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Full Length Research Paper

Effects of different drip irrigation levels on yield and some agronomic characteristics of raised bed planted corn

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This study was carried out to determine the effects of different irrigation levels on water use, yield and some agronomic parameters of drip-irrigated corn under the Eastern Mediterranean climatic conditions in Turkey. In the trials, irrigation water was applied as I_{20}: 20%, I_{40}: 40%, I_{60}: 60%, I_{80}: 80%, I_{100}: 100% and I_{120}: 120% of evaporation from a Class A Pan. The seasonal total irrigation water ranged from 55 to 381 mm and seasonal crop water use varied from 365 to 584 mm in different treatments. Irrigation levels significantly affected yield and yield contributing parameters at P<0.01 level. The average corn grain yields varied from 1.93 to 10.4 t ha^{-1}. The highest grain yield and yield components were found in I_{120} while the lowest were found in I_{20} treatment. Irrigation levels had statistically significant effect on fresh and dry above ground biomass production of corn at P<0.01 level. The highest water use efficiency (1.77 kg m^{-3}) value was found in I_{120} treatment. Seasonal yield response factor (ky) was 1.98 in the experiment.

Key words: Agronomic characteristics, corn, drip irrigation, yield, water use efficiency (WUE).

INTRODUCTION

Mediterranean countries are in the midst of a water crisis, and they are among the most arid regions in the world, with limited renewable water resources that are unequally distributed in space and time. Water availability is a prerequisite for the sustainable development of the Mediterranean region, which is characterized by water scarcity and extreme events of droughts and floods. Major current and future problems with fresh water resources in this region arise from the pressure to meet, agricultural, human and industrial needs of a fast-growing economy that generates growing imbalances between demand and supply of water (Yazar et al., 2009). The efficient use of water by modern irrigation systems is becoming increasingly important in arid and semi-arid regions with limited water resources (El-Hendawy et al., 2008). Several authors have shown that the water use efficiency (WUE) and yield of drip irrigated crops could be improved under limited water applications by decreasing the amount of water that leaches beneath the root zone (Viswanatha et al., 2002; Payero et al., 2008; El-Hendawy and Schmidhalter, 2010). Corn is one of the most important crops in the Mediterranean Region in Turkey (Bozkurt et al., 2006; Yazar et al., 2009). Total corn production of Turkey is about 4,250,000 tons in 2009 (Anonymous, 2010). Corn is a popular and nutritious snack food (boiled or charbroil) besides the grain and silage production in Turkey.

In the Eastern Mediterranean region where this study is carried out, irrigation water supplies are mainly from groundwater sources that are being depleted. Odemis et al. (2006) evaluated the seasonal fluctuations of groundwater level and quality in the research area. They reported that the excessive use of water resulted in a decline in the water table levels in the irrigation season and inefficient methods of irrigation lead to desertification as well as deterioration in water quality and quantity over time. However, it is possible to achieve optimum quality and quantity of crop production per unit area if a proper

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Table 1. Long-term mean monthly (1975-2009) and corn growing season (2010) mean climatic data.

Years	Climatic parameters	April	May	June	July
Long- term means (1975-2009)	Max. temperature (°C)	21.8	24.9	27.4	29.8
	Min. temperature(°C)	13.7	17.2	21.8	24.9
	Mean temperature(°C)	17.6	21.1	24.6	27.1
	Relative humidity (%)	76.8	79.6	80.9	81.9
	Rainfall (mm)	62.2	45.6	13.9	5.30
Growing Season (2010)	Max. temperature (°C)	22.4	24.9	28.0	29.7
	Min. temperature(°C)	14.7	19.4	22.7	25.9
	Mean temperature(°C)	14.0	22.0	25.1	27.5
	Relative humidity (%)	72.1	78.3	82.1	87.5
	Rainfall (mm)	58.2	31.1	37.6	0.0

Table 2. Some chemical and physical properties of the experimental soil.

Soil depth (m)	Texture class	Field capacity (%)	Wilting point (%)	Bulk density (t m^{-3})	EC(dS m^{-1})	pH
0.0-0.30	C	42.2	21.8	1.41	0.270	8.1
0.30-0.60	CL	34.4	17.6	1.39	0.266	7.7
0.60-0.90	CL	38.7	22.7	1.45	0.275	8.0

EC – Electrical conductivity of soil in 1:2.5 soil: distilled water suspension.

irrigation method is applied along with other agronomic interventions (Oktem, 2006). The relationships between crop water use (ET) and yield have been a major focus of agricultural research in arid and semi-arid regions (Oktem et al., 2003). Corn has been reported in the literature to have high irrigation requirements. Corn dry matter and grain yield increased significantly by irrigation (Yazar et al., 1999).

However, corn has been reported to be very sensitive to drought. Water stress can affect growth, development, and physiological processes of corn plants, which can reduce biomass and, ultimately, grain yield due to a reduction in the number of kernel per ear (cob) or the kernel weight (Payero et al., 2009). Seasonal ET of corn was reported to be 474 to 605 mm in the Cukurova region of Turkey (Kanber et al., 1990), 353 to 586 mm in the Thrace region of Turkey (Istanbulluoglu et al., 2002), 581 mm in southeast of Turkey (Yazar et al., 2002), 525 to 574 mm in Kirklareli, Turkey (Cakir, 2004), 488 to 497 mm in the Aegean region of Turkey (Dagdelen et al., 2006) and 466 to 656 mm in eastern Mediterranean region of Turkey (Bozkurt et al., 2006). However, local information from East Mediterranean region of Turkey on the response of corn growth, yield and other yield components with drip irrigation is very limited, especially dealing with the effect of limited water allocations.

