigations. The moisture levels were also determined before the start of the growing period, which is obtained as the leaf freshening time and at the end of the growing period, that is leaf-shedding time. Measurements were done with neutron scattering and gravimetric methods using 20 and 30 cm soil layer in the 120 cm soil profile, respectively.

3.12. Measurement of Gas Exchange Parameters

The pistachio leaf gas-exchange response is being carried out between July and August when the evapotranspiration is high. The "irrigation" and "nutritional" treatments under investigation were chosen as a combination between "high" and "low" status of "water" and "nitrogen". Specifically: *"Traditional"* (which corresponds to a condition of "low nitrogen" and "no irrigation" status); "$N_3 I_{f2} K_{pc1}$" (which corresponds to a condition of "high nitrogen" and "low water" status); "$N_3 I_{f1} K_{pc2}$ (which corresponds to a condition of "high nitrogen" and "high water" status); "$N_0 I_{f1} K_{pc2}$" (which corresponds to a condition of "low nitrogen" and "high water" status).

The purpose of the measurement was to characterize the photosynthetic capacity the stomatal conductance and the photosynthetic water use efficiency of pistachio under different irrigation and nutritional treatments. Furthermore observations on the leaf photosynthetic response and stomatal conductance to different environmental variables (such as leaf water potential light vapour pressure deficit and CO_2 concentration) were conducted as well to acquire insight on the physiology of the plant. In order to take these variables a LI-6400 *Portable Photosynthesis System* (LiCor Inc. Lincoln Nebraska USA) was used. This system is operated as open gas-exchange steady-state system and consisting of two main components: the *system console* and the *sensor head*.

3.13. Measurement of Leaf Water Potential

Leaf water potential of pistachio was measured using a *3000 Series* plant *Water Status Console Pressure Chamber* (Soil Moisture Equipment Corp. Coleta CA USA; Figure 17) for $I_{f1}N_3K_{cp1}$ $I_{f1}N_3K_{cp2}$ $I_{f2}N_3K_{cp1}$ $I_{f2}N_3K_{cp2}$ and *traditional*. **T**he diurnal pattern of leaf water potential was measured at the sunrise, noontime and sunset between the consecutive irrigations. Three or two stem samples on each tree which were full exposed leaves from the canopy were taken on each measurement time.

3.14. Harvest

Pistachio trees were harvested on September 7 and 11 in the experimental years of 2001 and 2002, respectively. Harvests were done after the irrigation seasons, which finished in September. All pistachio nuts from trees were removed by hand to determine gross yield of trees in each plot. Fruits, which reach the physiological maturity stage by having reddish hull, were harvested by shaking the trees. All remaining nuts were picked by hand and separated from clusters. Harvest sub-samples (one kg per tree) were collected from each plot for evaluation of yield components and quality. Blanks (no embryo growth), unsplit nuts, split nuts, fresh and dry weights of hulls, shell and kernels were determined. Some parts of these samples were used to determine water content of the yield. These samples were dried until reach to constant weight in an oven with 65 ºC in the laboratory.

4. RESULTS AND DISCUSSION

4.1 Irrigation and Evapotranspiration

Irrigation dates and water amount applied in the different treatments and other irrigation parameters are given in Tables 2 and 3. Irrigation period in the year 2001 begun on May 29 and ended at harvest which is September 10, whereas it was between May 4 and September 10 in 2002. The irrigation treatments with 7 and 14 days interval were irrigated 15 times and 8 times, respectively during the both irrigation season in the years. Of course the larger water application was for the treatment with 7 days interval and 0.9 K_{pc}. All treatments received the highest amount of water in July. The total irrigation water varied depends on irrigation interval and K_{cp} values. The highest water amount was obtained in treatment with 7 days interval and 0.90 K_{pc} with 906 and 794 mm in the experimental years.

Table 2. Amount of Irrigation Water Given to Treatments in 2001 Year

Irrigation Date	Evaporation (CAP) (mm)	Applied Irrigation Water Amount (mm)							
		I_{f1}=7 days				I_{f2}=14 days			
		Kcp_1=0.6		Kcp_2=0.9		Kcp_1=0.6		Kcp_2=0.9	
		Wetted Area, 244 m^2	Plot Area 813m^2	Wetted Area, 244 m^2	Plot Area 813m^2	Wetted Area, 244 m^2	Plot Area 813m^2	Wetted Area, 244 m^2	Plot Area 813m^2
29.05.2001	64	39	12	39	12	39	12	39	12
05.06.2001	65	39	12	59	18				
12.06.2001	62	37	11	56	17	37	11	56	17
19.06.2001	65	39	12	59	18				
26.06.2001	75	45	13	67	20	45	13	67	20
03.07.2001	73	44	13	66	20				
10.07.2001	75	45	13	67	20	45	13	67	20
17.07.2001	80	48	14	72	22				
24.07.2001	84	50	15	75	23	50	15	75	23
31.07.2001	77	46	14	69	21				
07.08.2001	64	38	11	57	17	38	11	57	17
14.08.2001	66	40	12	59	18				
21.08.2001	57	34	10	52	15	34	10	52	15
28.08.2001	63	38	11	56	17				
04.09.2001	60	36	11	54	16	36	11	54	16
Toplam	**1028**	**617**	**185**	**906**	**272**	**324**	**97**	**467**	**140**

Table 3. Amount of Irrigation Water Given to Treatments in 2002 Year

Irrigation Date	Evaporation (CAP) (mm)	Applied Irrigation Water Amount (mm)							
		I_{f1}=7 days				I_{f2}=14 days			
		Kcp_1=0.6		Kcp_2=0.9		Kcp_1=0.6		Kcp_2=0.9	
		Wetted Area, 244 m^2	Plot Area 813m^2	Wetted Area, 244 m^2	Plot Area 813m^2	Wetted Area, 244 m^2	Plot Area 813m^2	Wetted Area, 244 m^2	Plot Area 813m^2
04.06.2002	58.2	58.2	17.5	58.2	17.5	58.2	17.5	58.2	17.5
11.06.2002	53.9	32.3	9.7	48.5	14.6				
18.06.2002	60.9	36.5	11.0	54.8	16.4	36.5	11.0	54.8	16.4
25.06.2002	69.6	41.7	12.5	62.6	18.8				
02.07.2002	69.6	41.7	12.5	62.6	18.8	41.7	12.5	62.6	18.8
09.07.2002	73.0	43.8	13.1	65.7	19.7				
16.07.2002	57.4	34.4	10.3	51.6	15.5	34.4	10.3	51.6	15.5
23.07.2002	65.2	39.1	11.7	58.7	17.6				
30.07.2002	73.0	43.8	13.1	65.7	19.7	43.8	13.1	65.7	19.7
06.08.2002	69.6	41.7	12.5	62.6	18.8				
13.08.2002	60.9	36.5	11.0	54.8	16.4	36.5	11.0	54.8	16.4
20.08.2002	60.9	36.5	11.0	54.8	16.4				
27.08.2002	52.2	31.3	9.4	47.0	14.1	31.3	9.4	47.0	14.1
03.09.2002	52.2	31.3	9.4	47.0	14.1				
10.09.2002	47.0	28.2	8.5	42.3	12.7	28.2	8.5	42.3	12.7
Toplam	**876.6**	**549.0**	**165.0**	**794**	**238**	**282**	**85**	**395**	**118**

