Response of Deficit Irrigation levels and methods on yield and water productivity of maize at Werer agricultural research center, Afar, Ethiopia.

Wondimu T. Adugna[1], Jemal M. Hassen[1], Fikadu R. Borena[1], Nigusie A. Sori1, Kebede N. Tufa[1]*

[1]*Ethiopian Institute of Agricultural Research/Werer Agricultural Research Centre, P.O. Box 2003, Addis Ababa, Ethiopia*

*Corresponding Author, E-mail: kuleshawa@gmail.com

Abstract

The study was conducted at Werer Agricultural Research Center, Amibara Middle Awash, Ethiopia, starting from 2016 up to 2018 for three consecutive cropping years. The experiment was laid out in Randomized Completely Randomized Block Design (CRBD) with three furrow irrigation systems and three irrigation levels. The three furrow irrigation systems are Alternate furrow irrigation (AFI), Fixed furrow (FFI) and Conventional furrow irrigation (CFI) and the three irrigation levels are 100% ETc, 75%ETc, and 50% ETc of the requirement. The maximum plant height was observed for 100%Etc and 75%Etc irrigation levels with pooled mean of 2.08m and 2.02m, respectively and the minimum plant height was recorded on 50%Etc irrigation level with pooled mean of 1.9m height. The highest thousand-seed has been recorded on conventional furrow irrigation method (305.74g) and the lowest (296.20g) on alternate furrow irrigation method. In this study, the highest grain yield (6,125 kg/ha) in terms of irrigation method was obtained under conventional furrow irrigation method and the minimum (4,711.8kg/ha) grain yield was observed using fixed furrow irrigation system. Alternative Furrow irrigation method was the highest water productivity (2.09kg m^{-3}), fixed furrow (1.90kg m^{-3}) and conventional furrow (1.25kg m^{-3}) ranked second and third, respectively. While in deficit irrigation 50%Etc had the maximum (2.00kg m^{-3}) water use productivity and the minimum was observed in 100%Etc irrigation level. This shows that the combination of alternate furrow and 50%Etc irrigation level recommended to gate high water productivity for maize production for Amibara, Afar region and equivalent or comparable agro ecological zones in the lowlands of Ethiopia.

IJSER

Keywords: Deficit *irrigation, Maize ,water productivity*

INTRODUCTION

Among the freshwater users sectors agriculture is the largest user on the planet consuming more than two thirds of the total water withdrawals (Gan *et al.* 2013). In the arid and semi-arid areas of the world fresh water shortage become a critical issue (Forouzani and Karami, 2011). As world`s population expected to increase by 30% by 2050 and coupled with forecasted climate change, the situation with scarcity of water may get worse (Godfray *et al.* 2010).

Many developing countries face challenges in production of maize due to production constraints such as rainfall, insufficient water resource for irrigation purpose, limited infrastructure investment, lack of financial resources and limited technological option (WMO, 2012).

In Ethiopia, maize, grown in varies range of agro-climate from lowland to high land, from moisture stress areas to high rainfall area and it is a one of the national commodity crops to assume to support food self-sufficiency program of the country (Mengesha *et al*. 1993).

Currently Ethiopia have a coverage of 2.7 million hectare of irrigated land and this coverage is less than 20% of country irrigation potential (MOA. 2018). More than 97.8% of Ethiopian irrigation practiced is surface irrigation methods specially furrow system in farmer`s fields and majority of commercial farms (FAO. 2001). Poor in both on-farm water management practice and performance (Eguavoen et al. 2012) generally characterize Ethiopian smallholder irrigation. Farmer`s lack of sound knowledge for on farm water management and both excess and insufficient allocation of water resource lead for water scarcity. So it is paramount important for emerging threat to sustainability of irrigated agriculture in Ethiopia to shift paradigm in the way irrigation is practiced. This paradigm shift should embrace irrigation water management strategy that can facilitate to enhance production per drop of water.