The objectives of this study are to: (1) determine the effect of water stress occurring during the whole growing season on growth and production of corn; and (2) evaluate the impact of water stress on yield, water use and water use efficiency of drip-irrigated hybrid corn in the Eastern Mediterranean region of Turkey.

MATERIALS AND METHODS

Experimental area and climate

A field experiment by drip irrigated corn (*Zea mays intendata cv* Cadiz) was conducted on the Research and Training Farm of the Samandag Vocational College, Mustafa Kemal University, Hatay, Turkey (36°04'N, 35°57'E, and 3 m above mean sea level) in 2010. Research area has a typical Mediterranean climate conditions with hot-dry summers and mild-rainy winters. Table 1 summarizes the monthly mean weather data compared with the long-term mean climatic data from the locality where the experiment was carried out. The mean temperatures ranged between 14.0 and 27.5°C and the mean relative humidity changed from 72.1 to 87.5% during the study period. During the experimental season, rainfall received (127 mm) was exactly equal to the long-term mean. Other climatic parameters inspected the experiment were also similar to long term data. Consequently, the climatic conditions of experimental period were typical of those that prevail in the Eastern Mediterranean Region of Turkey.

Experimental substructure

The soil of the study area is classified as Alluvial great soil group with medium texture and well drained class. Soil samples were taken with an auger from the soil layers 0 to 30, 30 to 60 and 60 to 90 cm to determine selected physical and chemical properties of the experimental field at the beginning of the experiment (Table 2).

The pH and electrical conductivity (EC) of the soil were measured in 1:2.5 soil:distilled water suspension by means of a combined electrode and EC meter, respectively. Standard methods were used to determine other properties of soils in the experimental field. Available water holding capacity of the soil is 160 mm in the 0.90 m soil profile. Water table depth was well below 90 cm soil profile in the study area. Fertigation was based on soil analysis and all the experimental plots received the same amount of total fertilizer during the growing season. The plots were fertilized with 200 kg P ha^{-1}, 150 kg K ha^{-1} and 250 kg N ha^{-1}. Weed, pest, and disease control were done with chemical agents in a timely manner. Hand harvesting was performed about 115 days after sowing.

Irrigation water used in the study was obtained from a deep well. The irrigation water sampled from the well at the beginning of the study was analyzed and classified by using the standard procedure of Anonymous (1954). According to results of the analyses, the irrigation water salinity was 1.5 dS m^{-1} and has no serious harmful effect on plant growing. Irrigation was applied by surface drip irrigation system. The drip laterals were 16 mm in diameter. The drippers placed 0.30 m apart were inline type and had 1.7 L h^{-1} flow rate at a pressure of 100 kPa. Drip laterals were placed at the center of adjacent crop rows on the experimental beds. The irrigation system has a typical control unit consisted of a pump, fertilizer tank, centrifugal sand separator, disc filters, control valves, pressure gauges and a flow meter. The amount of irrigation water was controlled by the flow meter. Each plot had one valve to control water application. The amount of water to be applied to each treatment plot was based on cumulative evaporation from Class A pan within the two irrigation events. Three tensiometers were installed at 30 cm depth on I_{100} treatment plots for irrigation timing. Irrigations were started in all plots when the tensiometer readings in the I_{100} treatment plots reached 30 cbar.

Experimental design and statistical analysis

Corn seeds were sown on March 16 (Day of the year-DOY 75) and hand harvested on July 7 (DOY 188) in the experiment. The plots were arranged in randomized complete blocks with three replications. Different irrigation water levels were randomly assigned to the plots. Each experimental plot was designed as 3.9 m wide 12.0 m long (6 rows per plot) and had a total area of 46.8 m^2. Each plot consisted of 3 raised beds with two adjacent crop rows formed a bed. Plants were arranged on the raised-bed at 20 cm spacing in each row. The irrigation treatments considered in the study were full irrigation (I_{100}) corresponding to 100% of total Class A pan evaporation, 120% of full irrigation (I_{120}; 20% excessive), 80% of full irrigation (I_{80}; 20% deficit), 60% of full irrigation (I_{60}; 40% deficit), 40% of full irrigation (I_{40}; 60% deficit) and 20% of full irrigation (I_{20}; 80% deficit). After the crop establishment period, water stress was applied continuously during the all growing cycle in the all deficit irrigation treatments.

All collected data in this study were analyzed using analysis of variance (ANOVA) appropriate for a randomized complete block design with three replications. Mean separation of treatment effects in this study was accomplished using Least Significant Difference (LSD) test. Probability levels lower than 0.05 or 0.01 were held to be significant. EXCEL and MSTAT-C statistical analysis software were used to analyze data and draw graphs, respectively.

