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Research Article

Response of Durum Wheat to Deficit Irrigation

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Abstract

Deficit irrigation trial has been conducted to see the response of durum wheat to the extent of deficit irrigation at Debre Zeit research center for three successive seasons from 2016 to 2018. Establishment irrigations were given for all plots after swing and irrigation water application events were monitored using long term meteorological data and soil moisture readings. Irrigation water application depths (amount of water applied) were calculated from cumulative crop evapotranspiration (ETc) values in a given period and plots were irrigated with depths that was replenish 100 %, 75%, and 50 % of the cumulative ETc as per the treatment to be applied. Measured amount of irrigation water applied to every plot measured by using 3 inch Parshall flume. Results indicated those grain yields significantly affected by deficit irrigation levels and furrow irrigation methods. The highest mean grain yield of 5.8 t/ha attained from 75% ETc irrigation level with alternate furrow irrigation method while the lowest mean yield of 3.989 t/ha was obtained from treatment irrigated with 50% ETc and conventional furrow irrigation method. Therefore, based on the current findings, the highest grain yield was obtained at 75% ETc with alternate furrow irrigation system while the highest WUE was recorded at irrigating 100% ETc with alternate furrow system.

Keywords

Deficit Irrigation, Growth Stages, Water Use Efficiency, Irrigated Wheat

1. Introduction

Agricultural production takes place in an environment characterized by risk and uncertainty. This is particularly in arid and semi-arid zones where water supply to crops from rainfall is variable and erratic. Even in areas under irrigation, water scarcity is common, and yields are often affected, therefore procedures and tools are needed to predict the crop response to a given supply of water, to reduce uncertainty, and to manage risk [1]. Water could be a strategic resource for the social, economic, and environmental property of various countries, notably for water-scarce countries wherever over 40% of the globe population lives. It's used for food production to satisfy the necessities of the increasing population [2]. It's getting scarce, both in volume and quality, not only in traditionally prone arid and semi-arid zones but also in regions where rainfall is abundant. Agriculture represents the major water user worldwide, and a general perception that agricultural water use is often extravagant and has less value than other uses is widespread [3]. Federal Democratic Republic of Ethiopia is deuced with ample water resources with twelve major stream basins with an annual runoff volume of 122 billion cubic meter of water and a numerable 2.6 to 2.65 billion cubic meter of groundwater potential [4]. Irrigation scheduling is significant for developing best management practices for irrigated agriculture [5]. Wheat is one amongst the foremost necessary staple food crops inside the globe. Ethiopia produces 70% of total wheat

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production in eastern Africa [6]. Macaroni wheat is one from the two major species of wheat fully grown in Ethiopia (tetraploid macaroni wheat & hexaploid bread wheat) [7]. In Ethiopia agricultural productivity is declining due to water failure owing to longer dry seasons. Wheat is one of the major food security crops in Ethiopia, but its productivity is reduced due to water scarcity, especially during the dry season. Addressing these problems might be essential increase productivity [8].

2. Material and Methods

2.1. Description of the Study Area

The field experiment was conducted at Debre Zeit Agricultural Research Center, located in the central highlands of Ethiopia. Its geographical extent ranges 08°45'51" N and 39°00'29" E. It has low relief difference with altitude ranging from 1610 to 1908 meters above sea level. The soil at the experimental site was heavy clay in textures with field capacity and permanent wilting point of 35% and 19%, respectively. The area receives an annual mean rainfall of around 810.3 mm.