The minimum value were 324 and 282 mm for 14 days interval with coefficient of 0.60. The irrigation programs and drip irrigation allowed significant water saving. The highest water saving were calculated with 180% (in 2001) and 182% (2002) according to the treatment with 14 days interval and 0.60 K_{pc}. The lowest values were 47 and 45 percent for first and second years, respectively as the treatment with 7 days interval and 0.60 K_{pc}.

The wetted area by the drip lines under the trees was measured to control the irrigation effectiveness after events. It was determined that almost more than 30 percent of the surface area was wetted after irrigations.

Seasonal evapotranspiration results of some selected treatments, which have received high and low water amounts including traditional treatment, were calculated and given in Tables 4 for two experimental years. As calculating evapotranspiration, all rainfall amount received during growing season were accepted as effective to plant due to their quantities and frequencies were small during the growing season. Additionally, it is assumed that irrigation water given to the plots was hold in the root zone, and no deep percolation and no runoff occurred. The highest evapotranspiration value was in the treatment, which is frequently irrigated and received more water, such as $I_{f1}K_{cp2}$. In year of 2001, evapotranspiration varied from 518 (I_{f1} N_3Kpc_1) to 345mm ($I_{f2}N_3Kpc_1$) for plot area and 1152 to 572mm for the wetted area except in traditional treatments. Similarly, in 2002 the maximum evapotranspiration was calculated in treatment $I_{f1}N_3Kpc_1$ as 1227mm for wetted area and 641mm for whole plot area, contrary, minimum values were in $I_{f2}N_3K_{pc1}$ treatment with 700mm (wetted area) and 482mm (plot area).

Table 4. Seasonal Evapotranspiration for Some Treatments

Treatments	Soil Water S mm		Rainfall P mm		Irrigation Water IR mm		Etc mm (Wetted Area)		Etc mm (Plot Area)***	
	2001*	2002**	2001	2002	2001	2002	2001	2002	2001	2002
I_{f1} N_3Kpc_1	130	87	85	236	617	577	832	900	400	496
$I_{f1}N_3Kpc_2$	161	154	85	236	906	837	1152	1227	518	641
$I_{f2}N_3Kpc_1$	163	153	85	236	324	311	572	700	345	482
$I_{f2}N_3Kpc_2$	164	160	85	236	467	437	716	833	389	527
Traditional	135	155	85	236	0.0	0.0	-	-	220	391

* April 20-November 07/2001; ** March 18-November 26/ 2002; *** ETc in irrigated treatments was calculated by summation of rainfall, soil water and 30 percent of total irrigation water.

There are significant reductions of evapotranspiration between treatments. The reduction rate of ET for irrigated treatments according to $I_{f1}N_3K_{pc2}$ varied between 28 for $I_{f1}N_3K_{pc1}$ and 50 percent for $I_{f2}N_3K_{pc1.}$ Similar results were determined in experimental year of 2002. There are 64 and 36 percent reduction in treatment of $I_{f1}N_3K_{pc2}$ compared to $I_{f2}N_3K_{pc1}$ and $I_{f1}N_3K_{pc1}$, respectively.

The monthly variations of average crop water use (ET_c) calculations in two trial years for two extreme treatments which have received high water with most frequent irrigation ($I_{f1}K_{pc2}$) and low water amounts with longer interval irrigation ($I_{f2}K_{pc1}$) at the same nitrogen level of N_3, including grass reference evapotranspiration (ET_o) calculated by Penman-Monteith approach are presented in Figure 2. These calculations assume clean cultivated conditions; no cover or actively growing native weeds or grasses. Additionally, it is assumed in the estimation of ET_o that the soil covered by pistachio trees is about 35 percent. The average maximum monthly evapotranspiration was obtained in July with 96 mm for $I_{f1}K_{pc2}$. In this month ET in treatment of $I_{f2}K_{pc1}$ and grass reference evapotranspiration are also the highest among the others monthly values with 46 and 79 mm, respectively.

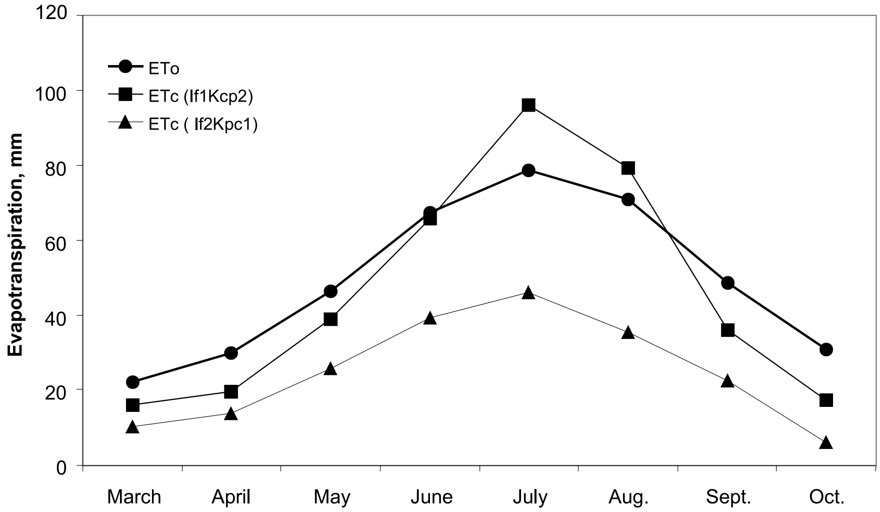

Fig. 2. The variation of ET_c for treatments of frequent irrigated with high water ($I_{f1}K_{pc2}$) and infrequent irrigated with low water ($I_{f2}K_{pc1}$) and ET_o values with time. ET_c values in November for treatments were small and they are not shoved in figure

At the beginning of the growing season and at harvesting, the crop evapotranspiration rates were found to be lower than those in irrigation season. The variation of measured ET for two irrigation treatments was similar to the change of ET_o. In the irrigation season, grass reference evapotranspiration are lower than those in frequent irrigated treatment. It can be reasoned by Penman-Monteith approach gives under estimation due to extra energy introduce by advection in this region (Steduto et al., 1996).

