

Response of Maize (*Zea mays* L.) Yield under Drip and Furrow Irrigation at Different Irrigation Levels at werer, Middle awash, Ethiopia

Fikadu Robi^{*1}, Teshome Seyoum², Tilahun Hordofa³

¹Ethiopian Institute of Agricultural Research, P. O. Box 2003, Addis Ababa, Ethiopia

²Haramaya University, Institute of Technology, P.Box 138, Dire Dawa, Ethiopia

³Ethiopian Institute of Agricultural Research, P. O. Box 2003, Addis Ababa, Ethiopia

Abstract

Field experiment was conducted at Werer Agricultural Research center to evaluate the effects of drip and furrow irrigation under different irrigation levels on maize yield and water use efficiency. The experiment was laid out in split plot design where drip and furrow irrigations assigned as main plot and irrigation levels (100, 85, 70 and 55% of ETc) assigned in the sub plot arrangement with three blocks. The highest seasonal water requirement of maize was 701.7 mm at 100% ETc under conventional furrow irrigation which is considered as control while the lowest was 192.9 mm at 55% ETc under alternative furrow irrigation. The analysis of variance revealed that there was significant ($p < 0.05$) difference in yield among treatments and the interaction effect of irrigation system and irrigation levels show highly significant ($p < 0.01$) difference among treatments. The highest yield (16.7t/ha) was obtained from drip irrigation with 100% of ETc application and while the lowest (4.04 t/ha) was obtained from plots treated with alternative furrow irrigation 55% ETc treatment.

Keywords: Experiment • Main plot • Sub plot • Split plot

Introduction

Water is the vital resource to sustain civilizations and pecuniary development and most importantly agriculture. In Ethiopia, irrigation development is a priority for agricultural transformation, but poor practices of irrigation management discourage efforts to improve livelihoods, and expose people and the environment to risks. Although available in abundance in some regions, increasing number of river basins of arid and semi-arid regions are facing problem of water scarcity as well as decline of water quality, due to population growth and increased water use [1]. One fifth of the global land area is arid or semiarid, where water scarcity can limit crop productivity in agricultural and native vegetation. Increasing fresh water scarcity has called for researchers into new irrigation technologies with the purpose of improving water use efficiency in plant [2]. About 75 of the global fresh water are used for agricultural irrigation. Most of the water is applied by conventional surface irrigation method. Maize is critical for food security in Ethiopia. Over 9 million smallholder farmers grow maize on about two million hectares (14% of total land area in Ethiopia) and around 88% of their production is used for food consumption. Nevertheless, the increasing need for crop production due to the growing population in the world is necessitating a rapid expansion of irrigated agriculture throughout the world. Irrigation in Ethiopia is considered as a basic strategy to alleviate poverty.

The uniformity of the water distribution into the soil with a good application for adding water with alternative furrow surface irrigation interactive mainly associated with the soil state and field condition and practices for the implementation of the process of regular irrigation. Holding the current rates of agricultural water use efficiency constant, an estimated additional amount

***Address for Correspondence:** Fikadu Robi, Ethiopian Institute of Agricultural Research, P. O. Box 2003, Addis Ababa, Ethiopia, Tel: 0911489536; E-mail: fikadurb@gmail.com

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Received 19 March 2021; Accepted 15 April 2021; Published 22 April 2021

of 5700 km³ of fresh water will be required annually to meet the estimated food demand in 2050. According to 56% water savings, a 22% increase in yield and a two-fold increase in water use efficiency have been found for drip irrigation in comparison with furrowirrigation [3].

Material and Methods

Description of the study area

The experiment was conducted in the 2019/20 at Werer Agricultural Research Center experimental site, located in Afar Regional State and 280 km far away from Addis Ababa. It is located at 9° 16 '8" latitude; 40°9' 41"E longitudes and 740 m above mean sea level. According to the classification of Agro-ecological zones by Ministry of Agriculture and Rural Development of Ethiopia the area is classified as semi-arid with average annual rainfall of 590 mm. Bestowing to meteorological data recorded at Agro meteorological observatory (Werer) the average minimum and maximum temperature is 19°C and 40.8°C respectively (Figure 1).

