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WATER - GRAIN AND BIOMASS YIELD RELATIONS OF WINTER WHEAT IN A SEMI-ARID CONDITIONS OF TURKEY

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Abstract
The aim of this study was to determine the effect of different irrigation regime on winter wheat yield and water-use efficiency (WUE). The field experiment was carried out between the year 2009 and 2011 at Murted Basin in Turkey with 4 different irrigation treatments which was Rainfed (RF), Full irrigation (FI), Moderate irrigation (MI), and Deficit irrigation (DI). Soil moisture was measured with neutron probe. According to results average wheat yield was obtained 3.35 t ha^{-1}, 4.54 t ha^{-1}, 4.22 t $ha^{-1}$and 4.31 t ha^{-1} and average harvest index was 29%, 31%, 32% 31% and 32% for RI, FI, MI and DI irrigation treatments respectively. The highest WUE value with 9.1 kg m^{-3} was calculated at DI treatment. A significant negative correlation was found between grain yield, total harvested biomass and the WUE. The results presented in this work suggest that the amount of soil water content affects grain yield and water use efficiency. It might be recommended that irrigation concentrated in the after heading period (DI) increase WUE in semi-arid climate condition such as Central Anatolia Region of Turkey.

Keywords: Wheat, water use efficiency, irrigation.

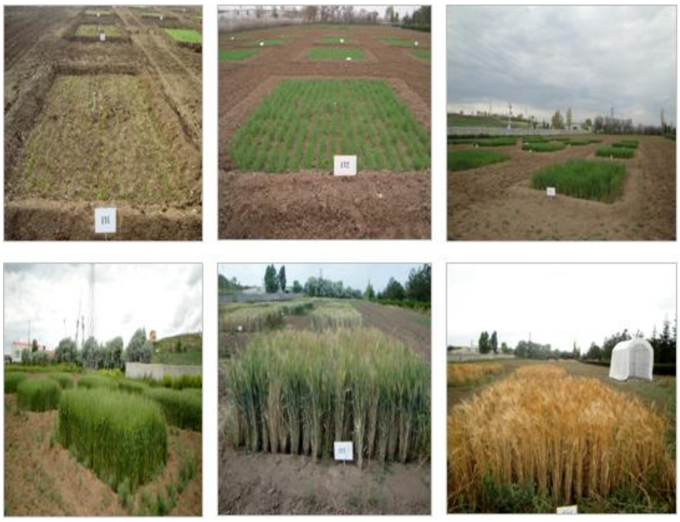
Introduction

One of the most important consequences of the climate change, perhaps the most important one, is its One of the most important consequences of the climate change, perhaps the most important one, is its negative effects on water sources (Agnew, 2011; Barnett et al. 2005). Turkey, particularly the Central Anatolia Region, is adversely affected due to high temperature and lack of precipitation. (Turkes and Akgunduz, 2011). Wheat is the main crop in this area. Approximately 90% of the agricultural lands do not compensate sufficient precipitation during the crop growing period (Cayci et al. 2009). Irrigation is necessary for this lands to avoid water stress and maximize wheat yield. Several researcher frequently emphasized that wheat has different sensitivity to water stress at different growth stages such as booting and heading (Zhang et al. 1998; Varga et al. 2013). Several studies have shown that the water use efficiency (WUE) is very essential indices for identifying the optimum water management strategies (Taylor et al. 1983; Musick et al. 1994; Kharrou et al. 2011). Consequently, the increase in WUE commonly causes to a decrease in the amount of total dry matter (Oweis et al. 1998). The aim of this study was to determine the impact of different irrigation regime on winter wheat crop and water-use efficiency.

Material and methods

The experiment was carried out at Saraykoy research station of Soil, Fertilizer and Water Resources Central Research Institute (39° 57′N and 32° 53′E) of central part of Turkey during the growing season 2009 to 2011. The soil of the research areas is mostly silty clay and field capacity about 35%, and wilting point 20% by volume for 90 cm soil profile. The climate is characterized as semi-arid where annual rainfall and evaporation is about 360 mm and 1300 mm respectively as an average for long time period. Wheat (*Triticum aestivum* L.) is major crop which is generally planted in the late fall.

The experiment was conducted with four different irrigation water strategies and a completely randomized block design with four replications. Treatments were; RF; Rainfed, FI; Full irrigation MI; Moderate irrigation (2 irrigation maximum) DI; No irrigation after establishment until heading. Each plot area was 17.5 m^2 (Picture 1). The wheat cultivated at 2009-2010 and 2010-2011 growing season.



