Corn yield response to partial rootzone drying and deficit irrigation strategies applied with drip system

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ABSTRACT

This paper evaluates the effect of partial root zone drying (PRD) and deficit irrigation (DI) strategies on yield and water use efficiency of the drip-irrigated corn on clay soils under the Mediterranean climatic conditions in Southern Turkey. Four deficit (PRD-100; PRD-75; PRD-50; and DI-50) and one full irrigation (FI) strategies based on cumulative evaporation (E_{pan}) from class A pan at 7-day interval were studied. Full (FI) and deficit irrigation (DI-50) treatments received 100 and 50% of E_{pan}, respectively. PRD-100, PRD-75 and PRD-50 received 100, 75 and 50% E_{pan} value, respectively. The highest water use was observed in FI as 677 mm, the lowest was found in PRD-50 as 375 mm. PRD-100 and DI-50 resulted in similar water use (438 and 445 mm). The maximum grain yield was obtained from the FI as 10.40 t/ha, while DI-50 and PRD-100 resulted in similar grain yields of 7.72 and 7.74 t/ha, respectively. There was a significant difference among the treatments with respect to grain yields ($P < 0.01$). The highest water use efficiency (WUE) was found in PRD-100 as 1.77 kg/m^3, and the lowest one was found in FI as 1.54 kg/m^3.

Keywords: partial root zone drying; deficit irrigation; water use efficiency; corn; drip irrigation; water scarcity

Water scarcity and drought are the major factors constraining agricultural crop production in arid and semi-arid zones of the world. Irrigation is today the primary consumer of fresh water on earth (Shiklomanov 1998), and thus agriculture has the greatest potential for solving the problem of global water scarcity. Consequently, improvements in management of agricultural water continue to be called for to conserve water, energy and soil while satisfying society's increasing demand for crops for food and fiber (Kassam et al. 2007).

Innovations for saving water in irrigated agriculture and thereby improving water use efficiency are of paramount importance in water-scarce regions. Conventional deficit irrigation (DI) is one approach that can reduce water use without causing significant yield reduction (Kirda et al. 2005). Partial root zone drying (PRD) is a further development of DI. PRD is commonly applied as part of a deficit irrigation program because it does not require the application of more than 50–70% of the water used in a fully irrigated program (Marsal et al. 2008). PRD is an irrigation technique based on alternately wetting and drying opposite parts of the surface soil under which the plant root system is thought to be located. This new irrigation strategy allows the exploitation of drought-induced ABA-based root-to-shoot signaling system to water saving. These irrigation techniques, and particularly PRD, are promising for saving water in drought-prone regions. Novel deficit irrigation techniques such as PRD allow enhanced water use efficiency in crop production by exploiting the plant's long-distance signalling mechanisms that modify plant growth, development and functioning as the soil dries. The novel science behind these mechanisms was revealed in the last 15 years (Davies et al. 2001).

The idea of using PRD as a tool to manipulate plant water deficit response has its origin in the observation that root-generated ABA can be transported to shoot regulating stomata of the leaves as shown in a number of crop species, such as corn (Bahrun et al. 2002) and soybean (Liu et al. 2003). As a consequence of plant response, the aperture of stomata can be regulated so that a partial closure of stomata at a certain level of soil water deficit may lead to an increase in WUE (Liu et al. 2005). To sustain the effect of PRD on stomata, it is necessary to regularly alternate the wet and dry compartments, usually every period of 10–14 days (Stoll et al. 2000); the length of the period depends on crop species, evaporative demands and soil conditions.

An important mechanism of plant response to PRD may be an increased ability to access soil resources. Soil water content of the wetted side of the row of PRD plants is depleted more rapidly than the same side of control plants, indicating thus that the root system can partially compensate for the increasingly limited water availability of the dry side of the row (Kang et al. 2002).

Corn is one of the most important crops in the Mediterranean Region in Turkey. Common irrigation methods used for corn production in this region are wild flooding, furrow and hand-move sprinkler. In recent years, drip irrigation has gained popularity among corn producers due to incentives provided by the government. In general, the farmers overirrigate, resulting in high water losses and low irrigation efficiencies, thus creating drainage and salinity problems (Yazar et al. 2002).

The objective of this study was to examine the effects of partial root zone drying (PRD) and deficit irrigation (DI) strategies on yield and water use efficiency of the drip-irrigated corn crop planted after harvesting wheat under the Mediterranean climatic conditions in Southern Turkey.