Irrigation practices and methodology

To avoid plant stress, 15 mm of water were applied to all irrigation treatment plots at the beginning with an additional irrigation of 40 mm for uniform plant establishment. Irrigation was carried out three times during this stage. Thereafter, irrigation treatment was started according to the prescribed irrigation rates. The first treatment irrigation was carried out on April 19, 2010 (DOY 109) and the final application was done on July 3, 2010 (DOY 184). A total of eleven irrigation applications were made and treatments received irrigation water depths varying from 55 mm in I_{20} to 381 mm in I_{120} irrigation treatments. Irrigation intervals varied from 8 to 10 days in April and May to 5 to 7 days in June. Crop water use (ET) was estimated based on the one dimensional water balance equation using soil water measured by the gravimetric sampling methods. Water use was the total of seasonal water depletion plus rainfall and irrigations during the same period. The water balance equation is as follows:

$$ET = I + P \pm \Delta S - D \qquad (1)$$

Where: ET is evapotranspiration (mm), I irrigation (mm), P precipitation (mm), D deep percolation (mm) and ΔS is change of soil water storage in a given time period Δt (days) within plant rooting zone. Deep percolation losses below the root zone were assumed to be zero in the study. During the experimental period, the variation of soil water content at 0 to 30, 30 to 60 and 60 to 90 cm soil depths in each treatment plot was continuously determined one day before an irrigation event until harvest by the gravimetric method (oven dry basis) for calculating the evapotranspiration.

Water use efficiency (WUE, kg m^{-3}), defined as the ratio of grain yield to seasonal ET, and irrigation water use efficiency (IWUE, kg m^{-3}), as the ratio of grain yield to the seasonal amount of irrigation water (I) applied, were calculated (Howell et al., 1990). Regression analysis was used to evaluate the water use–yield relationships derived from seasonal crop evapotranspiration and grain yield data obtained from the experiment. Seasonal values of the yield response factor (*ky*) which represent the relationship between relative corn yield reduction (1-Ya/Ym) and relative evapotranspiration deficit (1-ETa/ETm), were determined using the equation given by Doorenbos and Kassam (1980):

$$1\text{-}Ya/Ym = ky\,(1\text{-}Eta/ETm) \qquad (2)$$

Where, ETa and ETm are the actual and maximum seasonal crop evapotranspirations (mm), respectively, and Ya and Ym are the corresponding actual and maximum yields (kg ha^{-1}). *K*y the yield response factor.

Measurements and observations

The plant growth parameters were observed throughout the study. For this purpose, three plants in each replication plot at about 15 to 20 days intervals were randomly selected representing all the characteristics of its treatment. The plants were cut at ground level and plant height, stem diameter and leaf number measurements were carried out on these selected plants and average values were calculated for each treatment. Fresh weights of plant parts (stem, leaves, cob, etc.) were measured to determine the above ground biomass (AGB) by a digital scale. The dry-weight of the plant parts were determined by oven-drying samples at 70°C until constant weight was achieved. Area of green leaves was measured with a digital planimeter (X-Plan 300C+, Ushikata Mfg. Co., Ltd. Tokyo, Japan), then Leaf Area Index (LAI) was calculated.

Hand harvesting was performed about 115 days after sowing. Corn fresh ear (cob) and grain yields were measured by hand-harvested ten plants at the center bed of each plot. Grain yield values were adjusted to 15.5% moisture content. In addition, cob length and diameter, row and grain number per cob, grain weight per cob and 1000-kernel weight values were also evaluated. Harvest index (HI) is calculated as the ratio of the grain yield to above ground dry matter yield at harvest (Yazar et al., 2009).

Table 3. Seasonal irrigation water (I), rainfall (R), total received water (I+R), seasonal water use (ET), water use efficiency (WUE) and irrigation water use efficiency (IWUE) of corn under different treatments.

Treatments	Grain yield (kg ha^{-1})	I (mm)	R (mm)	I+R (mm)	Soil water depletion (mm)	ET (mm)	WUE (kg m^{-3})	IWUE (kg m^{-3})
I_{20}	1930	55	127	182	183	365	0.53	3.51
I_{40}	5623	120	127	247	160	407	1.38	4.68
I_{60}	6213	185	127	312	152	464	1.34	3.35
I_{80}	6797	250	127	377	126	503	1.35	2.71
I_{100}	7487	316	127	443	102	544	1.38	2.37
I_{120}	10370	381	127	508	76.9	584	1.77	2.72
Epan, mm					316			
No of irrigation					11			

