academicresearchJournals

Vol. 9(1), pp. 31-36, January 2021
DOI: 10.14662/ARJASR2020.790

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Evaluation of Alternate Furrow Deficit Irrigation for Water Productivity of Potato in Ziway Dugda District of Ethiopia

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Accepted 28 October 2020

The experiment was conducted at Ziway Dugda district with the Objectives of the study were to evaluation deficit irrigation practice and optimize water productivity under small scale farmer. Two types of furrow irrigation methods (100% ETc alternate furrow and 100% ETc conventional furrow irrigation) were evaluated in a plot size of 10mx10m. The comparison of the experiment shows that the maximum and minimum tuber yield (15.78 and 14.15ton/ha) was obtained at conventional and alternate furrow irrigation methods, respectively. On the other hand, the maximum and minimum water productivities of 6.81 kg/m3 and 3.59kg/m3 were obtained at 100% ETc alternate and 100% ETc conventional Furrow irrigation method respectively. 100% ETc AFI treatment saves about 50% of irrigation water than 100% ETc CFI for the production of potato. A deficit of irrigation water by 50% recorded yield loss of 10.33%. Therefore, in areas having enough irrigation water resources, farmers can use 100%ETc CFI for maximum potato yield production, nonetheless under limited irrigation water resource 100% ETc AFI method is an appropriate method, which can save about 50% of irrigation water.

Keywords: Water Productivity, Deficit Irrigation, Alternate Furrow and Conventional Furrow Irrigation Method

Cite this article as: Samuel, L., Bakasho, I., Mehiret, H. (2021). Evaluation of Alternate Furrow Deficit Irrigation for Water Productivity of Potato in Ziway Dugda District of Ethiopia. Acad. Res. J. Agri. Sci. Res. 9(1): 31-36

INTRODUCTION

Water is one of the basic natural resources for humanity, but it is often scarce. Mainly spatial and temporal variability in rainfall aggravates the water scarcity problem. Also, the water scarcity problem increased due to climate change, rapid population growth, and increasing consumption of water per capital and this tendency are likely to continue as water consumption for most uses is projected to increase by at least 50% by 2025 compared to 1995 level (Rosegrantet al., 2002).

Irrigated agriculture is the main user of the available water resources. About 70% of the total water withdrawals and 60-80% of total consumptive water use are consumed in irrigation (Huffaker and Hamilton, 2007). There is a conflict in the global increase in food demand and a decrease in water resources that should be resolved. Food security can be achieved by irrigated agriculture since irrigation on average doubles the crop yield compared to that usually produced in rain-fed conditions. The irrigated area should be increased by more than 20% and the irrigated crop yield should be increased by 40% in 2025 to secure the food for 8 billion people (Lascano and Sojka, 2007). Therefore, water resources should be used with higher efficiency or productivity. To achieve this goal, improvement in agricultural water productivity is highly imperative.

Many investigations have been conducted to gain experiences in the irrigation of crops to maximize performances, efficiency, and profitability. However, investigations in water-saving irrigation still are continued (Sleper et al., 2007). Full irrigation (FI) is used by farmers in non-limited or even water-limited areas. In this method, crops receive full evapotranspiration requirements to result the maximum yield. Nowadays, full irrigation is considered a luxury use of water that can be reduced with minor or no effect on profitable yield (Kang and Zhang, 2004). Water-saving irrigations are used to improve water productivity (WP) in recent years.

A recent innovative approach to save agricultural water is deficit irrigation (DI). Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield (Zhang, et al., 2004) and Mermoud (2005). In this method, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction (especially in water-limiting situations) will be compensated by increased production from the additional irrigated area with the water saved by deficit irrigation (Ali et al, 2007).

In the case of Deficit irrigation (DI) and partial root-zone drying irrigation (PRD), there is a partial wetting of the soil while the other part is kept dry and it stimulates the secretion of abscisic acid (ABA) in the roots. The presence of ABA sends a water stress signal to the stomata and forces the stomata to close. This in turn reduces transpiration or water loss without affecting photosynthesis (Kang et.al., 1998). The amounts of irrigation reduction is crop-dependent and generally accompanied by no or minor yield loss that increases water productivity (Ahmadi et al., 2010b).