MATERIALS AND METHODS

This research was conducted in the experimental field of the Irrigation and Agricultural Structures Department of the Cukurova University in Adana, Turkey during 2006 corn growing season. The station has latitude of 36°59'N, longitude of 35°18'E, and altitude of 20 m above mean sea level. The soil of the experimental site is classified as the Mutlu soil series (Palexerollic Chromoxeret) with clay texture throughout the soil profile. Some physical and chemical properties of the soil at the experimental field are given in Table 1. Available water holding capacity of the soil is 198 mm in the 1.20 m soil profile.

Drip laterals of 16 mm in diameter had in-line emitters spaced 0.35 m apart, each delivering 4 l/h at an operating pressure of 100 kPa. Drip laterals were placed at the center of adjacent crop rows of 0.70 m apart in the experimental plots. Locally produced drip irrigation system was used in the study (Betaplast Comp., Adana, Turkey).

The experimental field was planted with a four-row planting machine at 0.70 m row spacing with a planting density of 8 seeds per square meter. Pioneer-3394 hybrid corn variety was planted on June 7, 2006 following the harvest of wheat. All treatment plots received the same amount of total fertilizer. Nitrogen (N) was applied in split applications. A compound fertilizer of (15-15-15) was applied (48 kg N, 48 kg P_2O_5 and 48 kg K_2O as pure matter per ha) at rate of 320 kg/ha at planting. On July 6, 2006, all plots received 185 kg N per hectare in the form of urea (46% N), which was applied in banding along the rows and the incorporated into the soil. Pest control spraying against Mediterranean corn borer (*Sesamia nonagrioides* Lef.) and aphids (*Rhopalosiphum maidis*) was carried out as needed.

The experimental design was randomized blocks with three replications. Irrigation management treatments consist of one full (FI), and one conventional deficit (DI-50), and three partial root zone irrigation (PRD-100, PRD-75, and PRD-50). A

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

Soil depth (m)	ECe (dS/m)	pH	O.M. (%)	Texture class	Field capacity (%)	Wilting point (%)	Bulk density (t/m^3)
0.0–0.20	0.19	7.87	1.28	C	40.1	26.4	1.14
0.20–0.40	0.16	7.61	1.30	C	38.5	25.5	1.20
0.40–0.60	0.15	7.70	0.98	C	37.3	24.6	1.26
0.60–0.80	0.12	7.81	–	C	38.4	25.3	1.25
0.80–1.00	0.14	7.85	–	C	38.5	25.2	1.28
1.00–1.20	0.16	7.65	–	C	39.1	25.1	1.30

Ece – electrical conductivity of the saturation extract; OM – organic matter seven-day irrigation interval was used in the study. Full (FI) and conventional deficit irrigation (DI-50) treatments received 100 and 50% of seven-day cumulative evaporation from Class A pan located at the experimental station, respectively. PRD-100, PRD-75 and PRD-50 received 100, 75 and 50% cumulative pan evaporation value, respectively, on one half of the plot area. A wetting percentage of 100% in FI and DI treatments, and 50% in PRD treatments was used in this study (Howell et al. 1997, Bozkurt et al. 2006). Drip laterals were placed at the center of adjacent crop rows 0.70 m apart in the experimental plots. Experimental plots were 10 m long and 6 crop rows wide (4.2 m). In PRD treatment plots, 3 of the 6 drip laterals alternately provided irrigation water. Under the PRD practice, one-half of the rooting zone was wetted while the other half was maintained partially dry. A preplant irrigation of 60 mm was applied with a sprinkler system on June 2, 2006. Three uniform rate applications varying from 14 to 50 mm were carried out during the plant establishment period (on June 17, 24 and July 6), and a total of 87 mm of water was applied equally to all treatment plots with a sprinkler system. Treatment irrigations were started on July 13, 2006.

The soil water content measurements were done one day before irrigation until harvest in three replications for all treatments by gravimetric sampling in 0–0.20 m, and using a neutron probe (Campbell Pacific model 503 DR Hydroprobe) at 0.20 m depth increments over 1.20 m depth. In FI and DI-50 plots, access tubes were installed in the crop row, and in the PRD treatment plots two additional access tubes were placed under the alternate drip laterals to characterize separately wetted and dry sides. The probe was field calibrated for the experimental soil.

Plant and soil water measurements and observations were started 21 days after planting, and were terminated on the harvest date. In order to determine total dry matter above the ground level and leaf area index (LAI), three plants within 0.5–0.6 m of a row section in each plot were cut at the ground level at 14-day intervals until harvest. Leaf area was measured with an optical leaf area meter. Plant samples were dried at 65°C until constant weight was achieved.