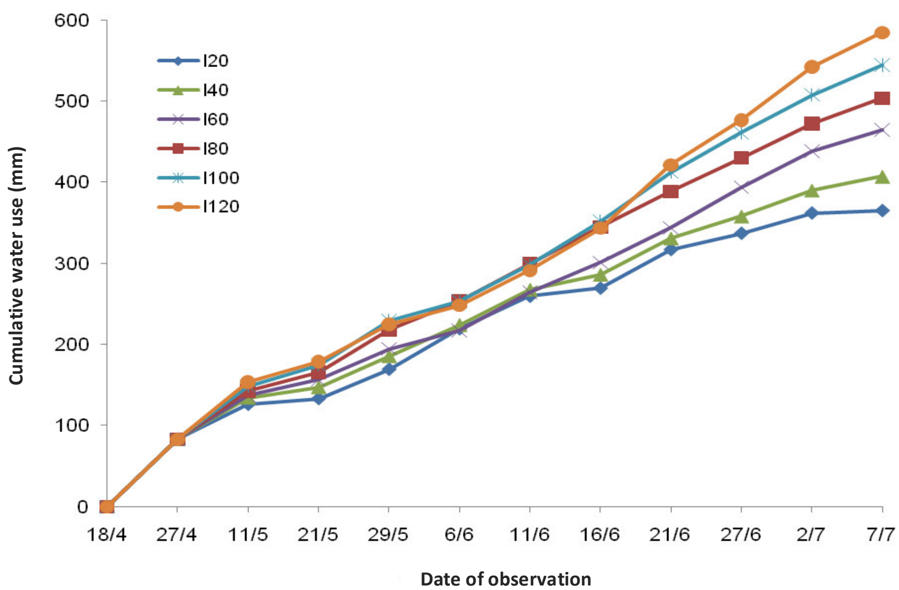

Figure 1. Cumulative water use in different irrigation treatments.

RESULTS AND DISCUSSION

Plant water use characteristics

Table 3 gives a summary related to seasonal amount of irrigation water applied (I), crop water use (ET), precipitation (R), pan evaporation (Epan), WUE and the IWUE of corn for the irrigation treatments. Seasonal total water received (irrigation water plus rainfall, TRW) varied from 182 mm in I_{20} to 508 mm in I_{120} irrigation treatment plots. Seasonal total irrigation water applied in our study are in agreement with the other reported literature such as Cavero et al. (2000) 568 and 505 mm for the semiarid region of Spain, Yazar et al. (2002) 581 mm for southeast Turkey. The seasonal crop ET varied from 365 to 584 mm among the different irrigation treatments (Table 3). Variation of cumulative water use of the crop during the growing season in different irrigation treatments is shown in Figure 1. The highest ET was observed in excess (I_{120}) irrigation treatment as 584 mm, and the lowest ET was measured in I_{20} treatment as 365 mm. Seasonal ET increased with increasing irrigation rates. Seasonal crop ET was higher at higher irrigation levels than the deficit irrigation treatments. There was a significant linear relationship (R^2=0.99) between ET and I or TRW. Similar seasonal ET trends were reported by Vural and Dagdelen (2008) and Yazar et al. (2009). The status of soil water content (SWC) was measured one day before an irrigation event during the experimental period by the gravimetric method. Variation of SWC in the 0.90 m soil profile under the irrigation treatments are shown in Figure 2. The SWC fluctuated between field capacity (346 mm) and wilting point (186 mm) and decreased gradually during the experiment in all irrigation treatments. While the excess irrigation treatment (I_{120}) ensured the highest SWC during the study, full irrigation treatment (I_{100}) were

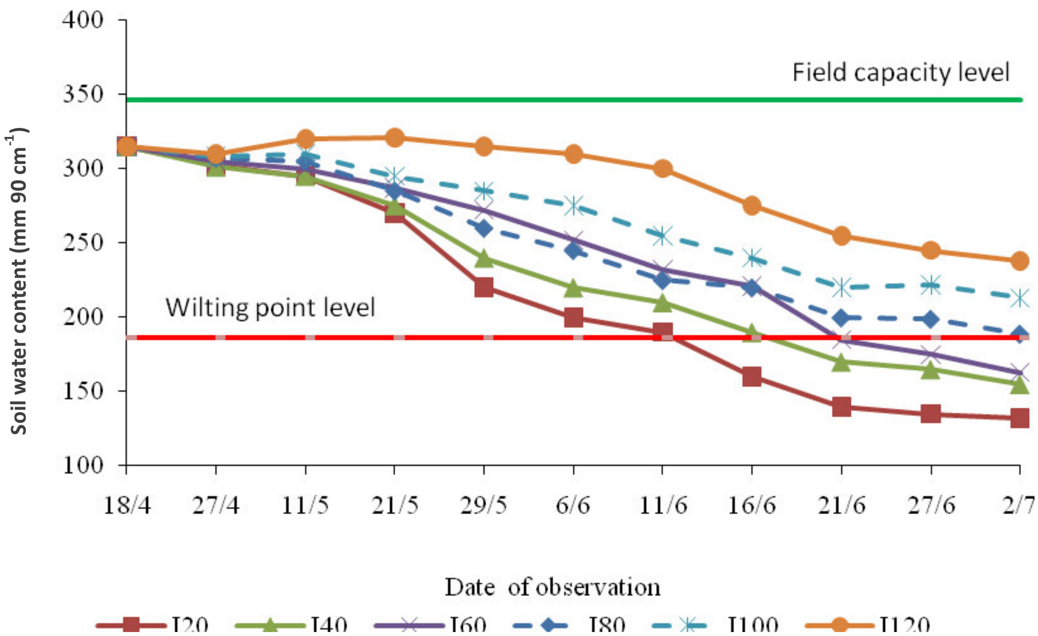

Figure 2. Variation of profile soil water content prior to irrigation under different irrigation treatments.

