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Enhancement of Water Use Efficiency of Wheat Utilizing Deficit Irrigation Concept

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Abstract:

Field experiment was conducted during the winter season of 2013 at Agricultural experimental station of soil and water Resources center in Babylon Governorate- Iraq. Main objective of this study was to water use efficiency of wheat depending on deficit irrigation concept. Study was conducted as a field experiment of Randomized Complete Block Design (R.C.B.D) with three replicates. Treatments are five irrigation practices of different volume of irrigation water for wheat crop. These are: T1: full irrigation water and other four deficit irrigation treatment each of 30% reduction of full irrigation water delivered at tillering growth stage (T2),Elongation T3, flowering (T4) and maturity (T5). Field soil moisture content was measured using Diviner – 2000 sensor for 0-0.3 meter depth. The results showed that the full irrigation treatment showed the highest consumptives use with 440 mm., however, was reduced to 308, 312, and 311mm for deficit irrigation treatments at Tillering, Elongation, Flowering and Maturity stages, respectively. These reduction in used water was, in fact, reflected in 24.5, 11.5, 19.4 and 20.6% increase in water use efficiency at Tillering, Elongation, Flowering and Maturity stage compared to full irrigation practice, respectively, Grain yield of wheat was 4765 Kg.ha^{-1} which was the highest under the full irrigation system. Lowest grain yield was 3821 Kg.ha^{-1}. was the lowest under the deficit irrigation at Elongation stage.

Key words: Crop stage, grain yield, full irrigation, Diviner, moisture content

INTRODUCTION

Availability of water in arid regions is real problem facing agriculture and will be a large challenge in the coming decades. That is due to the decline of water resources, extended drought period caused by climatic change and increasing water demand for human consumption due to continuous increase in population. Low efficient utilization of water resources is currently of considerable concerns in many countries around the world. Low quality of both water and soil necessitate higher volume of water needed to obtain adequate food supply (FAO, 2011). Therefore, one may conclude that global and domestic food production could face a significant risk in terms of the abundance of water resources. So the need arises in many of the countries that are facing this threat, to the use of modern methods of irrigation and salt water as well as the use of under-rated water for irrigation. The deficit irrigation is a method of rationing, which is identified as Rey limited process, i.e, addition an amount of water less than the required amount for the purpose for normal crops yield. Increasing irrigation water productivity, and this process can be applied to drought-resistant crops such as maize, wheat and cotton (ECK, 1986) known Ozturk (Kirda, 2000) used deficit irrigation as a way to increase water use efficiency (WUE) and the exposure of the crop to a certain level of tension in a certain stage of growth, or during the entire growing season. Therefore, it is expected that any reduction in the total water requirement will be invisible if it has been compared in order to save water, which can be used to irrigate other crops or expand agricultural area (Fereras and Soriano, 2007). Deficit irrigation practices differ from traditional water supplying practices. The manager needs to know the level of transpiration deficiency allowable without significant reduction in crop yields. The main objective of deficit irrigation is to increase the WUE of a crop by eliminating irrigations that have little impact on yield. The resulting yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops for which water would normally be insufficient under traditional irrigation practice. Among the factors that stand to face increased yields is the water scarcity, which is witnessed by the world and will increase in the coming decades, especially in the arid and semi areas (FAO, 2011). This study aims to estimate the actual water precautions to wheat crop depending from the concept of deficit irrigation and study some growth conferences.

MATERIAL AND METHODS

Field experiment was conducted during the winter season of the year 2013 to study the enhancing Wheat water use efficiency under deficit irrigation practices at different growth stages at soil and water recourses center station in middle of Iraq. (33.14^0 N 44.4^0) 34 m above sea level. The soil is of silty clay loam texture and classified as ((fine loam, mixed, hypothermic, typic, terrified events)), some soil physical and chemical properties were determined according to standard methods (Black,1965, page et-al,1982,Richarads, 1931). The field was divided into three equally blocks 3 m apart. Every block was divided into five experimented unit 4X4 size of 2 Meter apart. The entire experimented units were arranged in randomized completed block design (R.C.B.D) with three replicates. Treatments are:

