Evaluation of Furrow Irrigation Methods for Maize Production in Kobo GirranaValley, Ethiopia

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Abstract

The lack of irrigation water management techniques is a serious obstacle to the expansion of irrigation infrastructures in Kobo Girana valley. A new irrigation method for maize production was designed and tested for yield and water use efficiency (WUE). The objective of the experiment was to evaluate the effects of the furrow irrigation system under different water application levels and identify the furrow irrigation type which allows achieving optimum maize yield and water use efficiency. A field experiment was conducted in kobo Girrana valley and the experiment was carried out for 2 consecutive years (2011 and 2012). Irrigation water was applied to furrows using a siphon from a ditch at the head of the furrow lined with geomembrane plastic with an inflow rate of 0.17l/sec. Totally nine treatments were arranged in factorial RCBD design from three furrow irrigation techniques (alternate furrow irrigation (AFI), fixed furrow irrigation (FFI), and conventional furrow irrigation (CFI)) and three irrigation amounts (100%ETc, 75%ETc, and 50%ETc). The frequency of irrigation was fixed at 7 days interval. The resulting data were subjected to analysis and it was observed that treatment effects on most yield and yield-related parameters were significantly different. Both irrigation water levels and furrow types showed an interaction effect on almost all parameters except biomass yield which showed non-significant interaction. Maximum grain yield 3.32 ton ha^{-1} was observed in the treatment combination of CFI-100ETc and lowest water productivity of 0.64kgm^{-3}. However, 3.17 ton ha^{-1} grain yield and 1.23 kg.m^{-3} water productivity was recorded due to AFI and 40mm depth of application. Compared to the other methods tested in this research, alternate furrow irrigation technique tends to increase water productivity. Moreover, alternate furrow irrigation could save 50% of water and reduces the labor required to carry out the irrigation compare to the conventional type.

Keywords: Crop water requirement, water use efficiency, irrigation method, and alternate furrow

Introduction

Irrigation is an age-old art perhaps as an old human population. 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 (Awulachew *et al.,* 2005). This situation is similar in Ethiopia. Much of an increase in the irrigated area had come because of the expansion of small-scale irrigation in the country. Yet, the existing irrigation development in Ethiopia, as compared to the resources the country has, is negligible (Mintesnot *et al*., 2005). Moreover, the effect of a global climatic change is worsening the scarcity of water for irrigation (Behera and Panda, 2009). The great challenge for the coming decades will therefore be the task of increasing food production per unit of water consumption, particularly in countries with limited water and land resources as well as inefficient water use (Kirda, 2002).

Increasing optimum water productivity, especially the value produced per unit of water, can be an important pathway for poverty alleviation (Perry *et al*., 2009). Efficient water use has become an important issue in recent years because the lack of available water resources in some areas is increasingly becoming a serious problem. Irrigation water management implies the application of suitable water to crops in the right amount at the right time. The salient feature of an improved method of irrigation is the controlled application of the required amount of water at the desired time, which leads to minimization of range of variation of the moisture content in the root zone, thus reducing stress on the plants. Improvement of irrigation water management is portrayed as the key issue in copping up with crop irrigation needs and future water scarcity. One of the irrigation management practices which could result in water-saving is deficit irrigation (Eck *et al.,* 1987). One more option to increase water productivity through deficit level is an alternate and fixed furrow irrigation system.

Alternative furrow irrigation, some furrows are irrigated while adjacent furrows are not and water is saved mainly by reduced evaporation from the soil surface, as in the case of drip irrigation. The studies of Du *et.al*, (2010) improved by converting conventional furrow irrigation to alternate furrow irrigation (AFI) in order to increase water use efficiencies. According to Ghasemi and Sepaskhah (2003) reported, wide-spaced furrow irrigation and alternative furrow irrigation have been used as a means to improved water use efficiency (WUE). Alternate furrow irrigation (skipped furrow irrigation), which has a higher water use efficiency is one of the effective methods to minimize wastage of irrigation water (Halim, 2013). The economic and environmental benefits of using the alternative furrow irrigation methods are higher than all other irrigation methods because less water is applied and the economic return is higher (Nelson and Al-kaisi, 2011).

The hypothesis behind irrigating alternate furrows is that:

1. In alternate furrow irrigation, less surface water is wetted and less evaporation from the surface occurs.
2. More lateral roots are stimulated and a chemical signal is produced in drying roots to reduce the shoot water loss.
3. The amount of water needed (i.e., irrigation water use), time, and labor requirement for irrigation are decreased.
4. Water use efficiency (WUE) will be nearly doubled by using this method.