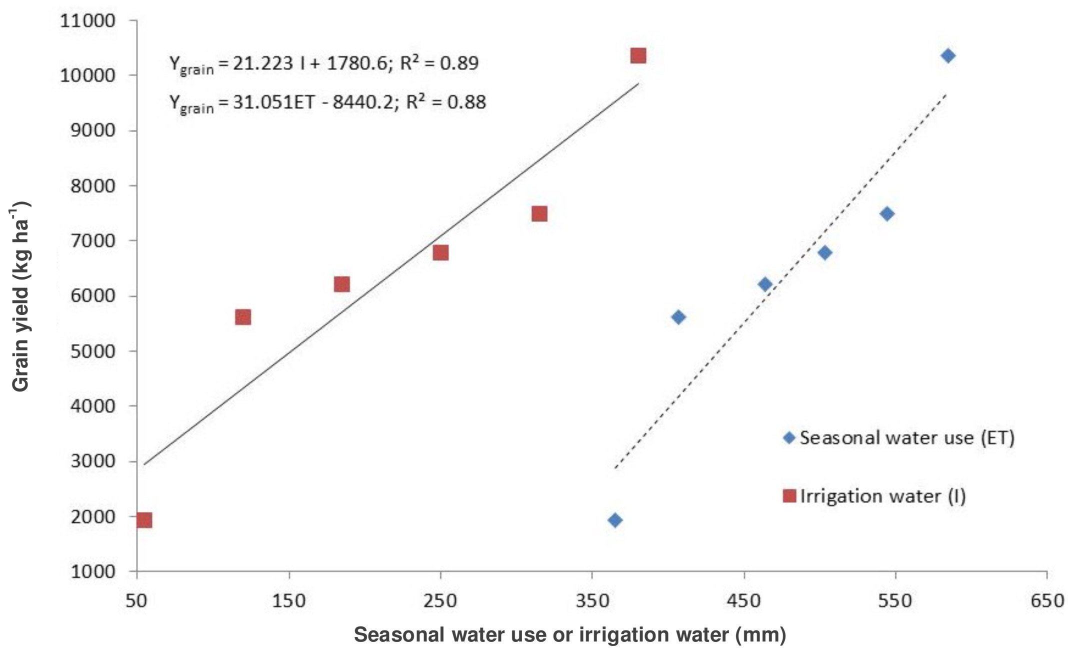

Figure 3. The relationship between corn grain yield and seasonal irrigation water (I) or seasonal water use (ET) under different irrigation levels.

unable to supply adequate SWC at grain filling stages. At this stage, 14 % water stress developed in I_{100} irrigation treatment compared to I_{120} treatment. Yield response of plant to this stress was intense and resulted with 28% grain yield reduction. Soil water depletions in deficit irrigation treatments were higher than the full or excess irrigation treatments. The SWC in deficit irrigation treatments except for I_{80} treatment fell below the wilting point level after the DOY 162. The degree of soil water depletion was depending on irrigation water amounts applied. Hence, decreased irrigation amounts applied in deficit irrigation treatments caused excess soil water

Table 4. The results of variance analyses for yield and yield parameters.

Parameter		Mean square	F value	CV %
Growth parameters	No of leaves per plant	3.27	9.72**	4.70
	Stem diameter (mm)	17.2	172.00**	1.48
	Crop height (cm)	6798.5	6.61**	12.7
	LAI	1.37	3582.54**	0.47
	Fresh AGB (t ha^{-1})	2064.3	22976.14**	0.46
	Dry AGB (t ha^{-1})	157.0	54.90**	7.92
Yields	Grain yield (t ha^{-1})	22.65	34.14**	12.7
	Fresh ear yield (t ha^{-1})	70.55	32.17**	10.8
	Harvest index (HI)	0.014	6.813**	15.3
Yield components	Fresh ear weight (g)	11931.6	32.58**	10.7
	Cob grain weight (g)	7840.6	34.14**	12.7
	Cob length (cm)	14.40	62.09**	2.82
	Cob diameter (cm)	72.66	28.13**	3.51
	No of row per cob	6.81	10.06**	5.20
	Grain number per cob	59735.3	22.54**	12.1
	1000-kernel weight (g)	6920.9	42.15**	4.74

depletion, consequently, relatively higher yield reduction. Similar soil water depletion trends were reported by Yazar et al. (2009).

Significant linear relationships (R^2=0.89) were found between grain yield and seasonal irrigation, as well as between grain yield and water use (R^2=0.88) as shown in Figure 3. El-Hendawy and Schmidhalter (2010) reported that the crop yield-water production function for corn is often linear, especially in the deficit irrigation range, because all the applied water is used. However, nonlinear relationships have also been reported by Gencoglan and Yazar (1999) and Bozkurt et al. (2006).

The IWUE values increased with the decreasing seasonal irrigation amounts or seasonal water use (Table 3). The IWUE values obtained in this study ranged from 2.37 to 4.68 kg m^{-3} and were mostly in good agreement with those values previously reported in the literature for corn. The highest WUE was found in I_{120} as 1.77 kg m^{-3}, and the lowest one was found in I_{20} as 0.53 kg m^{-3}. Significant linear relationships were obtained between grain yield and WUE from the regression analysis. The equation for the relationship was Y_{grain}= 6.417 WUE - 1.884 with R^2= 0.91. The results of the WUE or IWUE in Table 3 indicate that the decreased water applications up to 40% compared to the full irrigation may be sufficient for acceptable grain yields in drought condition.