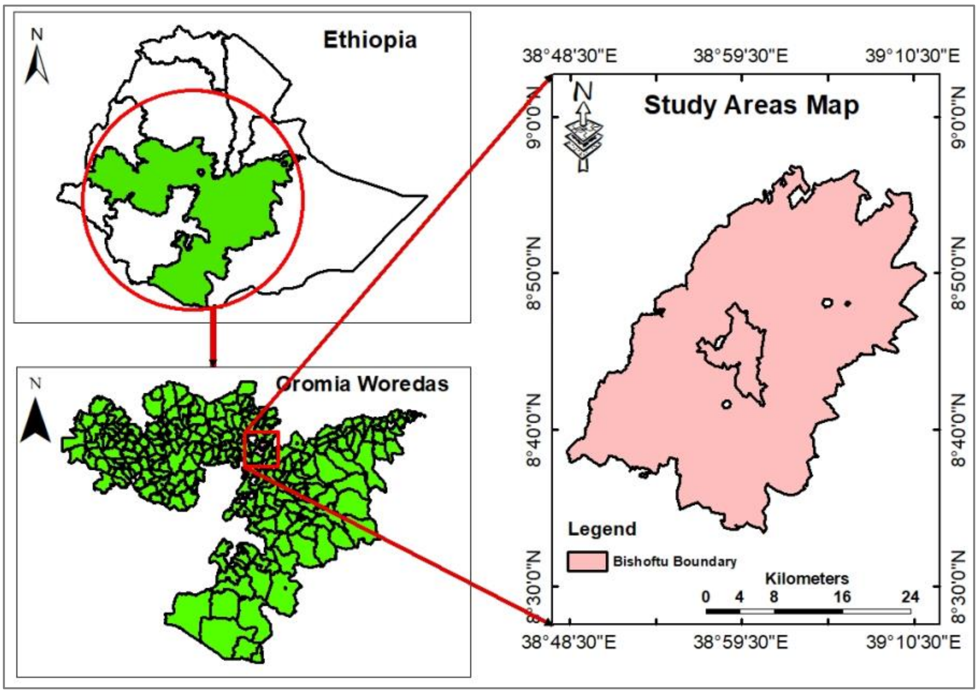

Figure 1. Location of the study area.

The data of average daily maximum and minimum temperature were obtained from the weather station located at the experimental area and are shown in Figure 2 below.

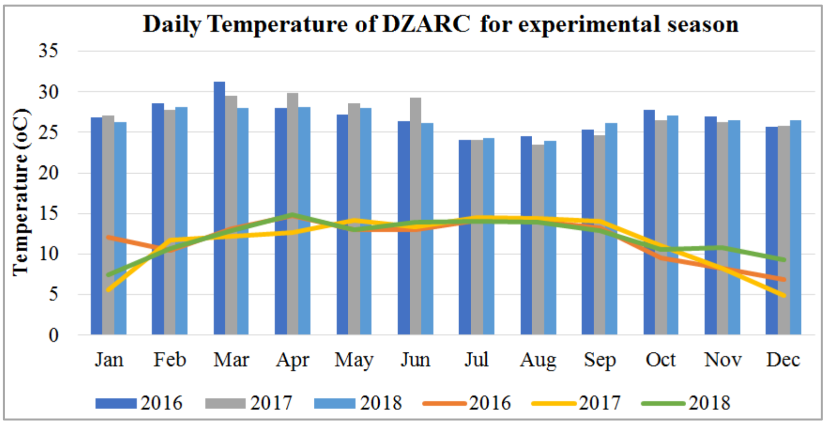

Figure 2. Daily maximum and minimum temperature (℃) of the study area during the experimental period.

2.2. Experimental Design

The experimental treatment was set up in three levels of deficit irrigation and three furrow systems with a total of nine treatment. Establishment irrigations were given for all plots after sowing and irrigation water application events were monitored using long term meteorological data and soil moisture readings.

The trial was laid out in Randomized Completely Randomized Block Design (CRBD) with three replications and two factors of irrigation level and furrow methods. The trial included three furrow irrigation systems (Alternate furrow irrigation (AFI), Fixed furrow (FFI) and Conventional furrow irrigation (CFI)) and three irrigation levels are 100% ETc, 75%ETc, and 50% ETc of the requirement. The experiment had nine treatment combinations and 27 total plots. The amount of irrigation water to satisfy the crop water requirement was computed with soil moisture balance model.