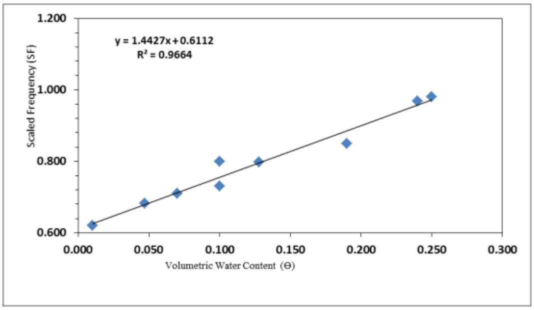
1. (T1):Full irrigation (irrigation after depletion of 50-55% of the available water).
2. (T2):Deficit irrigation (30% reduction from full irrigation treatment during Tillering stage).

3. (T3):Deficit irrigation (30% reduction full irrigation treatment during Elongation stage).
4. (T4):Deficit irrigation (30% reduction full irrigation treatment during Flowering stage).
5. (T5):Deficit irrigation (30% reduction full irrigation treatment during Maturity stage).

Table 1: Some soil physical and chemical properties to the studied soil:

Properties	Unit	Value
Sand	**$g.Kg^{-1}$**	257
Silt		408
Clay		335
Texture		***Silty Clay Loam***
Bulk density	**$\mu g.m^{-3}$**	1.36
Volumetric moisture content at 33 Kpa	**$cm^{-3}.cm^{-3}$**	0.34
Volumetric moisture content at 1500 Kpa	**$cm^{-3}.cm^{-3}$**	0.14
Available water	**$cm^{-3}.cm^{-3}$**	0.20
ECe	**$dS.m^{-1}$**	3.4
pH		7.6

Nitrogen fertilization was applied as urea (46% N) at a rate 400 $kg.ha^{-1}$ on two batches : the first batch is 260 $kg.ha^{-1}$ T. S. P and 200 $kg.ha^{-1}$ K_2SO_4 at the planting. The second was added after five weeks after planting, Wheat seeds were sown on 22/11/2013 in rows of 0.75m between rows and 0.25 between plants. Required Amounts of irrigation water was estimated based on measurement of soil water content using Diviner-2000 sensor for soil depth 0-0.8m depending on particular calibration equation for the soil (Fig.1).



Fig(1): Diviner-2000 calibration equation for (Si.C.L.) soil.

Linear correlation with r =0.966 was found between Volumetric water contant (Θ) and scaled frequency (S.F.).

$SF = 1.443\Theta+0.611$ ....(1)

$SF = \frac{FA-Fs}{FA-Fw}$ ....(2)

Where:

F_A =Diviner count in air.

Fs = Diviner count in soil.

Fw = Diviner count in water.

to moistening the 0-0.3m during growing season. After irrigated and before next irrigation by using equation (Kovda et al, 1973)

$d = (\theta_{fc} - \theta_{bi}) * D$ .... (3)

where:

d= depth of water applied (m)

θ_{fc} = Volumetric moisture content at field capacity ($m^3.m^{-3}$)

θ_{bi} = Volumetric moisture content before irrigation ($m^3.m^{-3}$)

D= soil depth (m).

The water equilibrium equation was used as a direct method to calculate actual water use for the crop:

$(I+P+C) – (ET_a+D+R) = \pm \Delta S$ .... (4)

Where:

I = Irrigation water applied (mm).

P= Precipitation (mm) .

C= Ground water input by capillary effect (mm)

ET_a = actual evapotranspiration (mm).

D= Deep percolation (mm)

R=Surface runoff (mm).

ΔS=Soil moisture storage at beginning and end of the season.

Thus equation (*4*) will be as follow:

$I+P= ET_a \pm \Delta S$ …………….. (5)

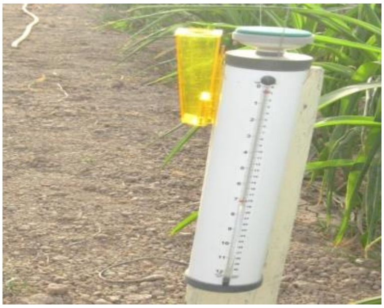
Because of

R=0 (Runoff equal Zero).