The rift valley area is a semiarid with limited water resources and increasing demand for water combined with high evapotranspiration rates limits the production and productivity of the crop. Hence, alternatives need to be explored for effective and efficient use of the existing water resources.

An important adaptation of furrow irrigation is Alternate Furrow Irrigation (AFI) in which furrows are irrigated alternately rather than consecutively during irrigation water application. This is a form of partial root-zone drying (PRD) system which has been found to increase the production of various vegetables in the ASAL areas (Fereres et al., 2007; Jones, 2004) as well as saving irrigation water. The application of deficit irrigation strategies to this crop may significantly lead to saving irrigation water (Costa et al., 2007). Furthermore, studies have shown that water deficit occurs during certain stages of the growing season improves fruit quality, although water limitations may determine fruit yield losses (Patane and Cosentino, 2010). Therefore, the objectives of this study were to identify the level of deficit irrigation which allows for achieving optimum potato yield and to investigate the effect of alternate, and conventional furrow irrigation systems on potato yield, quality, and water productivity.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in Ziway Dugda district, Arata PA of Arsi Zone, Oromia Regional State, Ethiopia. The study area is located around 180 km from Addis Ababa capital city of Ethiopia. The experimental area is between 08˚02’19”N to 39˚00’59”E, situated in an average elevation of 1700m above sea level.

Ziway Dugda is a semi-arid environment with a mean monthly maximum and minimum temperature of 26.3°C and 12.3°C, respectively. It is characterized by a uni-modal low and erratic rainfall pattern with an average annual rainfall of 689mm. The soil is a Silt clay type, at the experimental site has a field capacity of 29%, wilting point of 15 %, and the total available water was about 14% while, the bulk density of 1.20 g/cm.

Table 1: Long-term monthly climatic data of the experimental area

Month	T Max (°C)	T Min (°C)	RH (%)	Wind speed (km/day)	Sunshine (hrs)	ETo (mm/day)	Rainfall (mm)
January	26.2	10.3	60	112	9.7	4.11	12.0
February	26.6	12.1	54	86	9.3	4.24	47.0
March	27.4	12.9	56	86	8.4	4.39	44.0
April	28.5	13.2	57	69	7.7	4.25	85.0
May	28.6	12.8	60	78	7.6	4.18	41.0
June	27	13.4	69	130	7.6	4.2	72.0
July	24.6	14.3	81	95	5.1	3.26	132.0
August	24.2	14.1	84	86	5.8	3.41	118.0
September	24.4	13.1	84	60	5.3	3.26	89.0
October	26.2	12.4	71	69	8.4	3.94	32.0
November	25.5	10.3	56	104	9.3	4.02	11.0
December	26.2	8.8	57	78	9	3.64	6.0

Source: FAO. 2005. New-LocClim, Local Climate Estimator.