Corn grain yields were determined by hand harvesting the 8 m sections of three center rows in each plot on September 21, 2006. Then, grain yield values were adjusted to 15.5% moisture content. In addition, 1000-kernel weight, grain yield per cob, grain number per cob, and harvest index values were also evaluated. Harvest index (HI) is calculated as the ratio of the grain yield (GY) to above-ground dry matter yield (DM) at harvest.

Crop water use (ET) was estimated based on the one-dimensional water balance equation using soil water measured by the neutron probe and gravimetric sampling methods. Water use was the total of seasonal water depletion (planting to harvest) plus rainfall and irrigations during the same period. The water balance equation is as follows:

$$ET = I + P \pm DS - D \quad (1)$$

where: ET is evapotranspiration (mm), I irrigation (mm), P precipitation (mm), D deep percolation (i.e., drainage, mm) and DS is change of soil water storage in a given time period Dt (days) within plant rooting zone. Deep percolation losses below the root zone were assumed to be negligible in the study.

The water use-yield relationship was determined using the Stewart model in which dimensionless parameters are relative yield reduction and relative water use. Yield response factor (ky), defined as a decrease in yield with respect to per-unit decrease in water use (ET), is the slope of this relationship (Doorenbos and Kassam 1986).

Water use efficiency (WUE) was computed as the ratio of corn grain yield to seasonal water use. Irrigation water use efficiency (IWUE) was determined as the ratio of corn grain yield for a particular treatment to the applied water for that treatment (Howell et al. 1995).

MSTATC program (Michigan State University) was used to carry out the statistical analysis. Treatment means were compared using the Duncan's Multiple Range Test (Steel and Torrie 1980).

RESULTS AND DISCUSSION

The 2006 corn-growing season climatic conditions were typical of those that prevail in the Eastern Mediterranean Region of Turkey. Table 2 summarizes the monthly weather data compared with the long-term mean climatic data from the locality where the experiment was carried out. During the experimental season, rainfalls received (61 mm) were slightly higher than the long-term mean (51 mm).

Table 3 provides a summary of the seasonal amount of irrigation water applied, water use, water use efficiency and irrigation water use efficiency

Table 2. Long-term mean monthly and 2006 corn growing season climatic data

Years	Climatic parameters	June	July	August	September
Long-term means 1929–2005	mean temperature (°C)	25.9	28.3	28.8	26.2
	relative humidity (%)	66.6	71.9	71.2	65.2
	wind speed (m/s)	1.4	1.6	1.4	1.2
	rainfall (mm)	16.7	9.4	7.5	17.2
	pan evaporation (mm)	210.1	243.3	224.6	181
Growing season 2006	mean temperature (°C)	26.5	28.7	27.8	25.2
	relative humidity (%)	63.9	64.8	71	62.5
	wind speed (m/s)	1.2	0.9	1.3	1
	rainfall (mm)	14.4	8.1	14.8	24.2
	pan evaporation (mm)	206.3	231.7	220.6	182.9

data. Treatments received irrigation water varying from low of 271 mm in PRD-50 plots to high 644 mm in non-stress plots (FI). The irrigation treatments DI-50 and PRD-100 were essentially deficit irrigation treatments, which received 50% less water (396 mm) than the control treatment (FI), and a total of 271 mm was applied to PRD-75 treatment plots. Altogether 7 treatment irrigations varying from 43 to 82 mm in FI plots were practiced. The first treatment irrigation was carried out on July 13, 2006, and the final application was done on August 24, 2006.

Seasonal water use (ET) varied from 375 to 677 mm among the different treatments. The highest water use was observed in FI treatment as 677 mm, and the lowest water use was measured in PRD-50 treatment as 375 mm. DI-50 and PRD-100 resulted in similar water use values (438 and 445 mm, respectively) because both treatment plots received the same amount of irrigation water although application strategies were different between the two of them. Since the rainfall received during the corn growing season (61 mm) was not significant, the crop water consumption predominantly depended on the amount of the irrigation water supplied to the treatment plots. Variance analysis of the seasonal water use data revealed that irrigation treatments resulted in significantly different water use. In the deficit irrigation treatment plots (PRDs and DI); degree of the water stress gradually increased towards the end of the growing season and resulted in reduced crop yields. Water use was reported to vary from 476 to 645 mm for deficit and full irrigation, respectively; for sprinkler-irrigated corn by Boz (2001) it was from 483 mm in PRD-50 and DI-50 to 654 mm in full irrigation treatment for surface irrigated corn in the first year and from 324 to 532 mm in the second year by Kirda et al. (2005); and from 569 under deficit irrigation to 758 mm under full irrigation for drip-irrigated corn in the same experimental site, as reported by Bozkurt et al. (2006). The water use amounts are within the ranges reported in previous studies done in the Cukurova University corn irrigation experiments. Variation of cumulative water use