***Table 1**. Experimental treatment setup.*

Treatment	Description
Alternate Furrow (AF)	100%ETc
	75% ETc
	50% ETc
Fixed Furrow (FF)	100%ETc
	75% ETc
	50% ETc
Conventional Furrow (CF)	100%ETc
	75% ETc
	50% ETc

2.3. Crop Water Requirement

Using daily meteorological data, the daily reference evapotranspiration was determined with the help of CROPWAT software 8. The crop water demand of the test crop was calculated by multiplying the reference ETo with crop coefficient (Kc). However, the quantity of water applied was based on monitoring the allowable depletion level, growth stage and the correspondent effective root depth. The quantity of irrigation water applied at each irrigation application was measured using 3-inch Parshall flume.

Water productivity have been estimated as a rate of grain yield to the total ETc through the growing season and it has been calculated using the following equation [9].

$$CWR = \frac{Y}{ET_c} \quad (1)$$

Where:
CWP: crop water productivity (kg/m^3),
Y: onion yield (kg/ha)
ETc: seasonal crop water consumption (m^3/ha)

2.4. Deficit Irrigation Water Requirement

Deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. Outside these periods, irrigation is limited or even unnecessary if rainfall provides a minimum supply of water. Water restriction is limited to drought-tolerant stages, often the vegetative stages and the late ripening period. Total irrigation application is therefore not proportional to irrigation requirements throughout the crop cycle. While this inevitably results in plant stress and consequently in production loss, DI maximizes irrigation water productivity, which is the main limiting factor [10].

The effects of soil moisture deficit on ET_C are explained by reducing the value of the crop coefficient. This is done multiplying the plant coefficient by the water stress coefficient, Ks. Water content in the root zone can be expressed by root zone depletion, Dr, i.e., water deficiency relative to field capacity. At field capacity, the root zone depletion is zero (Dr =0). When soil moisture is extracted by evapotranspiration, the depletion increases, and stress will be induced when Dr becomes equal to readily available water, RAW. After the root zone depletion exceeds RAW (the water content drops below the threshold θt), the root zone depletion is high enough to limit evapotranspiration distribution below the potential values and the plant evapotranspiration begins to decrease in proportion to the amount of water left to the root zone Figure 3.

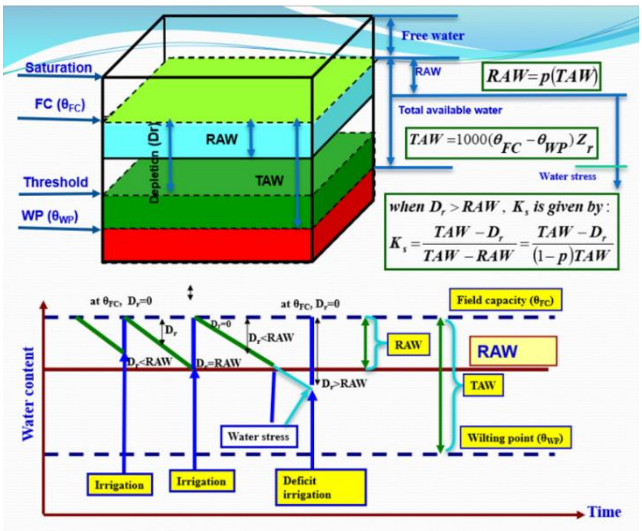

***Figure 3**. General soil profile chart of soil moisture content.*

2.5. Data Analysis

Data collected were statistically analyzed using R software version 4.3.2 and mean separation was done using least significant difference (LSD) method at 5% significance level to compare the differences among the treatments mean.