The yield response factor (*k*y) was determined as 1.98. This result was in agreement with the findings reported in the literature. For instance, the average *k*y values of 1.81 to 1.86 determined by El-Hendawy and Schmidhalter (2010) were reported for total growing season of corn. The average ky value determined from our study is higher than that of 0.93 pointed out by Kanber et al. (1990) for the coastal part of Cukurova, that of 0.76 estimated for the coastal part of Thrace by Istanbulluoglu et al. (2002) and that of 0.89 obtained by Yazar et al. (2002). The differences can be attributed to local soil, climatic and production conditions as well as irrigation programs applied.

Plant yield and yield components

Fresh ear yield and grain yield were significantly affected by the water application levels (P<0.01) as shown in Table 4. The results revealed that crop water use and yields were clearly related. The higher the crop water use, the higher the fresh ear yield and the grain yields of corn. Linear relationships were found between seasonal ET and fresh ear yield of corn. Equation of the relation was $Y_{freshear}$= 55.14 ET-12618 (R^2=0.89). While the highest fresh ear yield was obtained from the I_{120} irrigation plots as 20.8 t ha^{-1}, the lowest one was in I_{20} plots as 5.97 t ha^{-1} (Table 5). Garcia et al. (2009) reported that the highest fresh ear yield of 20.4 t ha^{-1} was obtained for the April 10 planting date under irrigated conditions and the lowest fresh ear yield of 13.1 t ha^{-1} was obtained for the March 27 planting date under rain-fed conditions. However, Oktem et al. (2003) reported that the highest fresh ear yield of sweet corn was 13.66 t ha^{-1} for the 2-day irrigation frequency with 100% ET water application by a drip system.

Corn grain yield was significantly increased by the irrigation level (P<0.01). Highest yield, averaging 10.4 t ha^{-1},

Table 5. The effect of irrigation treatments on vegetative growth and yield components of corn for the experimental period.

Parameter		Irrigation treatments						
		I_{20}	I_{40}	I_{60}	I_{80}	I_{100}	I_{120}	$LSD_{0.05}$
Growth parameters	No of leaves per plant	12.9^{ab}	13.4^{a}	12.2^{bc}	13.2^{ab}	11.7^{c}	10.6^{d}	1.06
	Stem diameter (mm)	21.0^{b}	19.3^{d}	20.0^{c}	20.3^{c}	26.0^{a}	21.3^{b}	0.58
	Crop height (cm)	180.0^{c}	215.7^{bc}	284.0^{a}	295.3^{a}	295.3^{a}	245.0^{ab}	58.4
	LAI	3.1^{f}	3.3^{e}	3.9^{d}	4.3^{c}	5.0^{b}	5.4^{a}	0.02
	Fresh AGB (t ha^{-1})	30.1^{f}	46.3^{e}	56.4^{d}	76.1^{c}	81.6^{b}	102.4^{a}	0.54
	Dry AGB (t ha^{-1})	11.5^{e}	16.0^{d}	19.6^{c}	23.6^{b}	25.6^{b}	31.8^{a}	3.08
Yields	Grain yield (t ha^{-1})	1.93^{d}	5.62^{c}	6.21^{bc}	6.80^{bc}	7.49^{b}	10.4^{a}	1.48
	Fresh ear yield (t ha^{-1})	5.97^{d}	12.1^{c}	13.5^{bc}	14.3^{bc}	15.7^{b}	20.8^{a}	2.69
	Harvest index (HI)	0.16^{b}	0.35^{a}	0.33^{a}	0.29^{a}	0.29^{a}	0.33^{a}	0.081
Yield components	Fresh ear weight (g)	77.2^{d}	157.6^{c}	175.0^{bc}	186.0^{bc}	204.0^{b}	270.5^{a}	34.8
	Grain weight per cob (g)	35.9^{d}	104.5^{c}	115.6^{bc}	126.4^{bc}	139.2^{b}	193.0^{a}	27.6
	Cob length (cm)	12.9^{c}	17.8^{b}	16.9^{b}	17.7^{b}	17.7^{b}	19.4^{a}	0.88
	Cob diameter (mm)	36.4^{c}	48.2^{a}	44.7^{b}	47.5^{ab}	47.6^{a}	50.1^{a}	2.92
	No of rows per cob	13.0^{b}	15.5^{a}	16.6^{a}	16.0^{a}	17.0^{a}	16.9^{a}	1.50
	Grain number per cob	200.2^{d}	402.1^{bc}	391.3^{c}	423.7^{bc}	495.1^{b}	631.1^{a}	93.7
	1000-kernel weight (g)	178.0^{d}	260.1^{c}	295.4^{ab}	299.6^{ab}	281.7^{bc}	306.2^{a}	23.3

was measured in the I_{120} treatment (Table 5). The results in this study are in agreement with some literature. For instance, Gencoglan and Yazar (1999) reported that average corn grain yields were 1.05 t ha^{-1} for non-irrigated treatment and 10.02 t ha^{-1} for full irrigated treatment. Yazar et al. (2002) reported also that the highest average corn grain yield obtained from the full irrigation treatment with 6-day irrigation interval using drip irrigation method with 11.92 t ha^{-1}. Irrigation treatments had significant effect ($P<0.01$) on harvest index (HI) values in the experiment (Table 4). However, HI values for the treatments were in the same LSD group except for severe deficit irrigation treatment (I_{20}) (Table 5). The excess soil water deficit in I_{20} treatment affected the HI values, adversely. The effects of the irrigation strategies applied in this study were statistically significant also for other yield components such as cob diameter and length, no of rows per cob, grain number per cob, 1000-kernel weight and grain weight per cob. It was found that these components were higher in full or excess irrigation treatments as compared to the deficit irrigation rates.