Table 3. Seasonal irrigation water, water use, soil water depletion, WUE and IWUE data for different treatments

Irrigation treatments	Seasonal irrigation water (mm)	Seasonal water use (mm)	Soil water depletion (mm)	Water use efficiency (kg/m^3)	Irrigation water use efficiency (kg/m^3)
FI	644	677[a]	33	1.54	1.61
DI-50	396	445[b]	49	1.73	1.95
PRD-100	396	438[b]	42	1.77	1.95
PRD-75	333	413[bc]	70	1.69	2.09
PRD-50	271	375[d]	104	1.63	2.25

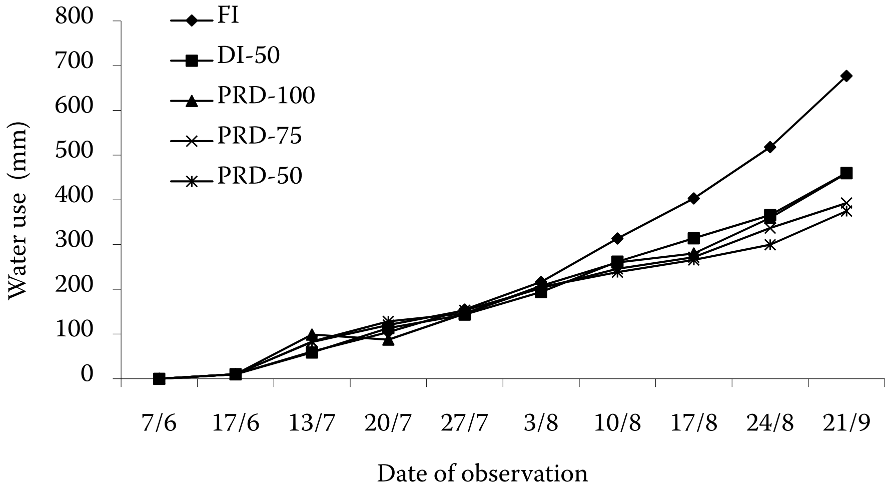

Figure 1. Cumulative evapotranspiration in different irrigation treatments

of the corn crop during the growing season with respect to the treatments is shown in Figure 1. Crop water use was higher at full irrigation level (FI) than in the deficit and PRD irrigation plots. As indicated in Figure 1, cumulative water use was similar in all treatment plots until the beginning of August; then the treatments varied in water use depending on the irrigation water applied. Gradual build up of the soil water deficit in the DI-50 and PRD plots reduced the soil water use. Severe water stress occurred in the PRD-50 and PRD-75 treatment plots since these two received the lowest amount of irrigation water. Water use in DI-50 and PRD-100 plots was reduced about 35% as compared with FI treatment. Kang et al. (2000) reported that alternate irrigation on half the root zone reduced water consumption by 35% with a total biomass reduction of only 6–11% as compared with conventional watering of pot-grown maize plants where the plant root system was divided into two or three parts and only the partial root zone was watered.

Soil water content measurements in the experimental plots were carried out throughout the growing season at weekly intervals using the neutron probe. Treatment irrigations were started on July 13, 2006. Variation of soil water contents in the 1.20 m profile depth prior to irrigations in the different treatments are shown in Figure 2. As depicted in Figure 2, profile water contents in all treatment plots fluctuated differently between the field capacity and wilting point until August 3 and then soil water contents fell below wilting point gradually towards the end of the season in