3. Results and Discussion

The activity has been executed during 2016 to 2018 for three years, at Debre Zeit Agricultural Research center, main station on vertosols. The objective of this study was to identify the level of deficit irrigation which allows achieving optimum durum wheat yield and investigate the effect of irrigation method (alternate, fixed, and conventional furrow) on wheat yield and water use efficiency. The experiment had nine treatments which is three types of furrow irrigation method (Alternative Furrow (AF), Fixed Furrow (FF) and Conventional Furrow (CF)) and three deficit irrigation levels (100, 75 and 50 % of ETc) with three replications which were laid out in randomized complete design. From over year analysis of three years result it has been observed that wheat yield and water use efficiency showed a significant difference on the use of different furrow system as well as on different deficit levels of irrigation at $P \leq 0.05$. Application of 75 % ETc for irrigation water applied and Alternative furrow (AF) for irrigation method gave the highest yield (5.802 t/ha) of wheat by saving 25 % of water applied but highest water use efficiency (WUE) was observed when alternative furrow and 50% ETc water application was used as indicated in Table 1 above.

Generally, the implication of this result is that applying irrigation water though alternative furrow technique to wheat crop as compared to farmer practice or application of conventional furrow and application of 100 % ET_c has been significantly improved yields and water use efficiency of wheat. Therefore, this result can be applicable for a similar climatic condition and vertosol like Debre Zeit and particularly where irrigation water is limited temporally and spatially.

Table 2. *Crop water demand of durum wheat under.*

Treatments	Three Year Combined Analysis Result				
	PH (cm)	**N<u>o</u> of tillers per plant**	**BM (t/ha)**	**GY (t/ha)**	**WUE (kg/m^3)**
T1 (AF + 100% ET_c)	86.67^{a}	16.3^{a}	10.42^{bac}	4.72^{bac}	2.45^{ba}
T2 (AF + 75% ET_c)	82.00b^{a}	15.0^{a}	11.81^{a}	5.80^{a}	2.67^{ba}
T3 (AF + 50% ET_c)	78.67^{b}	13.0^{a}	10.07^{bac}	5.49^{ba}	3.11^{a}
T4 (FF + 100% ET_c)	79.00^{b}	16.3^{a}	11.11^{ba}	5.01^{bac}	2.40^{b}
T5 (FF + 75% ET_c)	78.00^{b}	13.3^{a}	83.33^{c}	4.48^{bc}	2.68^{ba}
T6 (FF + 50% ET_c)	80.67^{b}	11.7a	97.22^{bac}	4.32^{bc}	2.43^{b}
T7 (CF + 100% ET_c)	77.67^{b}	11.0^{a}	10.07^{bac}	4.66^{bac}	2.39^{b}
T8 (CF + 75% ET_c)	79.00^{b}	10.7^{a}	9.38^{bc}	4.58^{bac}	2.26^{b}
T9 (CF + 50% ET_c)	79.47^{b}	11.3^{a}	8.33^{c}	3.989^{c}	2.28^{b}
R-Square	0.52	0.41	0.76	0.58	0.52
CV (%)	4.11	26.65	12.30	15.98	15.54
$LSD_{0.05}$	5.69	NS	2.11	1.32	0.677

PH = plant height
N<u>o</u> = number
BM = biomass
GY = grain yield
WUE = water use efficiency

4. Conclusions

The combination of both deficit irrigation levels, and furrow irrigation methods significantly affected the grain yield of wheat. The combined over year analysis result of the study showed that there was a significant yield differences among the irrigation water applications at a $P \leq 0.05$ level of significance. The highest yield (5.80 tone ha^{-1}) was obtained by applying irrigation water of 75%ETc followed by 50%ETc (5.49 tone ha^{-1}) with alternate furrow techniques however, the least yield (3.99 tone ha^{-1}) was observed at irrigation water application of 50% ETc with conventional furrow technique.

Abbreviations

ET_c	Crop Evapotranspiration
PH	Plant Height
№	Number
BM	Biomass
GY	Grain Yield
WUE	Water Use Efficiency

Conflicts of Interest

The authors declare no conflicts of interest.

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