One strategy that is widely used to increase irrigation water productivity in arid and semi-arid regions is the deficit irrigation and different furrow irrigation methods. Maize is a very sensitive crop to water stress. As many studies have shown that, there is a significant reduction in yield

IJSER

and yield components due to water stress. Application of different furrow irrigation system is considered as the most effective methods to increase water use efficiency, produce higher yield and reduce irrigation cost. However, the response to water deficit at different levels of crop evapotranspiration (ETc) coupled with different furrow irrigation system needed to be investigated considering the irrigation water scarcity in the region in order to produce optimum yield with less amount of water applied.

MATERIALS AND METHODS

Site Description

The experiment was conducted at Werer Agricultural Research Center, Amibara Middle Awash, Ethiopia, located at 9°16'N latitude and 40°9'E longitude, with a mean altitude of 740 m.a.s.l. starting from 2016 up to 2018 for three consecutive cropping years. The soil at the experimental site was Vertisol with bulk density of 1.17 g/cm^3. The field capacity and permanent wilting point on a mass basis were 46 and 30.4%, respectively. The climate of the area is characterized as semi-arid with bi-modal low and erratic rainfall pattern, with annual average of 590 mm. The mean temperature varies from 26.7 to 40.8°C.

The long-term climatic data indicated that evapotranspiration exceeds the rainfall throughout the year (Figure 1)."

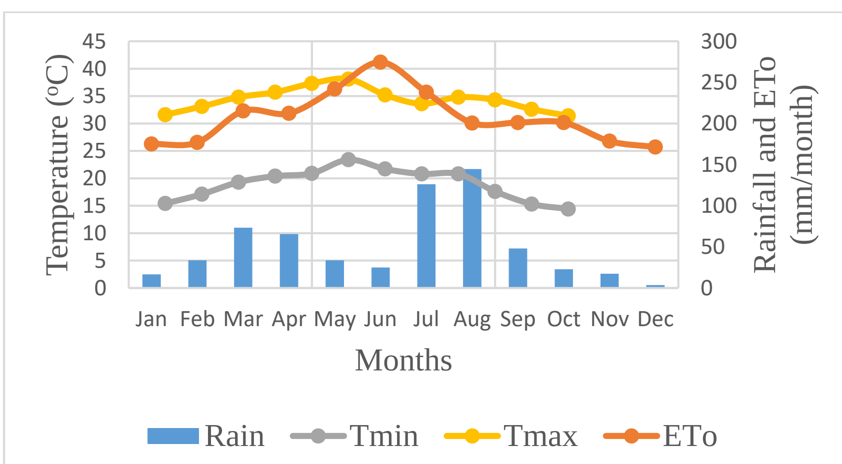

Figure 1. Long-term (1965 – 2019) mean monthly climatic data of the study area

Experimental Design

The experiment was laid out in Randomized Completely Randomized Block Design (CRBD) with three replications and with two factors. The experiment included three furrow irrigation systems and three irrigation levels. The three furrow irrigation systems are Alternate furrow irrigation (AFI), Fixed furrow (FFI) and Conventional furrow irrigation (CFI) and the three irrigation levels are 100% ETc, 75%ETc, and 50% ETc of the requirement. The experiment had nine treatment combinations and 27 plots. The amount of irrigation water to satisfy the crop water requirement was computed with soil moisture balance model. Each experimental plot had $50m^2$ area and 1.8m free space between plots and 3.6m wide double bund between replications and maize variety BH-546 had been sown on each experimental plot.

Crop Water Requirement and Measurement

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

Water Productivity

Water productivity have been estimated as a ratio of grain yield to the total Etc through the growing season and it has been calculate using the following equation (Zwart and Bastiaanssen, 2004).

$$CWP = (Y/ET)$$

Where, CWP is crop water productivity (kg/m^3), Y crop yield (kg/ha) and ET is the seasonal crop water consumption by evapotranspiration (m^3/ha).

Statistical Analysis

Data collected were statistically analyzed using SAS software version 9.0 when treatments are significant mean separation using least significant difference (LSD) at 5% probability level was employed to compare the differences among the treatments mean.