C = 0 (ground water table deep about 2m).

D = 0 (because we irrigation when 50-55% of available water is depleted and for certain depth of the soil 0-0.20 and 0-0.4 m).

Reference evapotranspiration (ET_o) was estimated by using Atmometer (ET *gauge) pic.1*



Pic. 1: Atmometer(ET_{gauge})

Water use efficiency was estimated by equation:

$WUE_e = Gy / ET_a$ …….. (6)

WUE_e= water use efficiency ($Kg.m^{-3}$)

GY = total grain yield ($Kg . ha^{-1}$)

ET_a = actual evapotranspiration for unit area (m^3. ha).

The crop factor (K_c) was calculated by using (Allen et al , 1998)

$ET_a = K_c . ET_0$ …….. (7)

Yield response factor (K_y) was calculated by using Stewart et al ,1977 equation:

$$\left[1-\frac{Ya}{Ym}\right] = Ky\left[1-\frac{ETa}{ETm}\right] \quad \text{………..(8)}$$

RESULT AND DISCUSSION

Results (Fig.2): Showed that reducing 30% of total water required by crop by applying deficit irrigation practices caused resulted in saving (1320m^3 water ha^{-1} seasons^{-1}) compared with full irrigation treatment (T_1). Despite reduction in the volume of the water applied, there isno signification reduction in grain yield observed.

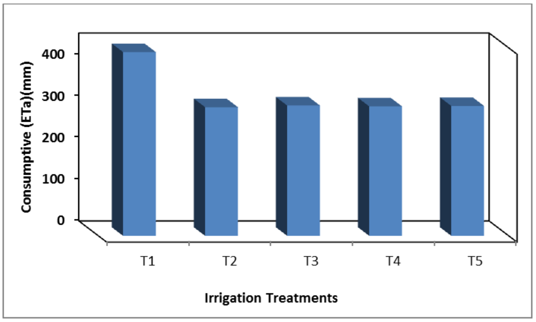


Fig.2: Actual water consumptive (mm) for irrigation treatments.

Applying the reduction of irrigation water during Tillering, flowering and maturing stages, reduce in 7- 12% of the grain yield of wheat (figure 3). However, reduction in yield grain was 20% when deficit irrigation applied during elongation stage. This means wheat is sensitive to water stress during elongation stage.

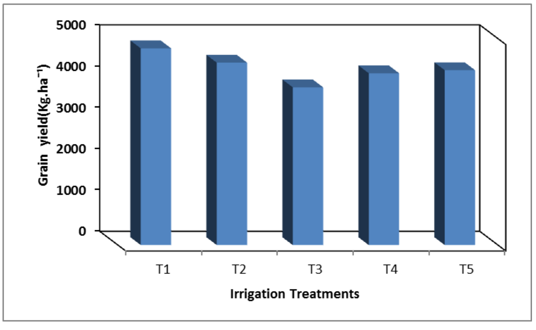


Fig.3: Grain yield (Kg.ha^{-1}) for irrigation treatments.

Grain yield reduction as affected by deficit irrigation was in the following order of plant stage of growth: Elongation > flowering > maturity> tillering. The reason for the highest decrease in grain yield when deficit irrigation is applied at elongation growth stage is related to the water stress condition for plants which reduce the number of spikes, Number of grain and weight of grain. This may be attributed to the fact that athis this stage deficit water limited developing of stools that carried of spikes. Also water stress may reduce the number of grains spikes in spike. Palta et.al(1994). In conclusion, crop response factor (K_y) for wheat were different according the water irrigation treatment (Fig.4).

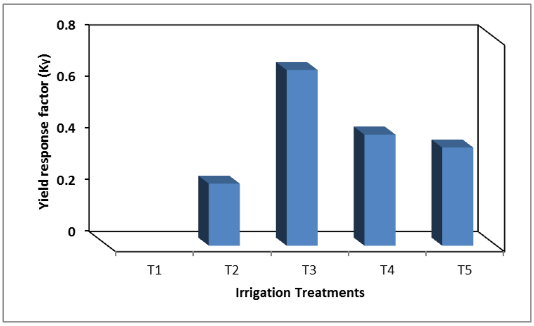


Fig.4: Yield response factor (Ky) for irrigation treatments.