4. 2. Crop Coefficients (K_c)

The crop coefficient (K_c) values calculated using equation of Penman-Monteith, which were obtained from treatment of $I_{f1}N_3K_{pc2}$ for two years and average are shown in the Figure 3. The pistachio trees in this treatment are grown under completed irrigation condition compared to other treatments.

In general, K_c values gradually increase from March with very low values to July with maximum values in two years. Maximum K_c values start to decline from July towards to November due to leaf senescence. This behaviour is covered with what has been reported by Goldhamer et al. (1985) and Kanber et al. (1992). Maximum and minimum values of K_c were obtained in November and July, respectively. Monthly values of K_c were calculated between 0.21 and 1.32 for 2001 and 0.19 and 1.56 for 2002 as minimum and maximum. All the experimental years have the highest K_c values in July when the highest evapotranspiration was measured. The average values for two years varied between 0.2 and 1.44 for the months during the growing period.

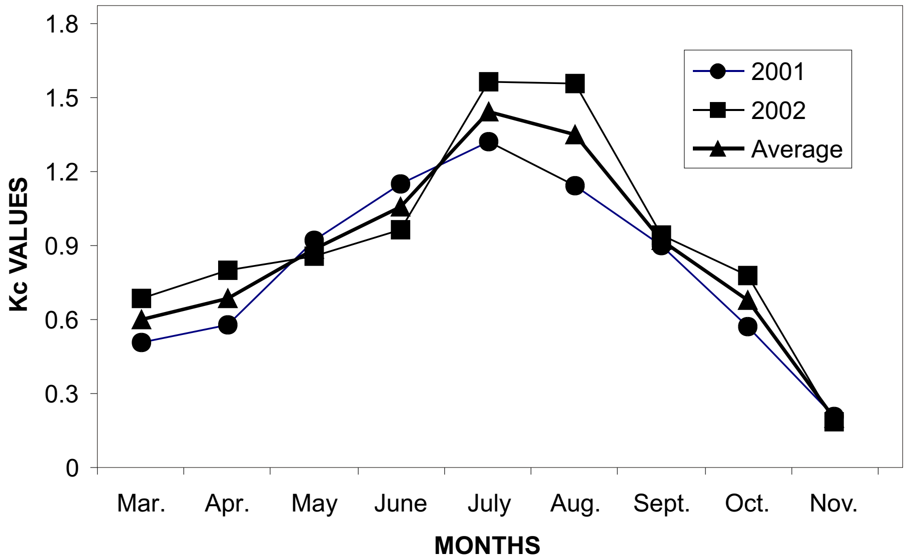

Fig. 3. Crop coefficients for pistachio tree obtained using grass reference evapotranspiration of Penman-Monteith equation

It can be seen from Figure 3, high crop coefficients were calculated during two years. In arid and semi-arid areas, high crop coefficient can be calculated due to excessive radiant energy, long day time, hot and dry air conditions (Doorenbos and Pruitt, 1984; Allen et al., 1998; Steduto, 1999). To our surprise, these K_c values for the treatment of $I_{f1}N_3K_{pc2}$ are very high. Goldhamer (1995) indicate that advective energy can cause ET_c rates to increase drastically if orchard is bordered upwind by bare ground. So, this situation can be assumed for this region where is border upwind by bare ground. Similar opinions were given by Allen et al. (1998) based on relation between energy entrance and crop evapotranspiration. On the other hand, Kanber et al. (1986) have found that K_c values, which were calculated with using SCS-Blaney-Criddle procedure, were lower than K_c values obtained by Penman-Monteith procedure in this experiment.

4.3 Fertilizers

Some results on fertilizer as a pure material, applied to the treatments during experimental years are shown in Table 5 and 6.

Table 5. The amount of fertilizers as a pure elements (N P and K) given to the treatments (2001)

Treatments	IR mm	N g/m^2	Wetted Area $g/244m^2$	P g/m^2	Wetted Area $g/244m^2$	K g/m^2	Wetted Area $g/244m^2$
$I_{f1}N_0Kpc_1$	617	0.0	0.0	4.9	1185.8	3.2	790.6
$I_{f1}N_0Kpc_2$	906	0.0	0.0	4.9	1185.8	3.2	790.6
$I_{f1}N_1Kpc_1$	617	6.2	1505.5	4.9	1185.8	3.2	790.6
$I_{f1}N_1Kpc_2$	906	9.1	2210.6	4.9	1185.8	3.2	790.6
$I_{f1}N_2Kpc_1$	617	9.3	2258.2	4.9	1185.8	3.2	790.6
$I_{f1}N_2Kpc_2$	906	13.6	3316.0	4.9	1185.8	3.2	790.6
$I_{f1}N_3Kpc_1$	617	12.3	3011.0	4.9	1185.8	3.2	790.6
$I_{f1}N_3Kpc_2$	906	18.1	4421.3	4.9	1185.8	3.2	790.6
$I_{f2}N_0Kpc_1$	324	0.0	0.0	4.9	1185.8	3.2	790.6
$I_{f2}N_0Kpc_2$	467	0.0	0.0	4.9	1185.8	3.2	790.6
$I_{f2}N_1Kpc_1$	324	3.2	790.6	4.9	1185.8	3.2	790.6
$I_{f2}N_1Kpc_2$	467	4.7	1139.5	4.9	1185.8	3.2	790.6
$I_{f2}N_2Kpc_1$	324	4.9	1185.8	4.9	1185.8	3.2	790.6
$I_{f2}N_2Kpc_2$	467	7.0	1709.2	4.9	1185.8	3.2	790.6
$I_{f2}N_3Kpc_1$	324	6.5	1581.1	4.9	1185.8	3.2	790.6
$I_{f2}N_3Kpc_2$	467	9.3	2279.0	4.9	1185.8	3.2	790.6
Traditional	0.0	-	500.0*	-	600.0*	-	400.0*

* Per tree

The fertilizers varied depending on irrigation interval and K_{cp} coefficients. Fertilizers (N P and K) amounts received by the treatments are higher than those in the traditional one. The maximum nitrogen amount was applied to treatment $I_{f1}N_3K_{pc2}$ with 18.1 $g.m^{-2}$ (in 2001) and 15.9 9 $g.m^{-2}$ (in 2002) among irrigated treatments. The same amounts of phosphorus and potassium fertilizers were applied to the all irrigated treatments except for the traditional. These chemicals are given via irrigation at two weeks interval when I_{f1} and I_{f2} treatments were irrigated together.