Picture 1. Field experiment design

The sowing date was late October in all study period. Commercial N fertilizers was divided into two, half was applied at planting and the other half was at early tillering stage (110 kg N ha^{-1}). Approximately 50 kg P ha^{-1} were applied to ensure adequate phosphorous nutrition. Meteorological data were measured on hourly basis from automatic meteorological station at the field site. Irrigation water were applied with basin method. Soil moistures contents were monitored using a neutron probe (CPN) from soil surface to 90 cm soil depth with 20 cm interval twice a week. ET value was calculated according to the "Soil Water Budget".

$$ET = I + P + \Delta S - R - D$$

I = Irrigation water (mm),

P = Precipitation (mm),

ΔS = Change in soil water content (mm),

R = Surface flow (mm),

D = Percolation from the root zone to depth.

Results and discussion

Daily precipitation and ET_o values from the year 2008 to 2012 (including experimental period 20 October 2009 -15 July 2011) was given at Figure 1. As apparent from the graph, although the amount of rainfall during the winter months in 2010-2011 was not high, it reached high levels in autumn and spring season.

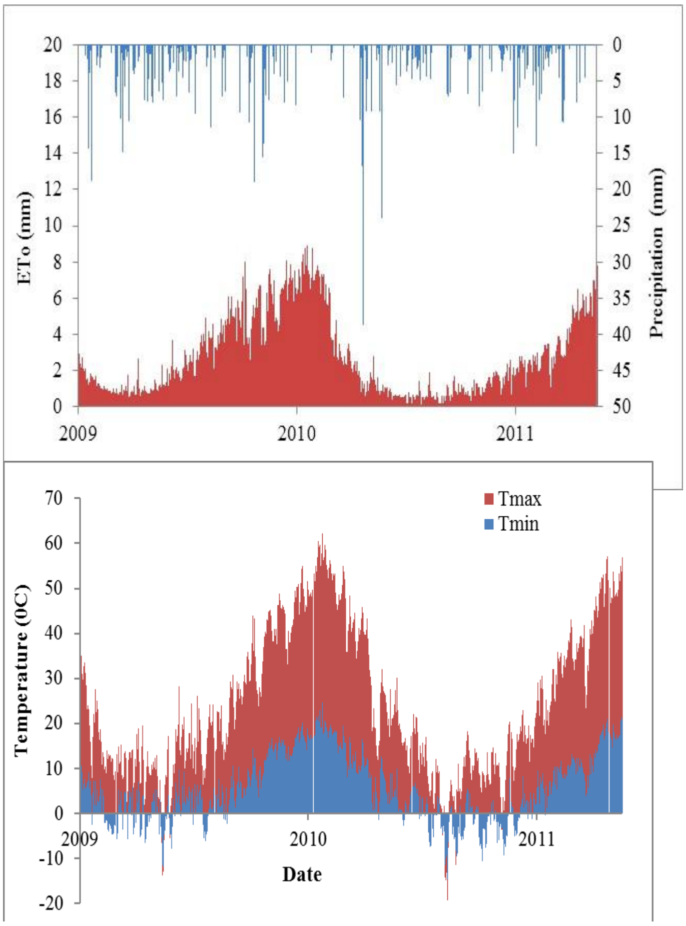


Figure 1. Daily precipitation and ET_o distribution for growing seasons

Average applied irrigation water amount was about 247 mm, 151 mm and 133 mm for FI, MI and DI treatments respectively. The changes of soil water content for whole growing period were presented in Figure 2.

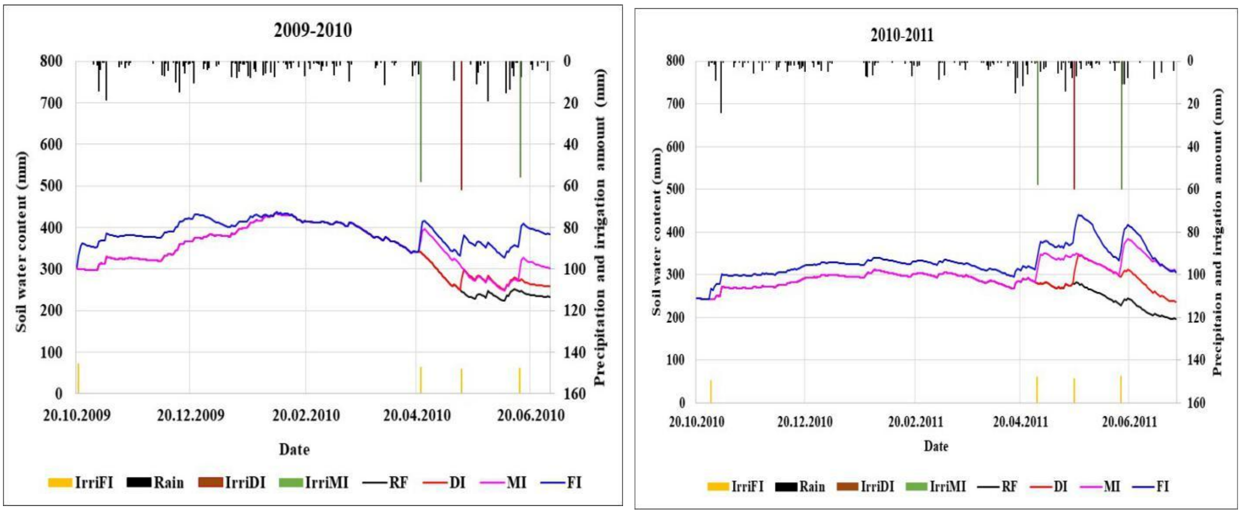


Figure 2. Soil water content data (for the growth period of 2009-2010 and 2010-2011)