The highest value of grain reduction at deficit irrigation treatment during elongation stage was 0.7. The sensitivity of wheat to deficit irrigation at the different water irrigation treatment were: Tillering < maturity < flowering < elongation. This mean that wheat is more sensitive to deficit irrigation during elongation stage. This can be explain according to the fact that deficit irrigation (water stress) applied to wheat at elongation growth stage will affect the leaves configuration and cell expanding which will be reduced as a result of water stress and this will cause a reduction in yield. These results are in agreement with the findings of (Kilic and Yagbasaular 2010). Who reported that the most sensitive growth stage of wheat to water stress is the early growth stages. Results (Fig.5) showed that there were 24.5, 11.5, 19.4 and 20.6% increase in WUE under deficit irrigation a practices at tillering, elongation, flowering and maturing stages, respectively compared to full irrigation.

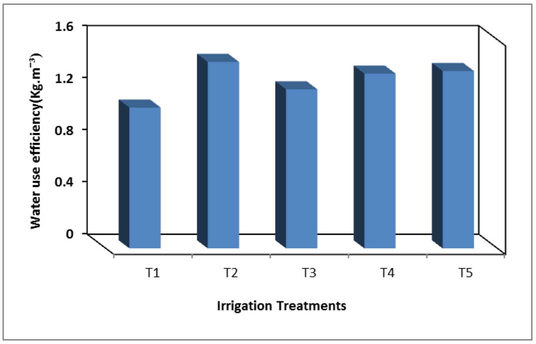


Fig.5: Water use efficiency (WUE) (Kg.m^{-3}) for irrigation treatments.

These high values of WUE correlated to the high plant productivity under these treatments. Also, the amount of irrigation water added and the ET_a were low because of small amount of water needed by plant for cells building in comparison to other crop growth stages. These results agreed with Farre et. Al.(2006) who found that the deficit irrigation treatment resulted in high WUE.

Kang et.al (2000) and Debarke et. al (2004) pointed out that when irrigation water was reduced, the plant made more effort to absorb more water from soil and all roots system would react activity to absorb water which lead WUE increased Fig.(6).

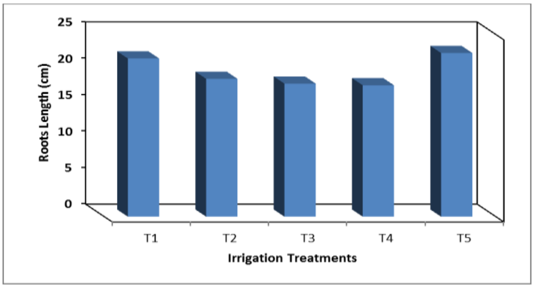


Fig.6: Roots Length (cm) for irrigation treatments.

Results of this study also showed there was no signification impact of any of irrigation treatments on content of protein, in grain (figure7). The highest protein content was (17.82%) under deficit irrigation applied during the maturity stage. On the other hand, the lowest value was (16.31%) at elongation stage. This results was in agreement with the (Kilic and Yagbasaular 2010. Who found that protein content increasing when the wheat yield exposed to water stress during maturing stage.

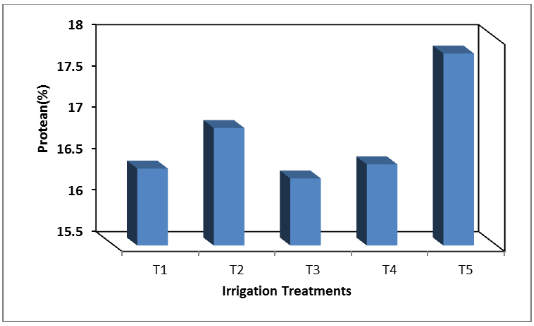


Fig.7: Protean (%) for irrigation treatments.

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