Thus, this study was initiated to evaluate efficiencies of different furrow irrigation methods and amount of water-on-water productivity and yield of maize.

Materials and Methodology

Description of Study Area

The experiment was conducted in Kobo irrigation research station which is located about 50 kilometers from Woldia town to the North-East direction. The area is situated at 12.08^0 N (latitude), at 39.28^0 E longitudes, and at an altitude of 1470 m mean above sea level (Figure 1).

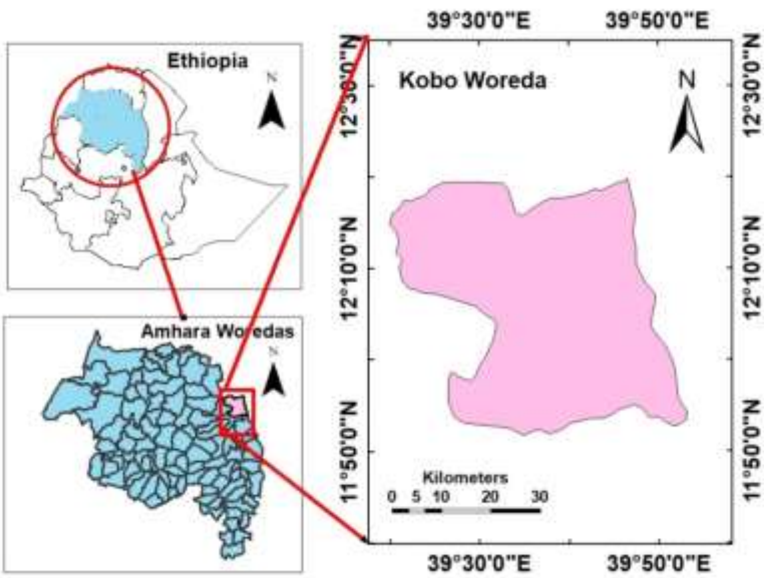

Figure 1. Location map of the study area

The 15 years mean annual rainfall is about 630 mm and the average daily reference evapotranspiration rate of 5.94 mm/day. The mean annual maximum and minimum temperature is 26.2 0C and 14.8oc, respectively. The soil type in the experimental site is silty clay loam with average FC and PWP of 17.57% and 12.3% on a volume basis accordingly. The site is characterized by an average infiltration rate of 8 mm/hr and a pH value of 7.8.

Experimental Design and Treatment Arrangement

Each treatment was replicated three times and the plot has lied following Factorial-RCBD. Totally nine treatments were composed of three furrow methods; Alternate furrow irrigation (AFI), Fixed furrow irrigation (FFI) & conventional furrow irrigation (CFI), and three Irrigation amounts; 50%ETc, 75%ETc, and 100%ETc of irrigation requirement (Table 1). The irrigation depth of application was determined by using CROPWAT version 8 software programs. The experiment was conducted for two consecutive years of 2011 and 2012.AFI means that one of the two neighboring furrows was alternately irrigated during consecutive watering. FFI means that irrigation was fixed to one of the two neighboring furrows while CFI was the conventional way where every furrow was irrigated during each watering. With 100% ETc (full irrigation) implies the amount of irrigation water applied in accordance with the computed crop water requirement with the aid of the CROPWAT program. 75% ETc, and 50% ETc means 75%, and 50% of full irrigation requirement, respectively. Each experimental plot was 3 m x 6 m with 1.5m free space between plots and 2m wide spacing between blocks.

Table 1. The treatment arrangement and seasonal water requirements of each treatment

Treatment	Furrow type	Depth of application (mm)	Seasonal Irrigation Water Requirement(mm)
1	CFI	100%ETc (40)	560
2	CFI	75%ETc (30)	420
3	CFI	50%ETc (20)	280
4	FFI	100%ETc (40)	280
5	FFI	75%ETc (30)	210
6	FFI	50%ETc (20)	140
7	AFI	100%ETc (40)	286
8	AFI	75%ETc (30)	210
9	AFI	50%ETc (20)	140