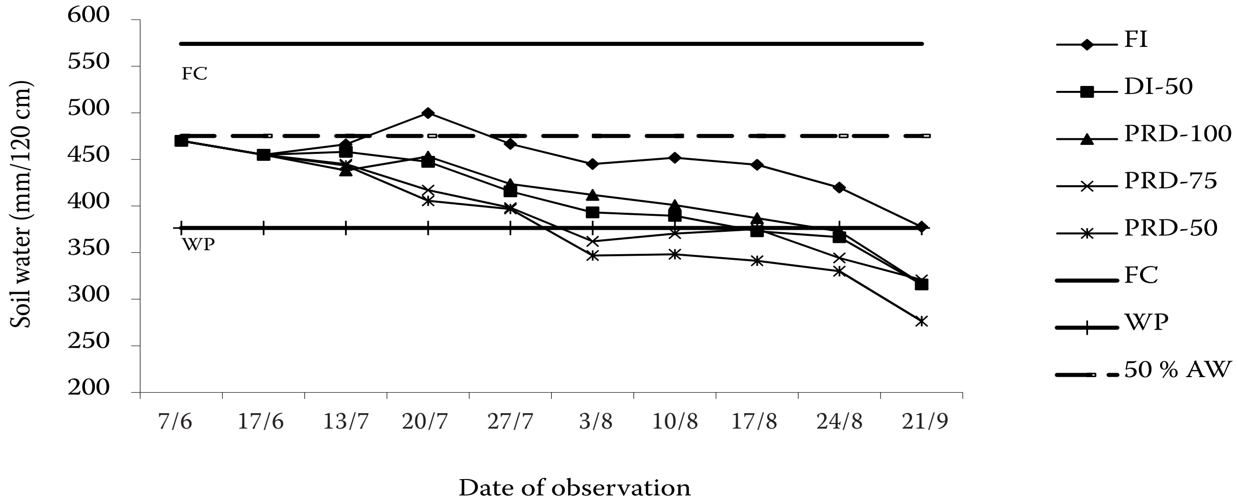

Figure 2. Variation of profile soil water content prior to irrigation under different treatments

PRD-75 and PRD-50 treatment plots. Although an equivalent quantity of water to weekly accumulated evaporation form Class A pan was applied in FI treatment it seems that this quantity was not enough to replenish the soil water deficit to field capacity after the beginning of the tasselling stage (July 23), as indicated in Figure 2. As a consequence, a slight water stress developed in FI treatment plots towards grain filling stage. On the other hand, soil water deficit in the 1.20 m depth in the DI-50 and PRD-100 treatment plots, which received about 40% less water than FI plots, remained well below soil water contents in the FI plot. Profile soil water contents in the FI plots remained higher than the other treatment plots. In general, in full irrigation treatment plots, soil water contents before the irrigation applications remained below the 50% of the available water in the 1.20 m profile depth throughout the growing season except during the tasselling stage. Soil water monitoring indicated that irrigating the PRD-100 and DI-50 at 50% of the FI caused a gradual, continual decline in soil water over the season and was insufficient to maintain a 'wet' profile. In PRD-100 and DI-50 treatments, soil water contents were well below the 50% of the available water and reached the wilting point towards the end of the season. In PRD-75 and PRD-50 treatments, profile soil water content reached wilting point on 10 August and remained below the wilting point from this date on. Corn is the most susceptible to water stress during the period covering tasselling through the milk stage. As shown in Figure 2, soil water contents in the PRD-100 and DI-50 treatment plots during the abovementioned period were below the 10% of the available water in the crop root zone depth. As in the field study, PRD-100 or DI-50 at 50% of FI resulted in significant soil water depletion with little differences between them. Seasonal soil water depletion increased with decreasing irrigation amounts. Thus, water stress in deficit irrigation treatments resulted in lower yields as compared to the full irrigation treatment.

Corn grain yield, above ground dry-matter yield, and yield components data are summarized in Table 4. Grain yields varied from 6.11 to 10.79 t/ha among the treatments. The highest average grain yield was observed in FI treatment as 10.79 t/ha, and the lowest yields were found in DI-50 treatment as 6.11 t/ha. PRD-100 and DI-50 treatments resulted in nearly the same grain yields (7.74 and 7.72 t/ha, respectively) and significantly ($P < 0.01$) lower (26%), compared to FI treatment. Yields in PRD-75 and PRD-50 treatments when irrigation was reduced by 52 and 58% as compared to FI decreased to 6.97 and 6.11 t/ha, respectively. Variance analysis of the grain yield data indicated that irrigation treatments significantly affected the yields ($P < 0.01$). As for the Duncan classification made with respect to irrigation treatments, the plots receiving the full irrigation (FI) resulted in significantly higher grain yields than DI-50 and all PRD treatments.