Soil sampling and analysis

Before sowing the maize, composite soil samples was taken at random from the experimental field at a depth of 0-30 cm, 30-60 cm, and 60-90 cm. Soil

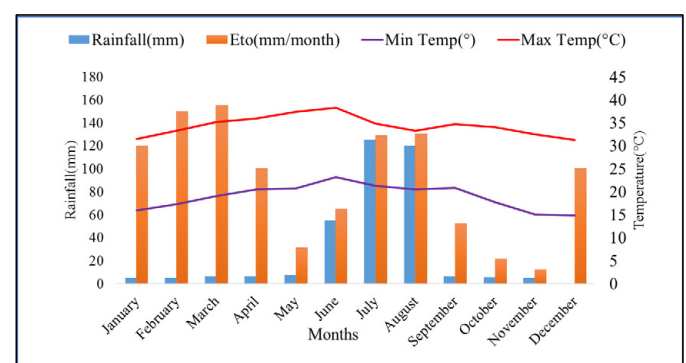


Figure 1. Climate of the study area (1990-2019).

samples were taken in Zigzag way across the experimental plot according to CSOSS recommendation and analyzed as suggested procedure by international soil reference and information center [4] (Table 1).

Infiltration characteristics of the experimental site

The infiltration rate which is the speed at which water enters into the soil is measured by the depth (in mm) of the water layer that can enter the soil in one hour. The equation of infiltration curve was developed by using Horton's infiltration equation.

$$f_p = f_c + (f_o - f_c)e^{-kt} \tag{1}$$

- f_p Infiltration rate at any time (mm/hr)
- f_c Steady state infiltration rate (mm/hr)
- f_o Initial infiltration rate (mm/hr)
- k Horton's decay coefficient
- t Time elapsed (hr)

The basic infiltration rate in this experiment site was found to be 5.2 mm/hr. This means that a water layer of 5.2 mm on the soil surface will take one hour to infiltrate which was in the upper range of clay soil (1-5 mm/hr.) (Figure 2).

Chemical properties of irrigation water

The sodium adsorption ratio (SAR) is estimated to determine the sodicity or alkalinity effect of irrigation water. The sodium adsorption ratio (SAR) was estimated from relative concentrations of sodium, magnesium, and calcium cation concentrations in a saturated paste extract (Table 2).

Table 1. Physical characteristics of soil.

Soil physical characteristics		Soil depth (cm)		
		0-30	30-60	60-90
Texture (Particle size distribution)	Sand (%)	11.8	12.6	12.8
	Silt (%)	31	31	34
	Clay (%)	57.1	55.3	53.0
Textural class		Clay	Clay	Clay
Field Capacity (%) (Weight basis)		40	39.5	39
Permanent Wilting Point (%) (Weight basis)		24	23	22
Bulk density (g/cm ³)		1.29	1.30	1.31
Total Available Water (mm/m)		206.4	214.5	222.7

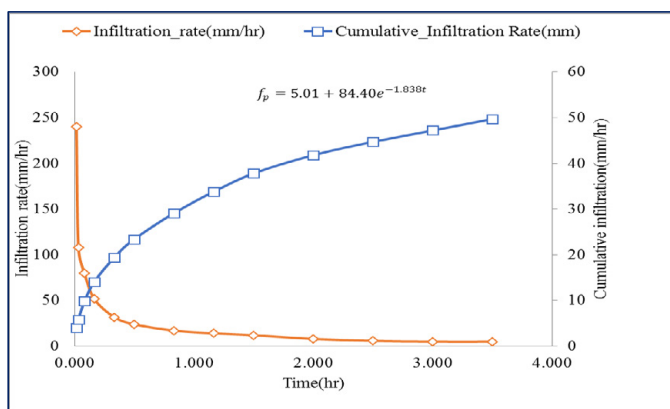


Figure 2. Soil infiltration curve of study area.

Table 2. Concentrations of sodium, magnesium, and calcium cation concentrations in a saturated paste extract.