Planting and crop management

Maize (*zea maize*) of variety in the 1st week of February and harvested around the middle of May with the length of growing period 90-100days. Two seeds were planted per hole with a plant spacing of 0.30 m. All plots were irrigated immediately after planting (planting irrigation). Prior to the third treatment irrigation; plants were thinned to one per stand for a population of 80 plants per plot. Blanket Fertilizer rates of 100 kg ha $^{-1}$ DAP and 100 kg ha $^{-1}$ UREA were applied. Nitrogen fertilizer was applied in two splits: two-thirds at planting and one-third at knee height. All other agricultural operations, including pesticide and hand weeding, were applied uniformly and simultaneously for all treatments. Maize was harvested by cutting the aboveground biomass and left for further drying before removing the cobs from the stalks. The crop was then threshed and grain yield (at 15% moisture content) was measured. Agronomic parameters grain yield, dry biomass yield, plant height, and water productivity were recorded. Finally, the collected data were subjected to Genstat 13th Edition for analysis.

Irrigation management

The frequency of irrigation was fixed as 7 days interval, which is determined by the CROPWAT model at no yield penalty level. Totally all plots were irrigated 14 times throughout the growing season. Irrigation water was applied to furrows using siphon from a ditch at the head the furrow was lined with geomembrane plastic with an inflow rate of 0.17l/sec. Prior to planting all plots were irrigated with an equal amount of water up to the field capacity to initiate germination.

Results and Discussion

Irrigation effects on maize yield and yield parameters

From the ANOVA table (Table 2), it was observed that most of the yield and yield parameters showed a significant

types had a significant interaction effect on measured agronomic parameters except for dry biomass yield.

Table 2. ANOVA table showing the effect of furrow irrigation method and irrigation depth on yield and related components of maize crop

Source of variation	Degree of freedom	Mean Square			
		Grain yield (ton/ha)	Biomass (ton/ha)	Plant height (cm)	Water productivity (kg/m^3)
Replication	2	0.02363	38.37	5.54	0.00387
Year	1	0.00104	28.16	56.63	0.000017
Rep/year	2	0.0083	36.29	105.16	0.001677
Irrigation level	2	7.94147**	39.15**	880.06**	0.014136*
Types of furrow	2	4.35283**	16.81**	330.76*	1.405746**
Irrigation Level/ furrow Types	4	0.2958**	41.49	146.68*	0.025753**
Errors	40	0.01147	38.23	41.27	0.002172

Grain yield and Yield Parameters

In all furrow irrigation methods, the grain yield produced showed an increasing trend when the amount of water added increased. The highest GY was in the CFI-100%ETc treatment with 3.16 t ha^{-1}, whereas FFI-50%ETc exhibited the lowest GY with 1.218 t ha^{-1} (Table 3). Grain yields under conventional furrow irrigation (CFI) were significantly higher than those under alternate furrow irrigation (AFI) and fixed furrow irrigation (FFI); due to the higher amount of applied water and crop evapotranspiration. This finding is similar to results obtained by Sepakhah and Khajehabdollahi (2005) evaluated the alternate furrow irrigation with different irrigation intervals for maize. Sepaskhah and Parand (2006) effect of alternate furrow irrigation with supplemental every furrow irrigation at the different stages on the yield of maize also reported alternate furrow irrigation resulted in a significant reduction of maize yield compared with every furrow irrigation due to water stress.

Decreasing applied water by 25% and 50% of ETc led to decreasing in grain yield of maize by 24% and 50%, respectively due to the small amount of applied irrigation water, which did not much full maize water requirements, caused water stress and consequently reduced crop yield. This result similar to reported by Abd EI-Halim (2013) impact of alternate furrow irrigation with different irrigation intervals on the yield of corn. Similarly, Seghatoleslami *et al.* (2005) reported water stress reduced seed yield in foxtail millet. On the other hand, AFI with different irrigation levels proved to be superior by increasing plant height than CFI and FFI based on a two-season mean. Even though the treatment combination of CFI-100ETc gave a maximum grain yield of 3.316 t. ha^{-1} and optimum grain yield 3.17 ton ha^{-1} obtained due to AFI-100ETc. This might be attributed to the better availability of soil moisture during the irrigation cycle for AFI (Table 3), which enhanced water and nutrient uptake and doubtless reflected on the final GY. This result confirms the results found by Abdel-Maksoud *et al.* (2002), Sepaskhah and Khajehabdollahi (2005). Additionally, alternate furrows gave a significant difference in each irrigation level. To take advantage of this type of plant response, Kang *et al.* (1997) suggested that irrigation might be designed so that part of the root system is exposed to drying soil while the rest is in wet soil. Such a design could lead to reduced stomata opening without leaf water deficit.