RESULT AND DISCUSSION

Plant Height

Due to different levels of irrigation, plant height was significantly different among treatments while furrow irrigation methods do not show significant different. The maximum plant height was observed for 100%Etc and 75%Etc irrigation levels with pooled mean of 2.08m and 2.02m, respectively and the minimum plant height was recorded on 50%Etc irrigation level with pooled mean of 1.9m height. Statistically the 100%Etc and 75%Etc have no difference while the 50% Etc irrigation level shows significant difference with($p< 0.0002$).

The difference may occur due to the higher application of water both for 100%Etc and 75%Etc.In agreement with this study, plant height were reported to be higher with full irrigation or 100Etc irrigation level by (Bozkurt et al., 2006; Cakir, 2004; Istanbulluoglu et al., 2002) and slightly decease with deficit irrigation. There was no statistically significant difference due to furrow irrigation methods among the treatments.

Weight of Thousand Seed

The weight of thousand seed on this experiment have been significantly influenced by the irrigation levels at the ($p<0.05$). On the other hand, the furrow irrigation methods does not have significant effect on thousand seed weight. The highest thousand-seed has been recorded on conventional furrow irrigation method (305.74g) and the lowest (296.20g) on alternate furrow irrigation method (table 2).

Grain Yield

In this study, the highest grain yield (6,125 kg/ha) in terms of irrigation method was obtained under conventional furrow irrigation method and the minimum (4,711.8kg/ha) grain yield was observed using fixed furrow irrigation system with the highest significant level ($p<0.0001$) among the treatments. In terms of deficit irrigation, the experiment reveled that grain yield is highest under satisfactory soil moisture than deficit irrigation. The maximum (6535.6kg/ha) pooled mean grain yield was obtained with irrigation level of 100%Etc while the minimum (4285.3kg/ha) was observed with deficit of 50%Etc irrigation water application. This result is

IJSER

inline consistence with the findings of Farre and Faci (2009), Ko and Piccinni (2009) and Mansouri et al. (2010) who indicated that deficit irrigation affects the grain yield.

Table 2: Means of yield and yield components (pooled mean).

Treatment		PH(m)	WTS(gm)	GY(kg/ha)	WP
Furrow Irrigation method	CF	1.98	305.74	6125.0^{a}	1.25^{c}
	AF	2.00	296.20	5238.9^{b}	2.09^{a}
	FF	2.03	303.91	4711.8^{c}	1.90^{b}
$LSD_{0.05}$		NS	NS	405.86	0.16
Deficit irrigation levels	100%Etc	2.08^{a}	319.80^{a}	6535.6^{a}	1.56^{b}
	75%Etc	2.02^{a}	302.92^{b}	5254.8^{b}	1.66^{b}
	50%Etc	1.93^{b}	283.13^{c}	4285.3^{c}	2.00^{a}
$LSD_{0.05}$		0.07	14.34	405.86	0.16
CV (%)		5.96	2.0	13.84	16.28

Letter with similar letter in the column are not significantly different; NS: not significant at $p<0.05$; CV: Coefficient of Variation; LSD: Least Significant Difference; CF: Conventional Furrow; AF: Alternate Furrow; FF: Fixed Furrow, Etc: crop evapotranspiration, 100% Etc: fully irrigated, 75%Etc: Deficit 25% of the Crop Evapotranspiration requirement and 50%Etc: Deficit 50% of the Crop Evapotranspiration requirement.

IJSER

Water Productivity

In this study, the water productivity is significantly different in both furrow irrigation methods and irrigation levels. Water productivity of (maize), ranging from 0.22 kg m^{-3} up to maximum of 3.99 kg m^{-3},which exhibits a wide range of variation when it compared with wheat, rice and cotton (Zwart and Bastiaanssen, 2004). The water productivity is significantly different in both furrow irrigation methods and irrigation levels. Alternative Furrow irrigation method was the highest water productivity (2.09kg m^{-3}), fixed furrow (1.90kg m^{-3}) and conventional furrow (1.25kg m^{-3}) ranked second and third, respectively. While in deficit irrigation 50%Etc had the maximum (2.00kg m^{-3}) water use productivity and the minimum was observed in 100%Etc irrigation level. This result in agreement with Kang *et al*. (2000) who reported deficit irrigation was applied alternatively to one of the two neighboring furrows.