Sample	PH	ECw(ds/m)	[ca+Mg](Meq/L)	[Na](Meq/L)	SAR
Water	8.20	0.92	2.2	6.85	6.70

$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$$

Where,

- SAR Sodium absorption ratio
- Na^+ Sodium concentration (mg/l)
- Ca^{+2} Calcium concentration (mg/l)
- Mg^{+2} Magnesium concentration (mg/l)

Hydraulic evaluation parameters of drip irrigation

During field installation of drip irrigation before planting the drip emitter discharge rate was calibrated at field condition and the emitter distribution uniformity were estimated (Table 3).

Experimental Treatments and Design

The experimental treatments include irrigation systems, viz., furrow (alternate furrow) and drip irrigation, and four irrigation levels (100, 85, 70 and 55%ETc). The experiment was designed as a split plot design in RCBD experiment with three blocks (Table 4).

The Maize Variety "BH-546" was sown by keeping row-to-row distance at 75 cm and plant-to-plant distance at 30 cm. Two seeds were planted per hole. Once the crop attained 100% germination and then thinned to one plant per stand. Each application of water for alternative furrow irrigation was measured using partial flume with 3 inch dimension. The source of water is from Awash River brought to the field under gravity using open canal. The total available water (TAW in mm) of the experimental field was determined

$$TAW(mm) = \left(\frac{(FC - PWP) * \rho_d * D}{100} \right) * \frac{1}{\rho_w} \tag{3}$$

Where,

- TAW Total available water (mm)
- FC Field Capacity (%)
- PWP Permanent wilting point (%)
- ρ_d Bulk density (g/cm³)
- D Effective root depth of crop(m)
- ρ_w Water density(g/cm³)

The soil moisture content was determined to estimate the initial soil moisture content to apply the first irrigation and refill the soil moisture content to field capacity

$$MC(\%) = \frac{Wws - Wds}{Wds} * 100 \tag{4}$$

Where,

- MC (%) Moisture content (gm)
- Wws Weight of wet soil (gm)
- Wds Weight of dry soil (gm)

According to Allen *et al* (1998) atmospheric evaporating power rate was estimated by

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{27}{T_{hr} + 273} U_2 (e^0(T_{hr}) - e_a)}{\Delta + \gamma (1 + 0.34U_2)} \tag{5}$$

Table 3. Condition and the emitter distribution uniformity were estimated.

No	Hydraulic Parameter	Calculated Value	Classification
1	Emitter flow variation	8%	Desirable
2	Field Emission Uniformity	92.2%	Excellent
3	Coefficient of variation	0.07	Average
5	Coefficient of uniformity	90.8%	Excellent
6	Application uniformity	85%	good

Table 4. Designed as a split plot design in RCBD experiment with three blocks.

Main plot		Sub-plot	Treatment designation
		Irrigation level	
Furrow	AFI	100% ETc	T1
	AFI	85% ETc	T2
MP1	AFI	70% ETc	T3
	AFI	55% ETc	T4
Drip Irrigation	DI	100% ETc	T5
	DI	85% ETc	T6
MP2	DI	70% ETc	T7
	DI	55% ETc	T8

Table 5. Ground biomass, yield, water use efficiency and harvest index.

Treat	WFC(g)	WFCS(g)	WTS(g)	BM(kg/ha)	Yld(kg/ha)	WUE(kg/m ³)	HI
Drip	207.30 ^a	929.63 ^a	326.53 ^a	22067.9 ^a	11368.3 ^a	1.96 ^a	51.1 ^a
Furrow	192.07 ^b	837.66 ^b	298.96 ^b	14181.1 ^b	5065.8 ^b	0.96 ^b	35.5 ^b
Lsd(0.05)	14.6	61.23	18.52	1827.4	797.07	0.25	5.26
CV	8.84	8.39	7.16	12.43	12.19	12.13	14.92

Δ Saturation slope vapour pressure curve at Thr [kPa °C⁻¹]

Rn Net radiation at the grass surface [MJ m⁻² hour⁻¹]

G Soil heat flux density [MJ m⁻² hour⁻¹]

γ Psychometric constant [kPa °C⁻¹]

Thr Mean hourly air temperature [°C]

e^o Saturation vapour pressure at air temperature

e^a Average hourly actual vapour pressure [kPa]

U₂ Average hourly wind speed [m s⁻¹]