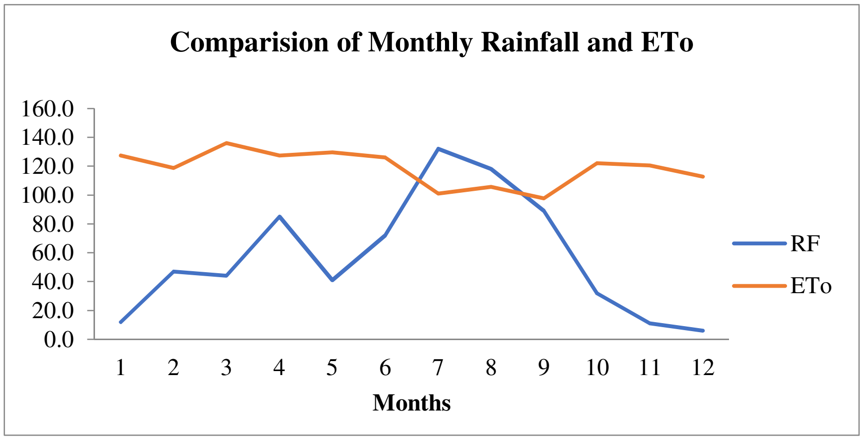

Figure 1: Monthly rainfall as compared with reference evapotranspiration

Experimental Comparison

Potato (Gudene Variety) was planted on a field plot of 10mx 10m. The furrows spacing of 0.75m were used for planting potato seed on both sides of a ridge at the row and plant spacing of 37.50 and 30cm, respectively. Two furrow irrigation methods were compared (AFI and CFI) Farmers practice as control described below in Table 2:

Table 2: Combination of the Experimental Treatments

Treatment	Combinations
T1	Alternative furrow (AF) irrigated at 100% ETc
T7	Conventional furrow (CF) irrigated at 100% ETc
T9	Farmers practice (control)

All plots were irrigated with a uniform amount of water a few days before planting to make the soil workable. The experiment was planted in 2016/17 and 2017/18 during the first week of December and January respectively. To ensure the plant establishment common irrigations were provided to all plots at two days interval before the commencement of the differential irrigation. Irrigation water was applied at allowable soil moisture depletion of the total available soil moisture throughout the crops growth stage. Plots were fertilized with the recommended rate of nitrogen and phosphorous fertilizer, 150kg/ha, and 244kg/ha, respectively. Phosphorus fertilizer was applied to all plots as a basal dose at planting, while the recommended rate of nitrogen fertilizer was uniformly applied in splits, half at planting, and the remaining half at the early development stage.

Measured depths of irrigation water were delivered to each plot according to the treatment arrangements and irrigation schedule through a water measuring device, namely two inch parshall flume, which was installed three meters before the start of experimental plots.

Crop water requirement (CWR) for the CFI method 100%ETc was calculated using CropWat version 8.0 software and soil water was monitored by the gravimetric method. Based on the calculated CWR, Irrigation water was applied according to the treatment percentage and the method of furrow irrigation. AFI treatments were received half of the conventional furrow irrigation method.

Soil samples before and after irrigation were taken from control treatment plots to check the moisture content before and after irrigation not to go above field capacity and below allowable moisture depletion level.

Data collection and analysis

Data collection tuber yield and yield components that include bulb diameter, biological yield. Water productivity and the effect of water stress on crop performance were quantified from WP and yield response factors (Ky), respectively. Estimation of water productivity was carried out as a ratio of total bulb yield to the total water applied (Central Statistics, 2011).

$$\text{Water Productivity}\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\text{Total Bulb Yield(kg)}}{\text{Crop Water Use (m3)}}$$

Data Analysis

The collected data were statistically analyzed using Microsoft Excel.

RESULT AND DISCUSSION

The comparison of the experiment between 100% ETc conventional furrow irrigation and 100% ETc alternate furrow irrigation method showed a significant difference in potato tuber yield and water productivity.

Potato tuber yield

Deficit irrigation water applications affected the tuber yield of potato. 100% ETc conventional furrow irrigation method recorded greater tuber yield than a 100% alternate furrow irrigation method. The highest tuber yield (15.78ton/ha) was recorded by treatment receiving 100% ETc CFI and the lowest (14.15 ton/ha) was from the AFI method (Table 2).

The previous study by (Enchalew et al, 2016) on onion confirmed that the highest marketable bulb yield was recorded from the control treatment of 100% ETc. Yemane M. et al, 2018 reported that CFI showed significantly higher yield at 100% of the irrigation level. It showed that the conventional furrow irrigation system gave more yield with irrigation water amount of 100%. Among the furrow irrigation treatments, conventional furrow irrigation produced the highest bulb yield than the alternate furrow irrigation system, while the fixed furrow irrigation system gave the lowest bulb yield. Furthermore, FFI and AFI all showed a substantial decrease in bulb yield. Bakker et al. (1997) and Sepaskhah and Ghasemi (2008), reported that a small amount of applied water reduced yield in every other furrow irrigation (AFI and FFI) as compared to CFI due to water stress when the same irrigation frequency was applied which supported the result of this research.