The highest grain weight per cob, grain number per cob and 1000-kernel weight was observed in I_{120} treatment (Table 5). Grain weight per cob varied from 35.9 for I_{20} treatment to 193.0 g for I_{120} treatment. Similarly, Bozkurt et al. (2006) reported that the grain yield per cob varied from 153.3 g for deficit irrigation to 194.9 g for full irrigation treatments. The 1000-kernel weight in current experiment varied from 178.0 to 306.2 g among treatments. Maximum deficit irrigation (I_{20}) treatments led to smaller fresh ear weight consequently, smaller kernels compared to those gained from the adequate or excess irrigation treatments (Table 5). This finding is consistent with the findings given by Bozkurt et al. (2006). As the applied irrigation amount increased, the grain number or grain weight per cob also increased. There were positive linear relationships between crop water use and grain weight per cob (R^2=0.88), number of grains per cob (R^2 = 0.85), 1000-kernel weight (R^2=0.66), cob length (R^2 = 0.64) and cob diameter (R^2=0.57) in the experiment.

Plant growth parameters

Plant growth parameters such as crop height, number of leaves, leaf area or LAI, stem diameter, fresh above ground biomass (F-AGB) and dry above ground biomass (D-AGB) was affected significantly ($P<0.01$) by the irrigation treatments (Table 4). The plots receiving the full (I_{100}) irrigation resulted in significantly higher stem diameter (26 mm) than deficit or excess irrigation treatments. The effects of irrigation treatment on crop height were not clear. While the I_{60}, I_{100} and I_{120} treatments were in the same LSD group, which had higher crop height values than I_{20} plots had lowest value. Polynomial relationships were obtained between crop height and seasonal ET of corn from the regression analysis. The equation for the relationship was $Y_{Height} = -0.0063ET^2 + 6.33ET-1306.2$ with R^2= 0.95.

The plots receiving the slightly deficit irrigation (I_{80})

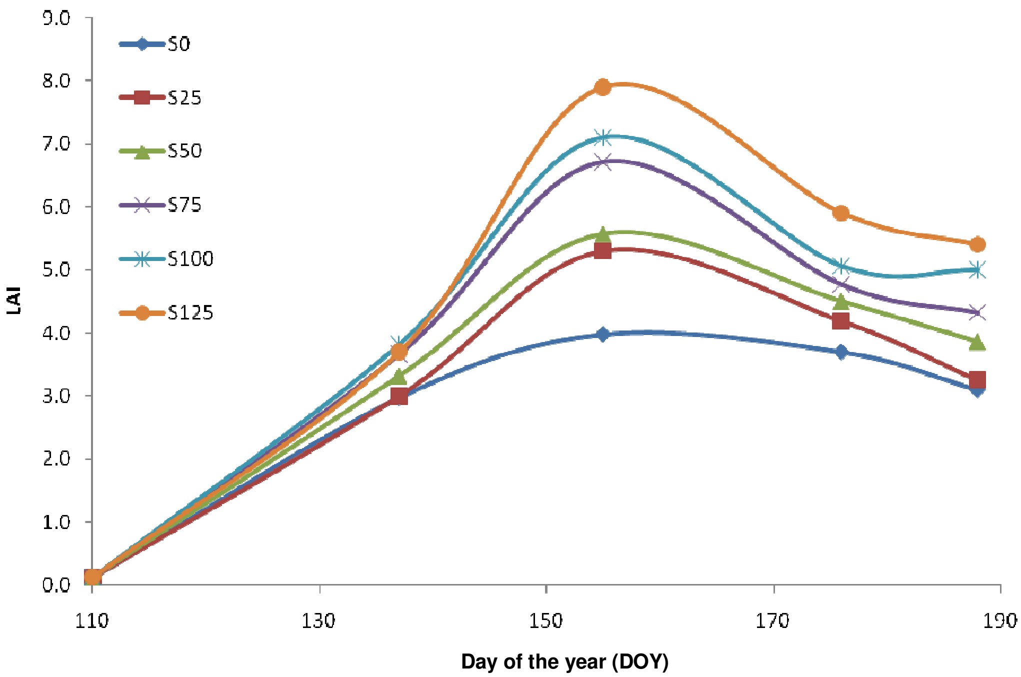

Figure 4. Leaf area index development of corn during the growing period in different irrigation treatments.