The changes in soil profile moistures showed a compatible change depending on the rainfall and irrigation treatments. Irrigation significantly affected to soil water content. Irrigation water had been applied until field capacity level at each irrigation event. Monthly and seasonal plant water consumptions are given in the Table 1 in line with the applied irrigation water and rainfalls. Soil water changes in the soil of 0-90 cm depth were used for the plant water consumption calculations. The highest water consumption was occurred at full irrigation treatments.

Table 1. Monthly and seasonal water consumption of treatments

Years	Treatments	ET (mm)							
		Oct.*	Nov.	Decem.	Apr.	May	June	July**	Total
2009-2010	RF	33.39	61.78	112.44	60.61	58.01	70.27	25.84	422.34
	FI	49.47	77.96	112.43	125.67	120.14	95.29	27.89	608.85
	MI	37.48	49.88	110.55	122.64	119.75	112.35	21.98	574.63
	DI	33.31	57.82	106.37	68.60	92.25	107.23	20.71	486.29
2010-2011	RF	17.53	58.33	59.31	72.50	68.16	76.92	56.23	408.98
	FI	25.27	63.82	82.65	101.48	129.42	96.25	54.71	553.60
	MI	14.42	50.40	57.39	105.21	99.39	105.27	57.48	489.56
	DI	15.14	53.21	52.47	86.14	103.81	93.53	56.34	460.64

*, **; For 10 and 20 days

The highest grain yield (GY) and above ground biomass (BM) (4.55 t ha^{-1} and 14.71 t ha^{-1}) was obtained from FI treatment. Average grain yield values of full irrigated treatment was 26.37%, 3.30% and 8.79% higher than RF, DI and MI treatments respectively. Harvest index (HI) values of the plots were calculated using the grain yield and biomass values (HI = Grain yield / Biomass yield). The highest average harvest index was found in DI, with the percent of 32.2. Average grain yield, abouve ground biomass and harvest index values of treatments were given at Figure 3.

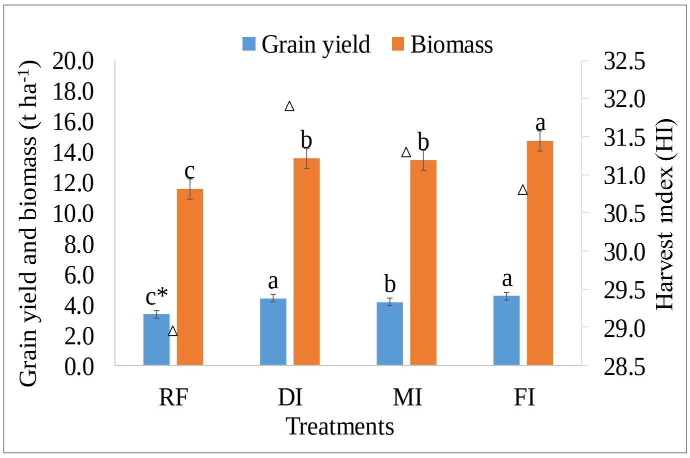


Figure 3. Average yield, biomass and harvest index values and (*) indicated that Duncan classes of treatments

Results of variance analysis showed that the difference between GY and BM of treatments was statistically significant (P <0.05). Additionally, GY and BM and HI was also positively correlated. Determination coeeficient (R^2) was 0.88 for GY, BM relationship and 0.66 for GY, HI relationship as given at Figure 5. Sevaral researcher reported similar results (Yagbasanlar et al., 1995; Villagas et al., 2001).