During the experimental years, the amount of P and K varied depended on irrigation water applied to the treatments. In 2001, all pistachio trees have received 4.9 and 3.2 gram per square meter phosphorous and potassium while in 2002 these values decreased to 4.2 and 2.8 gram per square meter.

The fertilizers were applied fixed dozes to traditional treatment according to project. Nitrogen, phosphorous and potassium that were 5, 6 and 4 grams per square meter were given beginning the February. The amounts of fertilizers given to traditional treatment are higher than those of irrigated treatments, except treatment, which has accepted maximum nitrogen.

Table 6. The amount of fertilizers as a pure elements (N, P and K) given to the treatments (2002)

Treatments	IR mm	N g/m^2	Wetted Area $g/244\ m^2$	P g/m^2	Wetted Area $g/244\ m^2$	K g/m^2	Wetted Area $g/244\ m^2$
$I_{f1}N_0Kpc_1$	549	0.0	0.0	4.2	1033.9	2.8	689.3
$I_{f1}N_0Kpc_2$	794	0.0	0.0	4.2	1033.9	2.8	689.3
$I_{f1}N_1Kpc_1$	549	5.5	1339.6	4.2	1033.9	2.8	689.3
$I_{f1}N_1Kpc_2$	794	7.9	1938.5	4.2	1033.9	2.8	689.3
$I_{f1}N_2Kpc_1$	549	8.2	2009.4	4.2	1033.9	2.8	689.3
$I_{f1}N_2Kpc_2$	794	11.9	2907.7	4.2	1033.9	2.8	689.3
$I_{f1}N_3Kpc_1$	549	11.0	2679.3	4.2	1033.9	2.8	689.3
$I_{f1}N_3Kpc_2$	794	15.9	3876.9	4.2	1033.9	2.8	689.3
$I_{f2}N_0Kpc_1$	282	0.0	0.0	4.2	1033.9	2.8	689.3
$I_{f2}N_0Kpc_2$	395	0.0	0.0	4.2	1033.9	2.8	689.3
$I_{f2}N_1Kpc_1$	282	2.8	689.3	4.2	1033.9	2.8	689.3
$I_{f2}N_1Kpc_2$	395	3.9	963.0	4.2	1033.9	2.8	689.3
$I_{f2}N_2Kpc_1$	282	4.2	1033.9	4.2	1033.9	2.8	689.3
$I_{f2}N_2Kpc_2$	395	5.9	1444.4	4.2	1033.9	2.8	689.3
$I_{f2}N_3Kpc_1$	282	5.6	1378.6	4.2	1033.9	2.8	689.3
$I_{f2}N_3Kpc_2$	395	7.9	1925.9	4.2	1033.9	2.8	689.3
Traditional	0.0	-	500.0*	-	600.0*	-	400.0*

* per tree

4.4. Number of Black Buds

The number of black buds (fruit bud) that affected the pistachio yield was counted in June 2001 from the branches, which are randomly chosen from the four sides (east west north and south direction) of the labeled trees of the plots. The same counting procedure was repeated in autumn. The second counting was taken to obtain the number of buds remained on the branches and to quantify the shedding of the buds after falling of the leaves.

At the same time the shoot length on which buds were counted was measured. The highest numbers of buds in June were obtained from the treatments that had no or small yields in the last year. However the bud number for all treatments decreased in November (Figure 4). The maximum bud reduction (94%) was obtained in the treatment of $I_{f2}N_1K_{cp2}$. In treatments receiving high levels of water and nitrogen such as $I_{f1}N_3$ had 50% of buds reduction.

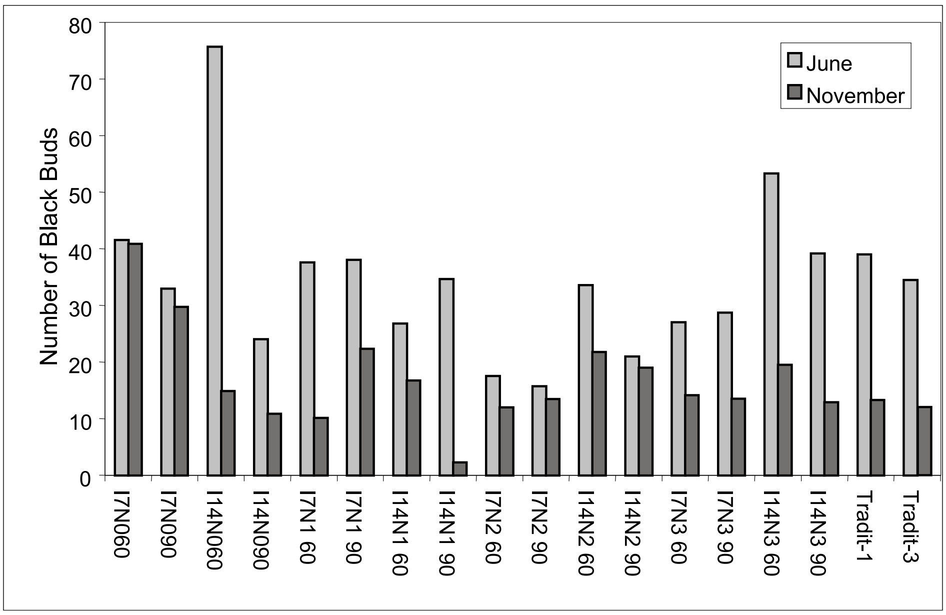

Fig. 4. The number of black bud on pistachio trees in June and November 2001

The traditional treatments had 66% bud reduction. The number and shedding of black buds can be caused by the fact that this year was off yielding year. However frequent irrigation and fertigation seems to decrease shading of black buds in off year too. The variations may indicate the expected yields in the forthcoming years. Almost the same results also were obtained in the year of 2002, as shown in Figure 5.