Corn grain yields were reported to vary from 1.05 t/ha for non-irrigated to 10.02 t/ha for full irrigated treatment by Gençoğlan and Yazar (1999); form 3.26 t/ha in dry-treatment to 8.51 t/ha for the full irrigation for sprinkler irrigated corn by Boz (2001); varying between 8.22–8.61 t/ha in PRD-50 and 8.30–8.04 t/ha DI-50, respectively, to 9.19–10.79 t/ha in full irrigation treatment for surface irrigated corn in the first and second year by Kirda et al. (2005); and from 6.18 t/ha for deficit irrigation to 9.79 t/ha for full irrigation for drip-irrigated corn in the same experimental site by Bozkurt et al. (2006). They also reported significantly higher yields from the 1.4 m spacing with full irrigation treatment than in the other two

Table 4. Dry matter yield, grain yield, harvest index, and yield components data for different treatments

Irrigation treatments	Dry matter yield (kg/ha)	Corn grain yield (kg/ha)	Harvest index (kg/ha)	Yield components kernel		
				mass (mg/kernel)	per ear (no/ear)	ear length (m)
FI	26668^{a}	10400^{a}	0.39^{ns}	411.9^{ns}	554.7^{a}	0.21^{ns}
DI-50	22884^{b}	7724^{b}	0.34	398.6	527.3^{ab}	0.19
PRD-100	21549^{b}	7743^{b}	0.36	409.4	471.3^{b}	0.19
PRD-75	21159^{b}	6974^{bc}	0.33	398.0	488.0^{b}	0.17
PRD-50	18246^{bc}	6119^{c}	0.34	382.1	394.3^{c}	0.16

^{ns}–not significant; Mean values followed with one or more of the same letters in the each column were not significantly different at $P < 0.05$

spacings (0.7 and 2.1 m). The corn grain yields obtained from this experiment are within those reported from the previous Cukurova University corn irrigation studies.

The highest water use efficiency (WUE) averaging 1.77 kg/m^3 was obtained in PRD-100, followed by DI-50 with 1.73 kg/m^3 and the lowest one was found in the FI treatment as 1.54 kg/m^3. WUE values decreased slightly with increased water stress as found in the PRD-75 and PRD-50 treatments. Globally measured average WUE values per unit water depletion is 1.80 kg/m^3 for corn. The range of WUE reported is very large (1.1–2.7 kg/m^3) and thus offers tremendous opportunities for maintaining or increasing agricultural production with 20–40% less water resources (Zwart and Bastiaanssen 2004). Kang and Zhang (2004) reported that water use as percent of fully irrigated treatment is decreased and irrigation water use efficiency (IWUE) is increased essentially by PRD as reported in a number of species, e.g. cotton, tomato, pear grapevine and hot pepper. PRD irrigation of corn reduced water consumption by 35% with a total biomass reduction of 6–11% as compared with fully watered plants. Irrigation water use efficiencies (IWUE) varied from 1.61 kg/m^3 in FI to 2.25 kg/m^3 in PRD-50 treatments. In all the cases, IWUE values related to deficit irrigations were higher than those of full irrigation. IWUE increased with decreasing irrigation amounts and/or water use. Therefore, the results clearly indicate that the efficient use of water is possible with PRD technique under the conditions of drought.

The highest dry matter yield was observed in FI treatment as 26.67 t/ha, and the lowest dry matter was found in PRD-50 treatment as 18.25 t/ha. Generally, the dry matter production under the full irrigation was significantly higher ($P < 0.05$) than those under the deficit irrigation treatment. Dry matter yields in DI-50 and PRD-100 plots were similar (22.88 and 21.55 t/ha, respectively) but lower than that in FI plots. The reason for higher dry matter yield in the FI treatment can be attributed to favorable soil water conditions created in FI plots, which enhanced the vegetative development.

Harvest Index (HI), known as the proportion of the corn/grain yield to the dry matter for the different treatments, is presented in Table 4. The highest harvest index was observed in FI treatment as 0.39, and the lowest harvest index was found in PRD-75 treatment as 0.33. Harvest index was affected by severe soil water deficit that developed during the grain filling period following anthesis in PRD-75 and PRD-50 treatment plots. It appears that irrigation treatments had significant effect on harvest index ($P < 0.05$). HI values were reported to vary form 0.20 to 0.43 by Gençoğlan and Yazar (1996); from 0.31 to 0.55 by Boz (2001); from 0.33 to 0.42 by Bozkurt et al. (2005) in the same experiment station. The HI values obtained in this study are within the values from the previous corn experiments.