resulted in significantly higher leaf number than full or excess irrigation treatments. However, it was determined that the higher the number of leaves, the lower the leaf area per plant or LAI. The equation for the relationship between number of leaves (LN) per plant and LAI of corn was LAI=-0.726 LN + 13.11 with R^2=0.67. LAI values were increased with the amount of irrigation water applied from I_{20} to I_{120} irrigation treatment (Table 5). Development of LAI with time in irrigation treatments is shown in Figure 4. As reported earlier by Cakir (2004), LAI development of corn was very slow in the first part of the vegetative stage, followed by an intensive increase during tasselling and ear formation. While maximum LAI was observed in I_{120} plots with 7.9 and the lowest one was measured in I_{20} plots exposed to water stress as 4.0 at the anthesis growth stage (DOY 155), maximum LAI was in I_{120} plots with 5.4 and the minimum was in I_{20} plots as 3.1 at the harvest time (DOY 188). Montemayor-Trejo et al. (2007) reported similar results that the maximum corn LAI under subsurface drip irrigation was 5.1. LAI values following anthesis declined gradually towards the end of the growing season in all plots. Similar LAI development trends were reported by Yazar et al. (2009). Linear relationships were observed between LAI and the ET from the regression analysis. The equation for the relationship was LAI= 0.011ET+1.132 with R^2= 0.98. A positive correlation between LAI and ET was also reported by Kang et al. (1998). Linear relationships were also observed between LAI and grain yield (t ha^{-1}) of corn from the regression analysis. The equation for the relationship was Y_{grain}= 2.645LAI – 4.587 with R^2=0.80.

Irrigation treatments had a statistically significant effect on fresh and dry above ground biomass production of corn at P<0.01 level (Table 4). Fresh and dry AGB accumulation during the whole growing period of corn was shown in Figure 5. Fresh and dry AGB accumulation of corn was very rapid up to tasselling stage, followed by a poor increase during ear formation. The water shortages in deficit irrigation treatments resulted in lower fresh and dry AGB as compared to the full or excess irrigation treatment. Significant linear relationships were found ET and Fresh or dry AGB production. Equations of the relations were AGB=3.994 ET-1068.5 (R^2=0.98) for fresh AGB and AGB=0.814 ET-128.4 (R^2=0.90) for dry AGB. Fresh AGB values varied from 30.1 for the I_{20} plot to 102.4 t ha^{-1} for the I_{120} plot among the treatments. Similarly, dry AGB values varied from 11.5 in I_{20} plot to 31.8 t ha^{-1} in I_{120} plot among the treatments (Table 5). Yazar et al. (2002) reported that the corn dry matter yields increased with increasing evapotranspiration ranged from 33.5 to 48.4 t ha^{-1} across treatments. Bozkurt et al. (2006) also reported that the total dry matter production varied from 22.2 to 31.4 t ha^{-1}.

Conclusions

The results of this corn research indicated that irrigation with 120% of Class A pan evaporation by a drip system would be optimal under adequate water source conditions. However, slightly deficient irrigation applications would be acceptable under scarce water conditions for

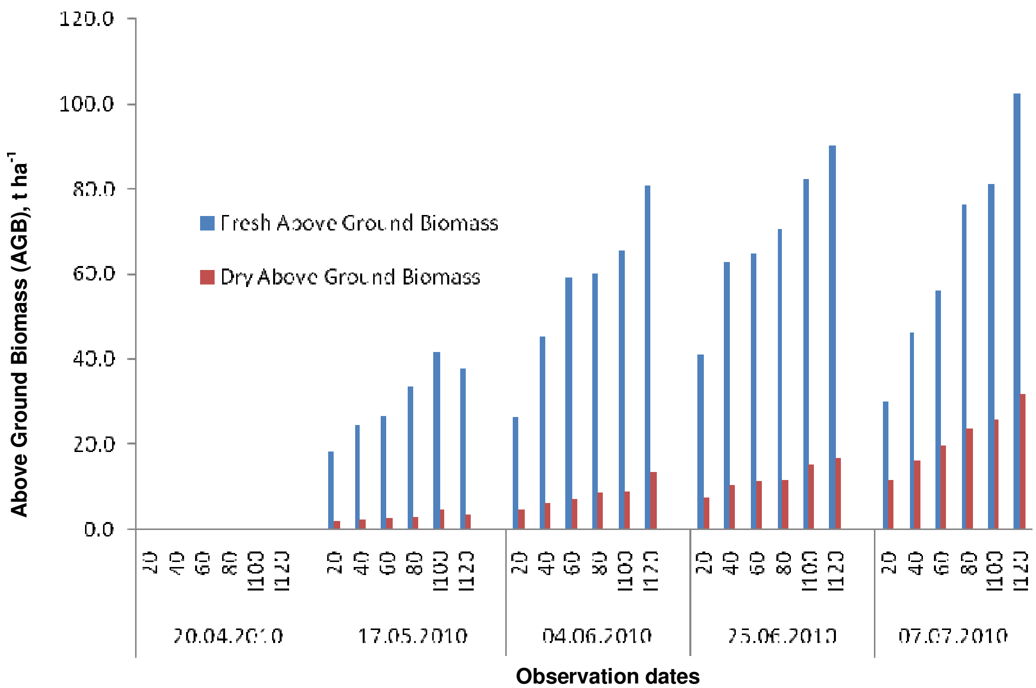

Figure 5. Fresh and dry AGB of corn during the growing period in the irrigation treatments.

corn grown in similar regions where this work was conducted.

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