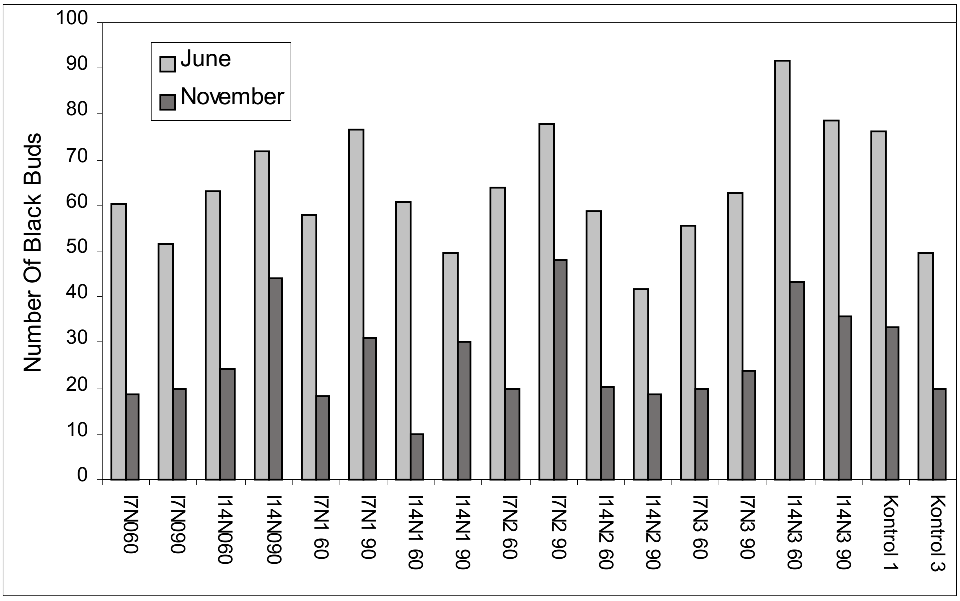

Fig. 5. The number of black bud on pistachio trees in June and November (2002)

4.5. Pistachio Leaf Gas-Exchange

Pistachio leaf gas-exchange response was carried out during summer periods at the experimental field in 2001. Five fully expanded and exposed leaves were measured for each treatment. Depending on the specific response to highlight measurements was taken either during noontime hours (i.e. the period of peak evaporative demand by the atmosphere) or diurnally at about 1.5-2 hr interval from pre-dawn to sunset. The measurements were repeated at various intervals including the days before and after irrigation applications.

The values of stomatal conductance (g_s) for the different treatments during the measurement period are shown in Figure 6. Although there was certain variability among trees it is possible to notice a trend of increase in g_s after irrigation as compared to the "Traditional" treatment.

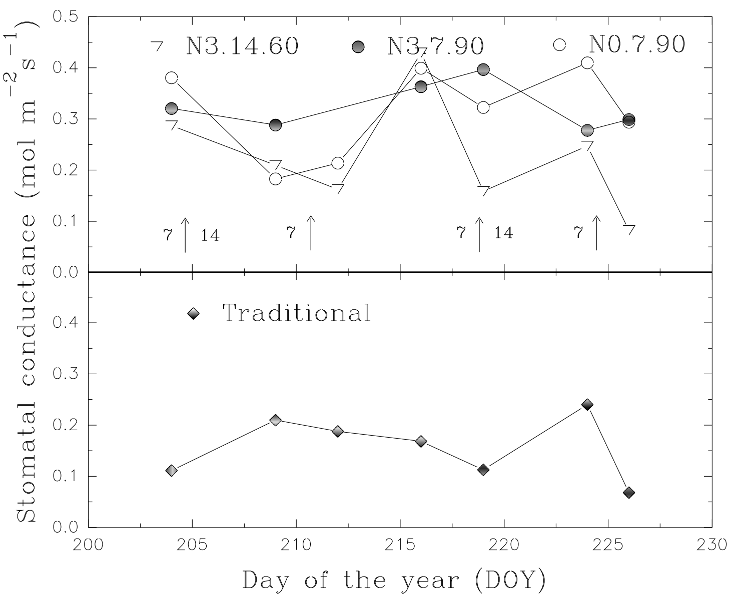

Fig. 6. Stomatal conductance during the period of measurements for the different treatments. Arrows indicate the time of irrigation. Numbers next to the arrows indicate the irrigation interval in days.

The g_s variation averagely ranged between about 0.2 and 0.4 mol m^{-2} s^{-1} for the irrigated treatments and between about 0.1 and 0.2 for the "Traditional" one. The treatment with high nitrogen and high water ($I_{f1}N_3$90) showed a tendency to maintain higher g_s values than the only irrigated treatments.

These tendencies are conserved when looking at the leaf net assimilation values or net photosynthesis (P_n) as reported in Figure 7 where the P_n variation averagely ranged between about 10 and 20 mol m^{-2} s^{-1} for the irrigated treatments and between about 5 and 15 mol $m^{-2}s^{-1}$ for the "Traditional" one.

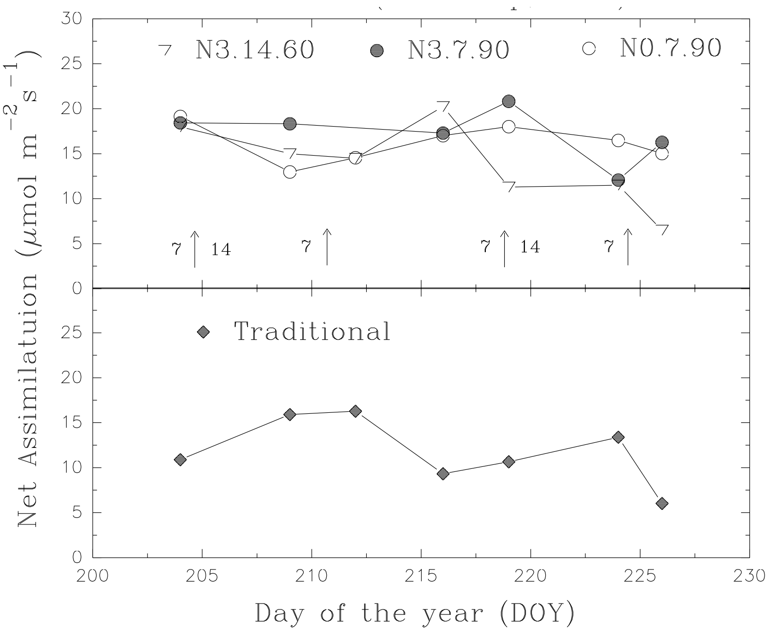

Fig. 7. Leaf net assimilation or net photosynthesis during the period of measurements for the different treatments. Arrows indicate the time of irrigation. Numbers next to the arrows indicate the irrigation interval in days.

This finding in turn is an indication of constant photosynthetic water use efficiency (WUE_{Pn}) as reported in Figure 8.