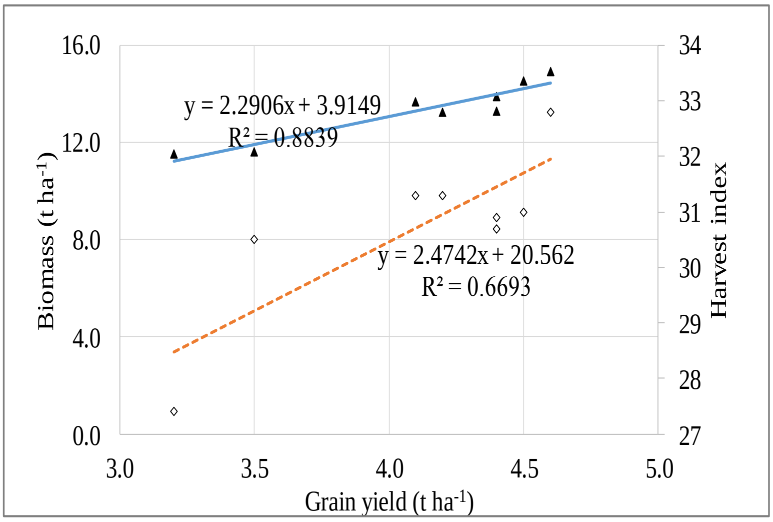


Figure 4. Relationship between grain yield, biomass and harvest indexes

WUE was calculated as grain yield (kg ha^{-1}) divided by seasonal ET (mm). According to treatments calculated WUE values, irrigation amount and ETo values were presented in Table 2. Some researcher reported that the winter wheat WUE ranges from 4.0 to 18.3 kg ha^{-1} mm^{-1} globally on a yield basis (Anderson, 1992; Oweis, et al., 2000).

Table 2. WUE values by treatments

Years	Treatments	ET (mm)	Yields (t ha^{-1})	WUE (kg ha^{-1} mm^{-1})
2009-2010	RF	422	3.54	8.38^{b}
	FI	609	4.58	7.52^{b}
	MI	575	4.15	7.22^{b}
	DI	486	4.36	8.97^{a}
2010-2011	RF	409	3.16	7.72^{b}
	FI	554	4.49	8.10^{b}
	MI	490	4.28	8.73^{b}
	DI	461	4.25	9.22^{a}

The water use had the lowest efficiency in the treatments MI and FI treatments. Applied irrigation water was positively affected to season ET_o (Zhang et al., 2008; 2011). The highest ET_o and grain yield values were obtained from FI treatment. As it was reported by Chang et al. (2014) while increasing ET values WUE was decreased and grain yield was increased. However according to results the highest WUE value was achieved at DI treatment (winter wheat irrigated only heading period). It was respectively followed by RF. This shows that there is no need to apply more water for wheat irrigation. Thus, especially in semi-arid regions, more areas can be irrigated with the same amount of water.

Relationship between grain yield and WUE

The relationships between WUE and grain yield are shown in Figure 5. A significant positive relationship was found between the irrigation water efficiency and grain yield with correlation coefficient 0.65 (R^2). Several researchers were reported similar positive relationships between the grain yield, biomass and WUE under arid and semi-arid climate (Oweis, et al., 2000; Kharrou, et al., 2011; Azizi, et al., 2014; Chen, et al., 2014; Bian, et al., 2016).

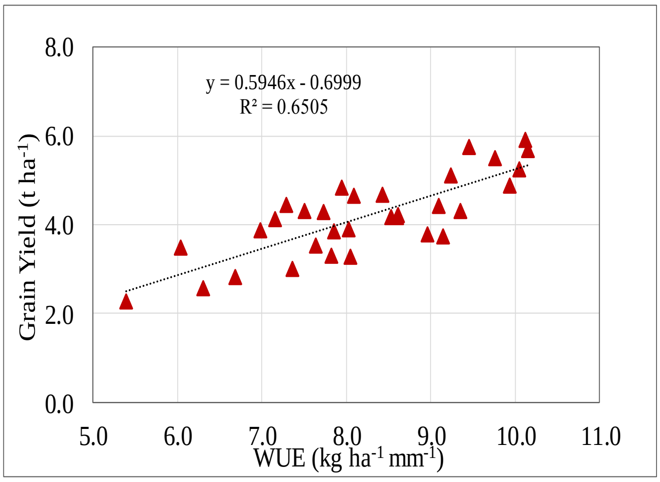


Figure 5. Relationship between grain yield and WUE

As a conclusion; efforts to get more crops per unit area are quite important and necessary for human nutrition in today's world having limited resources as well as a rapidly growing population. At the end of the research study conducted during the wheat growth period between the years 2009-2011 in average wheat yield was found to be 3.35 t ha^{-1}, 4.54 t ha^{-1}, 4.14 t $ha^{-1}$and 4.37 t ha^{-1} respectively according to the treatments (RF, FI, MI, DI). The highest yield was obtained from the full-irrigation treatment while the lowest yield one from the rainfed treatment. The highest average harvest index was found in DI, with the percent of 32. The treatment DI that was irrigated in the same way after the period of heading for both years appeared to have the highest value in the water use efficiency. It might be recommended that irrigation concentrated in the after heading period increase WUE in semi-arid regions such as Central Anatolia Region of Turkey. Two or three irrigation can be sufficient to minimize yield loss from water stress and to improve WUE.

Acknowledgments

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