Water productivity (WP)

Irrigation water productivity (WP) was significantly affected by furrow irrigation type and irrigation level. The highest WP values were 1.29 kg m^{-3} recorded for the AFI-75%ETc treatment followed by 1.24 kg m^{-3} obtained for AFI-100%ETc, whereas the lowest values reached 0.644 kg m^{-3} for CFI-100ETc (Table 3). There were significant statistical differences recorded for WP between AFI and the CFI treatment. These results indicated that AFI is appropriate to increase WP because they allow applying less irrigation water for maize production. The high WP values for AFI could be due to the small amount of applied water for AFI as compared with the CFI treatment. Sepaskhah and Hosseini (2008) reported similar results. In addition, Nouri and Nasab (2011) concluded that the AFI system generally increases sugar cane yield and field WUE.

Table 3. Effect of furrow type and irrigation level on agronomic parameters and water productivity

Furrow type With Irrigation levels	Plant height (cm)	Grain yield (t ha^{-1})	Water productivity (kg m^{-3})
AFI-50%ETc	186.4a	1.496f	1.1635c
AFI-75%ETc	181.1ab	2.395c	1.2901a
AFI-100%ETc	179.1ab	3.174b	1.2348b
CFI-50%ETc	172.9bc	1.849e	0.7195g
CFI-75%ETc	172.9bc	2.503c	0.6743gh
CFI-100%ETc	169.5c	3.316a	0.6449h
FFI-50ETc	168.7c	1.218g	0.9475d
FFI-75%ETc	167.9cd	1.59f	0.8564e
FFI-100%ETc	160.3d	2.058d	0.8005f
CV (%)	7.7	8.9	5.0
LSD(0.05)	7.496*	2232.3**	0.05439**

Note: Means followed by the same letter (s) are not significantly different at the 5% level of probability.

Dry Biomass Yield

Compared to conventional watering or watering fixed parts of the root system, alternate furrow irrigation reduced water consumption by 50% with a total biomass reduction of 10%. Low irrigation levels also significantly reduced the total dry biomass yield. The conventional irrigation method produced maximum dry biomass yield (Table 4). The two years data showed that if the AFI method uses less irrigation than the conventional irrigation method with no or minimal yield loss. Generally, results show that alternative drying of part of the root system is better than the drying of the fixed part of the root zone. Finally, it can be concluded that the AFI system can substantially save agricultural water use for irrigation.

Table 4: Mean effects of furrow types and irrigation levels on dry biomass yield

Water levels	Dry biomass yield (t ha^{-1})	Furrow types	Dry biomass yield (t ha^{-1})
100%ETc	8.14a	CCF	7.94a
75%ETc	6.94b	AFI	7.16b
50%ETc	6.55c	FFI	6.53c
CV (%)	10.0	CV (%)	10.0
LSD (0.05)	0.5036	LSD (0.05)	0.5036

Conclusions and Recommendation

Irrigation techniques and irrigation levels had shown a highly significant difference in grain yield, plant height, dry biomass, and water productivity. The interaction effect of irrigation techniques and irrigation levels

effect of irrigation techniques and irrigation levels was not shown significantly different on biomass. Results obtained from this study was shown that the AFI 100% system lead to lesser water input and yet was still able to generate comparable maize yield with CFI 100%.

Alternate furrow irrigation with appropriate irrigation levels can be used as an efficient method for maize production in rainfall stress areas like kobo woreda. From this experiment, it could be concluded that the alternative furrow irrigation treatment controlled stress irrigation without the risk of reduced grain yield of maize increase production and productivity of the society. Moreover, it increased the water use efficiency and saved irrigation water. Besides it also saves the energy and time for farmers to irrigate the whole land in turn it saves the cost for a water of irrigation. Therefore, it is recommended that using an alternative furrow irrigation system in areas where there is water scarcity as well as labor expensiveness like to the study area, AFI is the best option to increase the production of maize and other vegetables.