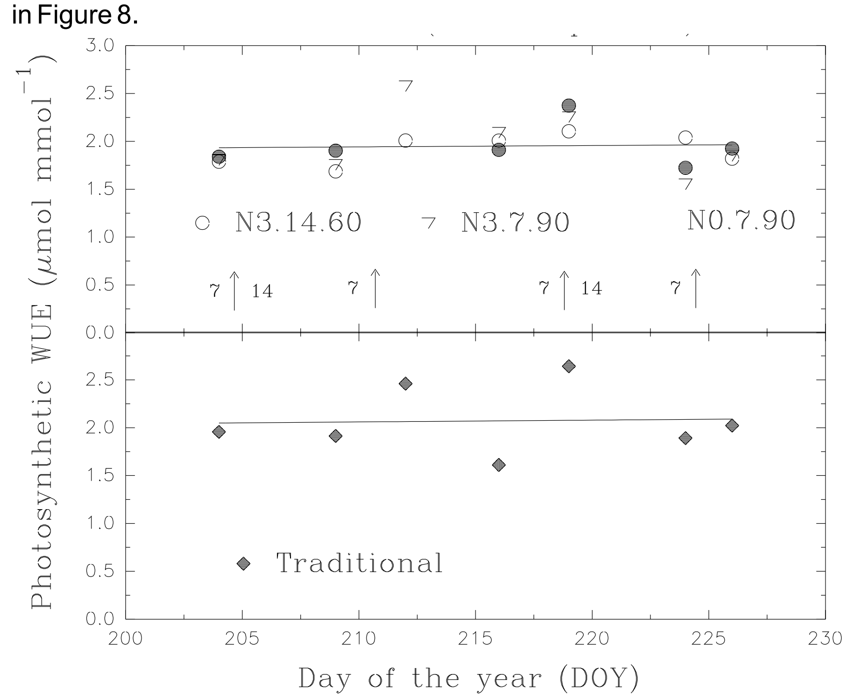

Fig. 8. Photosynthetic water use efficiency (WUE_{Pn}) during the period of measurements for the different treatments. Arrows indicate the time of irrigation. Numbers next to the arrows indicate the irrigation interval in days.

The WUE_{Pn} remained constant around 2 mol $_{(CO2)}$ mmol^{-1}$_{(H20)}$ regardless of the different treatments. This can be interpreted as an important feature of the *Pistachio* tree.

An additional response of photosynthesis and stomatal conductance was investigated in relation to leaf water potential. The major expression of the water status in the plant remains the water potential. A typical diurnal trend of photosynthesis and leaf water potential (LWP) is shown in Figure 9 for the well-irrigated and traditional (not irrigated) treatments. The corresponding diurnal trend of stomatal conductance and LWP is shown in Figure 10.

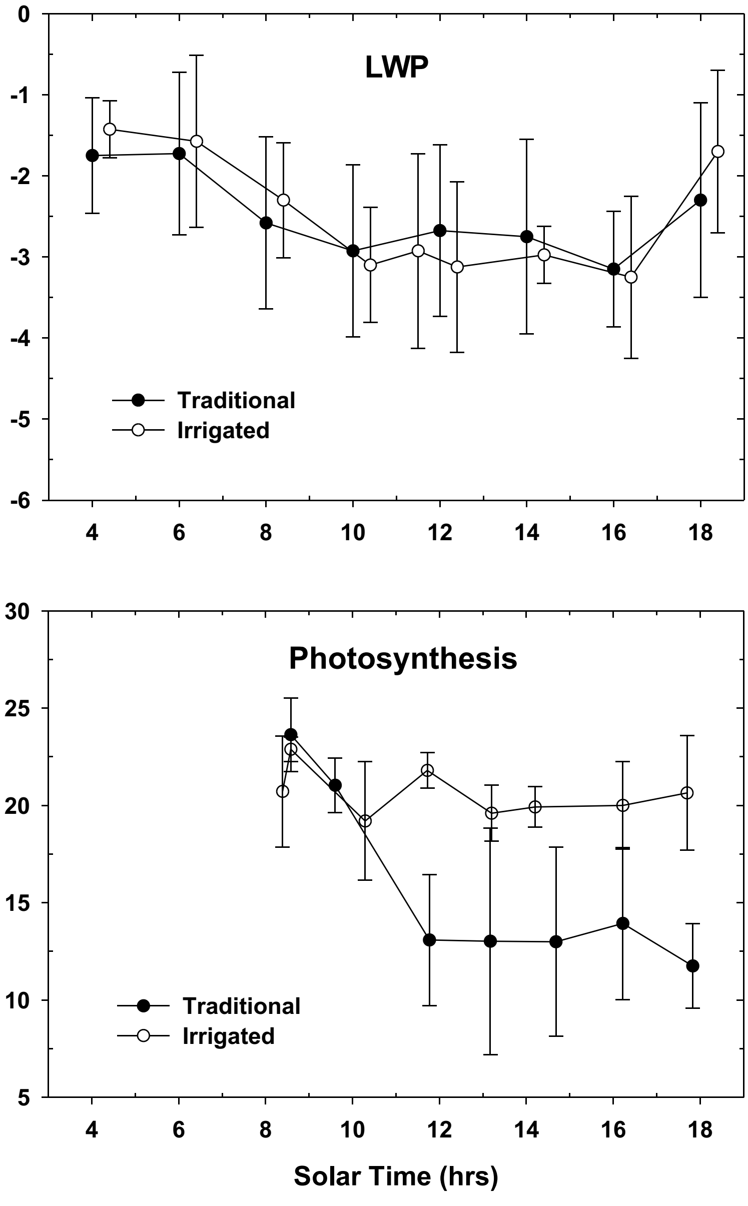

Fig. 9. Typical diurnal trend of leaf water potential (upper plot) and leaf photosynthesis (lower plot) of Pistachio for the traditional and irrigated treatments

It is worth noticing that leaf water potential can reach values as low as 4.0 MPa. This is of the same order of magnitude of what observed for olive trees and indicates the very low water status that *Pistachio* undergoes during his cycle.

Many other days were observed during the season of Pistachio with similar results. In summary the Pistachio seems responsive to the water status via the leaf water potential that affects the stomatal conductance (g_s). Stomatal conductance in turn is the major factor controlling photosynthesis.