The net irrigation requirement was calculated using the following equation

$$NIR = ET_c - P_e \quad (3.15)$$

Where,

NIR Net irrigation requirement(mm)

ETc Crop evapotranspiration(mm/day)

P_e Effective rainfall(mm)

Result and Discussion

Main effect of drip and furrow irrigation on yield

Analysis of variance showed that the mean values of plant height were statistically significant ($p \leq 0.05$) different due to the main effect of irrigation system (Table 5). Statistically significantly higher mean yield (11368.3 kg/ha) was recorded from drip and lower mean yield (5065.8 kg/ha) was recorded from furrow irrigation method. While, there was statistically ($p \leq 0.05$) significant difference between drip and furrow irrigation system in weight of five cobs, weight of five cobs seed, weight of thousand seed, Above ground biomass, yield, water use efficiency and harvest index.

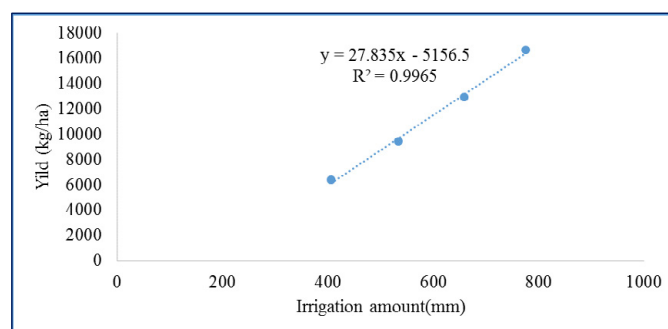


Figure 3. Yield-irrigation amount relationship for drip irrigation system.

Means within columns and rows indicated by the same letter are not statistically significant at 5% level of significance. WFC=weight of five cobs, WFCS, =weight of five cobs seed, WTS=weight of thousand seed weight, BM=above ground biomass, Yld=yield, WUE=water use efficiency, HI=harvest index. Effects of irrigations system and irrigation levels on yield parameters grain yield production of maize has significantly influenced by irrigation system in combination with different irrigation level [5].

Yield-Irrigation Relationship

The result of studies shows that there is a linear relationship between yield and irrigation amount. Some investigation similarly good linear relationships between yield and irrigation water applied in maize subject to drip and furrow irrigation under different irrigation level (Figure 3).

However, other studies found a nonlinear relationship between yield and seasonal irrigation amount. The relationship between yield and irrigation amount is affected by factors such as climate, soil properties and irrigation method. This results in lined with the works of Farre and Faci. These factors should be taken into account when proposing deficit irrigation approaches (Figure 4).

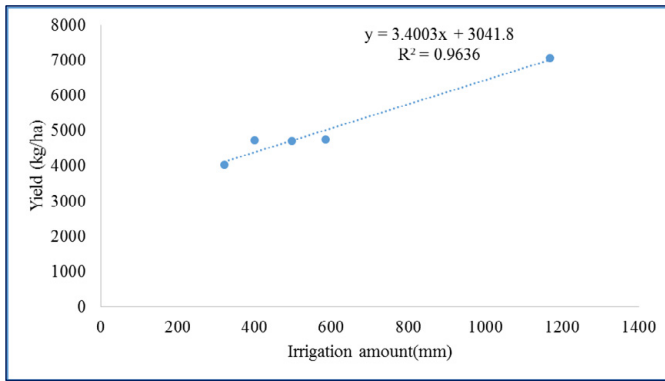


Figure 4. Yield-irrigation amount relationship for furrow irrigation system.

Conclusion

In this study, the field experiment under drip and furrow irrigation system was compared in terms of yield. The finding shows that using drip irrigation with 100%ETc gave a yield increase of about 71.48% compared to alternative furrow irrigation at 100%ETc. When comparing drip with furrow irrigation there is a significant difference in grain yield production.

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How to cite this article: Fikadu Robi, Teshome Seyoum, Tilahun Hordofa. "Response of Maize (*Zea mays* L.) Yield under Drip and Furrow Irrigation at Different Irrigation Levels at werer, Middle awash, Ethiopia." *Irrigat Drainage Sys Eng* 10 (2021): 265.