CONCLUSION

The combination of both irrigation levels and deficit irrigation and furrow irrigation methods significantly affected the grain yield of maize. Deficit irrigation and fixed furrow irrigation decrease grain yield. Conventional furrow irrigation methods and 100%Etc or fully irrigating the crop shows high grain yield. But, more than twice of additional grain yield can be produced under alternate furrow irrigation method and about duoble additional grain yield can be obtained by applying 50%Etc deficit irrigation level. This shows that the combination of alternate furrow and 50%Etc irrigation level recommended to gate high water productivity for maize production for Amibara, Afar region and equivalent or comparable agro ecological zones in the lowlands of Ethiopia.

IJSER

REFERENCES

Bozkurt Y, Yazar A, Gencel B, Sezen MS (2006). Optimum lateral spacing for drip-irrigated corn in the Mediterranean Region of Turkey. Agricultural Water Management 85:113120.

Cakir R (2004). Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Research 89:1-16.

Eguavoen, I., Derib, S.D., Deneke, T.T., McCartney, M., Otto, B.A. and Billa, S.S. 2012. Digging, damming or diverting Small-scale irrigation in the Blue Nile Basin, Ethiopia. Water Alternatives 5(3): 678–699.

FAO (Food and Agricultural Organization), 2001. AQUASTATFAO's Information systems on water and agriculture.

Farré I, Faci JM (2009). Deficit irrigation in maize for reducing agricultural water use in a Mediterranean environment. Agricultural Water Management 96(3):383-394

Forouzani M, Karami E (2011) Agricultural water poverty index and sustainability. Agron Sustain Dev 31:415–432. doi:10.1051/agro/2010026.

Gan Y, Siddique KHM, Turner NC, Li X-G, Niu J-Y, Yang C, Liu L, Chai Q (2013) Ridge-furrow mulching systems—an innovative technique for boosting crop productivity in semiarid rain-fed environments. Adv Agron 118:429–476. doi:10.1007/s11104-010 03127.

Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C (2010) Food security: the challenge of feeding 9 billion people. Science 327:812–818. doi:10.1126/science.1185383.

Istanbulluoglu A, Kocaman I, Konukcu F (2002). Water use production relationship of maize under Tekirdag conditions in Turkey. Pakistan Journal of Biological Science 5(3):287291

Kang, S.Z., P. Shi, Y.H. Pan, Z.S. Liang, X.T. Hu, J. Zhang, 2000b. Soil water distribution, uniformity and water-use efficiency under alternate furrow irrigation in arid areas. Irr. Sci. 19, 181190.

Ko J, Piccinni G (2009). Corn yield responses under crop evapotranspiration-based irrigation management. Agricultural Water Management 96:799-808.

IJSER

Mansouri-Far CSA, Sanavy MM, Saberali SF (2010). Maize yield response to deficit irrigation during low sensitive growth stages and nitrogen rate under semi-arid climatic conditions. Agricultural Water Management 97(1):12-22.

Mengesha K, Gashaw B, Birhanu T, Malesse W, Yirga D, et al. (1993) Maize production trends and research in Ethiopia. In: Tolessa B, Ransom JK (Eds.), Proceedings of the First National Maize Workshop of Ethiopia. IAR/ CIMMYT, Addis Ababa, Ethiopia, pp. 4-12.

MOA (2018). National Guidelines for Small Scale Irrigation Development in Ethiopia first Edition, Addis Ababa, Ethiopia.

WMO. (2012). Agrometeorlogy of some selected crops. In Guide to Agricultural Meteorological Practices (GAMP) (2010 ed., pp. 1–128). Geneva: Chair Publications Board.

Zwart, S.J. and Bastiaanssen, W.G.M., 2004. Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize, Agricultural Water Management.

IJSER