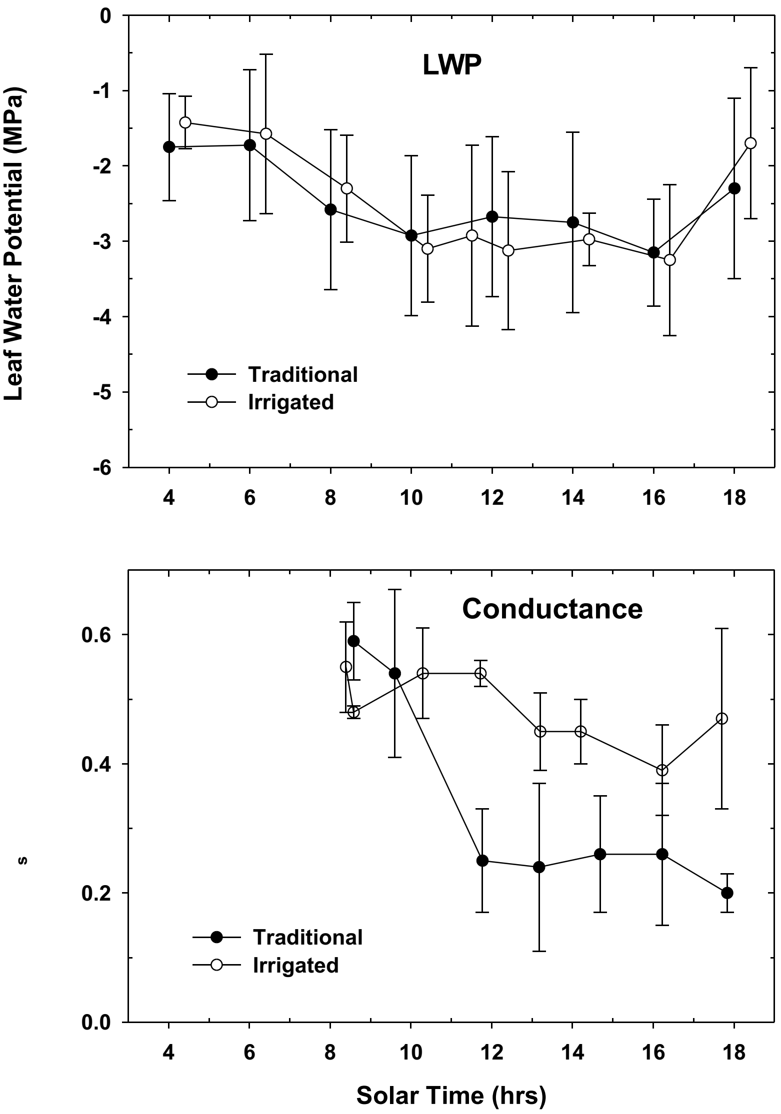

Fig. 10. Typical diurnal trend of leaf water potential (upper plot) and leaf stomatal conductance (lower plot) of Pistachio for the traditional and irrigated treatments

4.6. Yield

The average oven-dry yields for treatments for experimental two years are shown in Tables 7 and 8. Differences in yields from irrigation and nitrogen interaction are statistically significant at 0.05 levels. From the LSD test all treatments show 3 statistical yield groups (a, b, and c see Table 7). The maximum yields were taken from $I_{f2}N_3$ with average 11.7 kg per tree in 2001 and from $I_{f1}N_0$ with average 11.6 kg per tree in 2002.

Table 7. Pistachio Yield (Owen dry) From Treatments in 2001

Treatments	R1	R2	Average kg/tree	Groups*
$I_{f1}N_3K_{pc1}$	4.3	9.2	6.8	b
$I_{f1}N_3K_{pc2}$	4.1	7.1	5.6	b
$I_{f1}N_2K_{pc1}$	10.30	12.70	11.5	a
$I_{f1}N_2K_{pc2}$	8.66	13.04	10.9	a
$I_{f1}N_1K_{pc1}$	10.80	9.08	9.9	ab
$I_{f1}N_1K_{pc2}$	10.40	9.73	10.1	ab
$I_{f1}N_0K_{pc1}$	4.85	14.62	9.7	ab
$I_{f1}N_0K_{pc2}$	8.20	9.73	9.0	ab
$I_{f2}N_3K_{pc1}$	8.80	12.30	10.6	a
$I_{f2}N_3K_{pc2}$	11.00	14.70	12.9	a
$I_{f2}N_2K_{pc1}$	9.97	8.01	9.0	ab
$I_{f2}N_2K_{pc2}$	4.97	6.64	5.8	b
$I_{f2}N_1K_{pc1}$	6.96	14.46	10.7	a
$I_{f2}N_1K_{pc2}$	14.7	7.35	11.0	a
$I_{f2}N_0K_{pc1}$	8.10	10.90	9.5	ab
$I_{f2}N_0K_{pc2}$	7.30	9.70	8.5	ab
Sx_1	1.21			
Sx_2	1.51			
$I_{f2}N_3$			11.7	a
Traditional**			7.0	b
$t_{0.05}$ 2.26			t=3.3	

* Treatments marked with the same letter are in the same group at the P0.05 level.

** Mach analysis

Then traditional and $I_{f2}N_3$ treatments were compared using the *t* test. For this purpose 10 trees were used. There were statistically differences between two treatments at 0.05 significance level indicating that irrigation increased the pistachio yield of about 67% as compared to the traditional practice.

For year of 2002, pistachio oven-dry yield per tree was shown in Table 8. According to statistical analysis, there are no significant differences between treatments. The small differences between treatments obtained may be able to be coincidence.

In the on yielding year of 2002, irrigation has more effect on the yield than other such as nitrogen and irrigation intervals. The high yield was obtained from frequent irrigation with no nitrogen except phosphorous and potassium. Irrigation increased the pistachio yield of about 81% as compared to the traditional one, which is received all fertilizers without irrigation.

Table 8. Pistachio Yield (Owen dry) From Treatments in 2002 Year

Treatments	R1	R2	Average kg/tree	%Yield
$I_{f1}N_3K_{pc1}$	11.29	1.86	6.58	49
$I_{f1}N_3K_{pc2}$	14.38	2.73	8.56	64
$I_{f1}N_2K_{pc1}$	5.86	2.65	4.26	32
$I_{f1}N_2K_{pc2}$	2.68	3.75	3.22	24
$I_{f1}N_1K_{pc1}$	4.80	3.62	4.21	31
$I_{f1}N_1K_{pc2}$	2.62	4.52	3.57	27
$I_{f1}N_0K_{pc1}$	21.13	5.63	13.38	100
$I_{f1}N_0K_{pc2}$	14.74	5.06	9.90	74
$I_{f2}N_3K_{pc1}$	2.04	3.27	2.66	20
$I_{f2}N_3K_{pc2}$	4.41	2.59	3.50	26
$I_{f2}N_2K_{pc1}$	8.85	4.03	6.44	48
$I_{f2}N_2K_{pc2}$	11.41	2.44	6.93	52
$I_{f2}N_1K_{pc1}$	9.68	2.02	5.85	44
$I_{f2}N_1K_{pc2}$	4.61	1.23	2.92	22
$I_{f2}N_0K_{pc1}$	4.03	1.37	2.70	20
$I_{f2}N_0K_{pc2}$	4.64	2.15	3.40	25
Sx_1	4.14	For irrigation intervals at the same nitrogen content		
Sx_2	1.51	For irrigation intervals at the same and different nitrogen content		
Traditional			2.53	19

The cumulative yields of pistachio from treatments were analyzed according to irrigation and nitrogen factors used in this experiment. Generally, cumulative yield in all treatments increased as that in traditional measured beginning the experiment year of 2000 (Figure 11). The rate of increase of yield in irrigated treatments was quite higher than in traditional treatment, which has not been irrigated but been fertilized with nitrogen.