Development of leaf area index (LAI) with time in different treatments is depicted in Figure 3. Maximum LAI was observed in FI plots with 5.3 during the anthesis growth stage, and the lowest one was measured in PRD-50 plots as 3.0 at harvest time. LAI values in PRD-100 and DI-50 treatment plots fluctuated between these two treatments. LAI values following anthesis declined gradually towards the end of the growing season in all plots. LAI values were not greatly affected

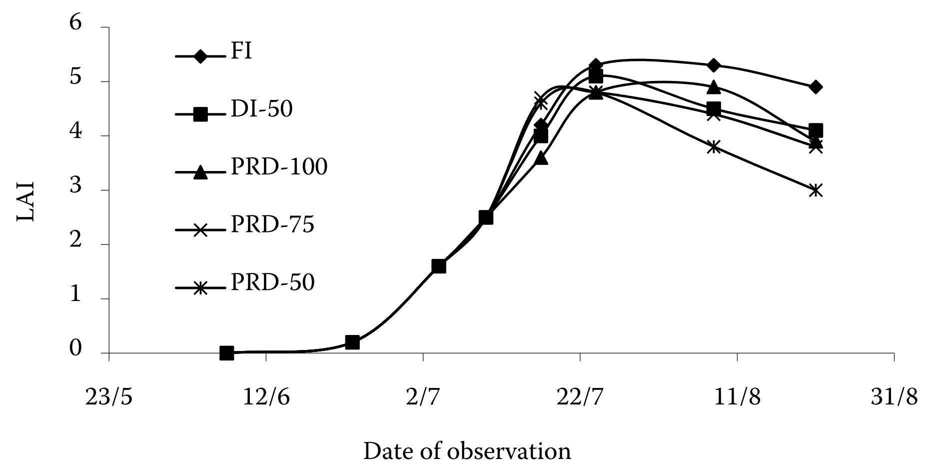

Figure 3. Evalution of LAI with time in different treatments

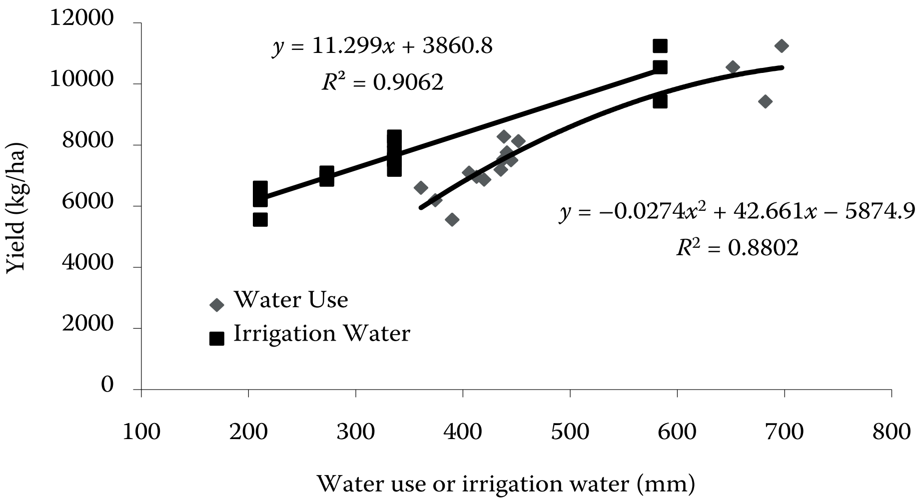

Figure 4. The relationship between grain yield and irrigation or water use

by the treatments during anthesis (varied from 4.6 to 5.3) but LAI declined more rapidly in severe deficit irrigation treatments of PRD-75 and PRD-50 following anthesis.

In the study, there was no significant difference in 1000-kernel weight among different irrigation treatments. 1000-kernel weight varied from 382.1 to 411.9 g. The highest 1000-kernel weight was observed in FI treatment as 411.9 g, and the lowest one was found in PRD-50 treatment as 382.1 g. Water shortage led to smaller kernels compared to those gained from the full irrigation cases. Generally, the 1000-kernel weight production with full irrigation is higher than the deficit irrigation treatments; deficit irrigation reduced 1000-kernel weight, but not significantly.

However, irrigation treatments had a significant effect on grain number per cob ($P < 0.05$). The highest grain number per cob was observed in FI treatment as 555, and the lowest grain number per cob was found in PRD-50 treatment as 394. As the applied irrigation amount increased, the grain number per cob also increased. DI-50 and PRD-100 treatments resulted in a similar grain number per cob values (496 and 502 kernels, respectively).