As intensive irrigation practice is already common in the study area, giving a training and advisory service for communities as to how to use crop water requirement based irrigation system is basic, as over application and high-frequency irrigation causes water logging, aggravate soil salinity, water losses as runoff or tailwater, increases the cost of labor and time to irrigate farms. An alternative furrow irrigation system is the best technology among the tested technologies to be recommended for the communities of the study area, because of its high-water productivity, in addition to time, labor and irrigation cost saving. Further research work is needed to give the appropriate irrigation interval with an alternative furrow irrigation system.

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References

Abd EL-Halim (2013). Impact of alternate furrow irrigation with different irrigation intervals on yield, water use efficiency, and economic return on corn. Middle Nile Delta, Egypt.

Abdel-Maksoud, H.H., Sanaa A. Othman, and A.Y. El-Tawil (2002). Improving water and N-use utilization for field crops via alternate furrow irrigation technique 1-Maize crop. Mansoura University Journal of Agricultural Sciences Mansoura University 27:8761-8769.

Awulachew, S.B., Merrey, D.J., Kamara, A.B., Van Koopen, B., De Vries, F. P. and Boelle, E. (2005). Experiences and Opportunities for Promoting Small-Scale/Micro Irrigation and Rainwater Harvesting for Food Security in Ethiopia. IWMI. Working Paper 98.

Behera, S.K. and R.K. Panda (2009). Integrated management of irrigation water and fertilizer for wheat crop using field experiment and simulation modelling: Agricultural water Management 96:1532 1540.

Du, T. S., Kang, S. Z., Sun, J. S., Zhang, X. and Y., Zhang, J. H. (2010). An improved water use efficiency of cereals under temporal and spatial deficit irrigation in north China. Agric. Water Manag. 97 (1): 66 74.

Eck, H.V., A.C. Mathers, and J.T. Musick. (1987). Plant water stress at various growth stages, growth, and yield of soybean. Field Crop Research, 17:1-16

Ghasemi, M.M. and Sepaskhah, A.R. (2003). Economic evaluation of every-other furrow irrigation for sorghum with real and subsidized irrigation water prices. J. Sci. Technol. Agric. Natur. Resour. 7(2): 1-11.

Halim, A.A.E. (2013). Impact of alternate furrow irrigation with different irrigation intervals on yield, water use efficiency and economic return of corn. Chilean journal of agriculture research, 73(2): 175-180.

Kang, S., Zhang, J.and Liang, Z., (1997). The controlled alternate irrigation: a kind of new thinking of water-saving on farmland. Chinese Agric. Res. Arid Areas 15 (1), 1-6.

Kirda, C. (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Food and Agricultural Organization of the United Nations, Deficit Irrigation Practices, Water Reports, 22, 102.

Mintesinot B., Abdulkedir M., Mezgebu A. and Mustef Y. (2005). Preliminary report community based irrigation management in the Tekeze basin: Impact assessment a case study on three small-scale irrigation schemes (micro dams). A collaborative project between Mekelle University, ILRI and EARO.

Nelson, D.J., and M.M. Al-Kaisi (2011). Agronomic and economic evaluation of various furrow irrigation strategies for corn production under limited water supply. Journal of Soil Water Conservation 66(2):114-120

Nouri, M., and S.B. Nasab (2011). Study of effect of alternate furrow irrigation in sugarcane (Var CP69-1062) at different growth stages on quality and quantity of yield. 21st International Congress on Irrigation and Drainage (ICID), Tehran, Iran. 15-23 October. International Commission of Irrigation and Drainage (ICID), New Delhi, India. 287-291.

Perry, C., P. Steduto, R.A. Allen and C.M. Burt (2009). Increasing productivity in irrigated Agriculture: Agronomic constraints and hydrological realities. Agricultural water Management 96:1517 1524.

Seghatoleslami., M.Kafi and E. Majidi (2005). Effect of drought stress at different growth stages on yield and water use efficiency of five proso millet (*Panicum Miliaceum L.)* genotypes. Pak. J. Bot., 40(4): 1427-1432.

Sepaskhah, A.R., and A.R. Parand (2006). Effects of alternate furrow irrigation with supplemental every-furrow irrigation at

Sepaskhah, A.R., and M.H. Khajehabdollahi (2005). Alternate furrow irrigation with different irrigation intervals for maize (Zea mays L.) Plant Production Science 8:592-600.

Sepaskhah, A.R., and S.N. Hosseini (2008). Effects of alternate furrow irrigation and nitrogen application rates on yield and water- and nitrogen-use efficiency of winter wheat (Triticum aestivum L.) Plant Production Science 11:250-259.