Nut yield at the end of two years-experiment increased nearly 5 times in I_{f1} and I_{f2} treatments according to the yield harvested in traditional treatment observed in 2000 as irrigation factors. Similarly, yield in the nitrogen factors increased 5, 6, 4.5 and 5 times in N_3, N_2, N_1 and N_0, respectively as the yield measured in traditional treatment in year of 2000. The rates of increase of yield according to irrigation factors were more than those in nitrogen factors. From this, it can be explained that irrigation has more effective for increasing the yield than nitrogen.

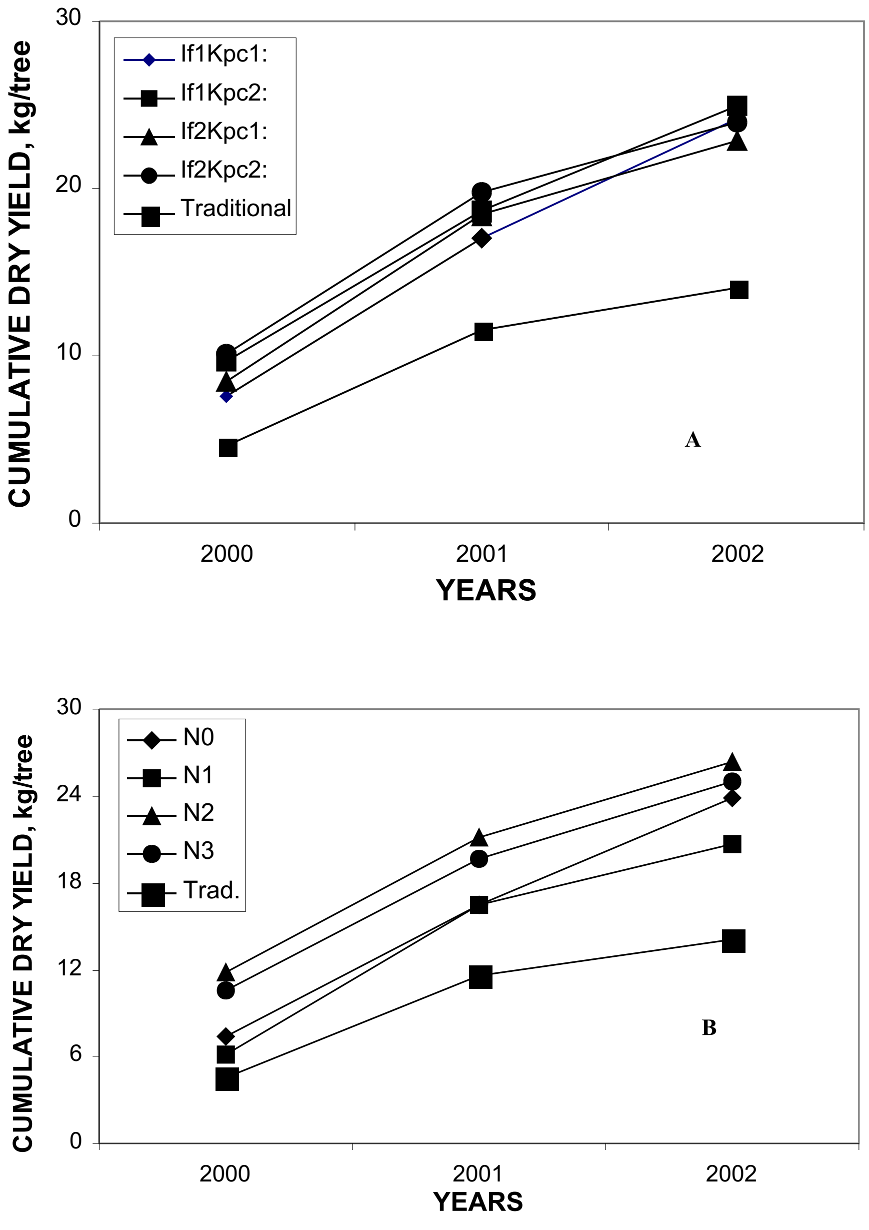

Fig. 11. Pistachio yield trend in trial years. Figure was designed according to factors determining water amount (A) and nitrogen dozes (B) in the treatments considered.

5. CONCLUSIONS

From results taken in the experimental years the following conclusions can be drawn:

(a) Pistachio trees seem to response to irrigation and nitrogen application. Although the year of 2001 was off-yielding year trees have given yield. This result is attributed to irrigation and fertigation. In 2002 (on-yielding year) there are no statistically significant differences between treatments but strong evidences were observed about the effects of irrigation on increasing the pistachio yield.

(b) The maximum nitrogen amount was applied to treatment $I_{f1}N_3K_{pc2}$ with 4.4 and 3.9 kg for wetted area among irrigated treatments in the experimental years, respectively.

(c) During the experimental years, the amount of P and K varied depended on irrigation water applied to the treatments. In 2001, all pistachio trees have received 4.9 and 3.2 gram per square meter phosphorous and potassium while in 2002 year these values decreased to 4.2 and 2.8 gram per square meter.

(d) In the traditional treatment, nitrogen, phosphorous and potassium that were 5, 6 and 4 grams per square meter were given beginning the February.

(e) The Pistachio seems responsive to the water status via the leaf water potential that affects the stomatal conductance (g_s). Stomatal conductance in turn is the major factor controlling photosynthesis.

(f) Water status (expressed by leaf water potential) represents the most relevant condition for *Pistachio* in order to achieve maximum rates of CO_2 assimilation.

(g) Although potential rates of net photosynthesis of 50 mol m^{-2} s^{-1} were observed under full CO_2 and light saturation actual values of no more than 20 mol m^{-2} s^{-1} were measured for the treatments receiving high nitrogen and high water applications ($I_{f1}N_3$90).

(h) The rate of photosynthesis was strictly linked to the stomatal conductance which ranged between about 0.1-0.2 mol m^{-2} s^{-1} of the "Traditional" treatment and about 0.4 mol m^{-2} s^{-1} of the $I_{f1}N_3$90 one.

(i) The photosynthetic water use efficiency of *Pistachio* was always held constant averagely around 2 mol $mmol^{-1}$ irrespective of treatments date of measurements and leaf sampled.

(j) Leaf water potential can reach values as low as 4.0 MPa. This is of the same order of magnitude of what observed for olive trees and indicates the very low water status that *Pistachio* undergoes during his cycle.

(k) The maximum yields were taken from $I_{f2}N_3$ with average 11.7 kg per tree in 2001 and from $I_{f1}N_0$ with average 11.6 kg per tree in 2002.

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