The effects of the irrigation strategies applied in this study were statistically significant also for other yield components such as cob length, grain yield per cob and grain number per cob. It was found that these components were higher in full irrigation treatments as compared to the deficit irrigation cases.

Significant second degree-polynomial relationship between grain yield (Y) and water use (ET), and linear relationship between grain yield (Y) and irrigation water (I) were found, as shown in Figure 4. Boz (2001) reported significant linear relationships between grain yield and seasonal irrigation as well as between grain yield and water use at the same location; Gençoğlan and Yazar (1999) and Bozkurt et al., (2006) found significant second-degree polynomial relationships between grain yield and irrigation water, and significant linear relationships between grain yield and water use under the Mediterranean conditions. Yield response factor (ky), which is slope of the relationship between relative yield reduction and relative evapotranspiration deficit, was found to be 1.06 for the whole growing season as shown in Figure 5. Ky values for corn were reported to vary from 0.98 to

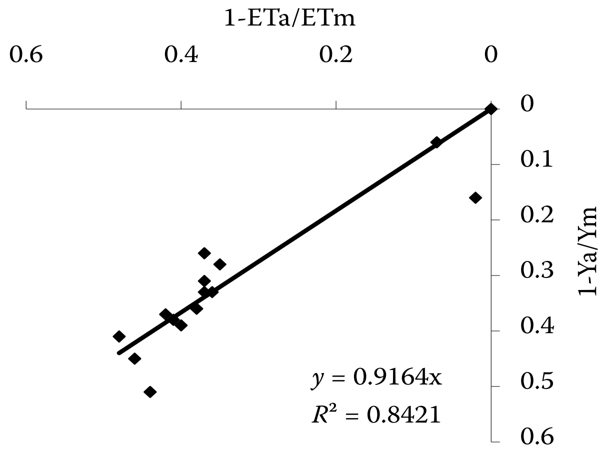

Figure 5. The relationship between the relative evapotranspiration deficit and relative yield deficit

1.23 in the same experimental site by Gençoğlan and Yazar (1999) and Yazar et al. (2002).

In this study, we evaluated the effects of partial root zone drying (PRD) and deficit irrigation (DI) strategies on yield and water use efficiency of the drip-irrigated corn crop planted after harvesting wheat under the Mediterranean climatic conditions in Southern Turkey in 2006. PRD-100 and DI-50 treatments received about 50% of irrigation water applied to the FI plots after July 13, and water use in these two treatment plots was reduced about 35%. On the other hand, the 50% deficit irrigation techniques (PRD-100 and DI-50) reduced corn yields by 26% compared to FI irrigation. Both irrigation strategies, the PRD-100 and DI-50, were equally effective in saving irrigation water. Although this technique was reported by Kang and Zhang (2004) to have the potential to reduce field-crop water use significantly, increase canopy vigour, and maintain yields when compared with normal irrigation methods, our results are not in accordance with this finding. The research results revealed that the PRD irrigation practice for corn did not provide any grain yield benefit as compared to conventional deficit irrigation (DI). Obviously, many situations need to be considered before it can be concluded whether PRD is practically useful in all situations. Our results, as well as similar results in recent publications on row crops, question the validity of the conclusions of many of the PRD studies done to date.

According to the research results, the highest water use efficiency (WUE) averaging 1.77 kg/m^3 was obtained in PRD-100, followed by DI-50 with 1.73 kg/m^3 and the lowest one was found in FI treatment as 1.54 kg/m^3. It is known for long that plants growing in dry land with periodic soil drying have a higher WUE (Bacon 2004). Apparently, the increased WUE should be an integrated result of both short-term, as a function of atmosphere condition, and long-term, as a function of soil water availability, regulation of water loss. Improved WUE with a responsive stomatal behaviour is indeed predicted by Cowan (1982) from an analysis of the optimization pattern of water use by plants.

The value of benefits from water savings should be balanced with value of yield reductions and cost of implementing PRD irrigation system compared with conventional systems. The research results also revealed that PRD technique is not suitable for the drip irrigated corn production under water scarcity conditions in the Mediterranean region of Turkey. Considering that the cost of the pipes (all tubing and laterals included) is about 45% of the total cost, one drip lateral per two crop rows (1.40 m lateral spacing) would result in considerable saving in total installation cost of a drip system as reported by Bozkurt et al. (2006). In addition, deficit irrigation of corn using drip system is not recommended in the region because of relatively high cost of the drip system.

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