The present result agreed with the general principle that the response of the crop to full irrigation is generally higher under irrigated conditions than none irrigated one (Michael, 1978). The increment in marketable bulb yield due to the application of irrigation water could be attributed to the increment in vegetative growth and increased production.

A study was done by Al-Moshileh A (2007), also presented similar findings with this result. Obtained by (Enchalew et al, 2016) the high soil moisture application attributes to vegetation growth and increases plant metabolic activities, which leads to marketable bulb yield increment value to result in an 18% yield penalty.

Table 3: Applied Water, Water Productivity, Water Saved, and Yield Reduction.

TRT	Treatments	Water Applied (mm)	Tuber Yield (ton/ha)	Water Productivity (kg/m3)	Water Saved (%)	Yield Reduction (%)
T1	AF 100%ETc	220	14.15	6.81	50	10.33
T2	CF 100%ETc	440	15.78	3.59	-	
T3	Farmer practice		15.35	-	-	2.75

Water Productivity (WP)

The water productivity of furrow irrigation techniques was significantly different by deficit irrigations for potato tuber yield. 100% AFI had recorded greater water productivity of 6.81kg/m3 when the conventional furrow irrigation method recorded 3.59 kg/m^3 (Fig.2). The alternate furrow irrigation method was saved 50% irrigation water when compared with the control treatment (100% ETc CF). The results also indicated that deficit irrigation enhances the water productivity of potato crops.

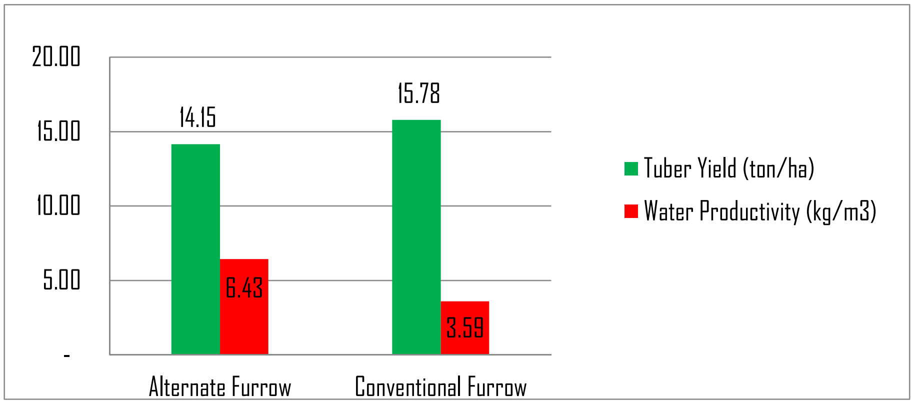

Figure 2: Potato tuber yield and water productivity comparison under deficit irrigation

Treatment receiving 100% ETc alternate furrow irrigation resulted in higher water productivity and saved 220 mm or (50%) of water (Table 3). The control treatment CFI 100% ETc gave practically the lowest WP. However, the 100% AFI method recorded a yield reduction of 10.33% of control treatment which is a tolerable value (Table 3). This conclusion is in line with a statement given by (Sarkar et,.al 2008) the decrease in yield is proportionally greater with an increase in water deficit.

Yemane M. et al, 2018 reported that the highest value of WUE was recorded on alternate furrow irrigation techniques compared to CFI. In alternate furrow irrigation techniques, a higher value of 7.9% of WUE was obtained as compared to that of FFI and 26% of conventional furrow irrigation techniques. Mulugeta M. and Kannan N., 2015 indicated that the reason of having high WUE and lower reduction of yield for AFI could be related to a better distribution of the roots in both sides of the ridges it increases water and fertilizer uptake by plants and the physiological response of the crop specifically in the root and leaf parts. Mohajermilani P., 2014 reported that AFI increased WUE for Maize production relative to CFI, and the study of Kang S.Z et al., 2006 indicated that AFI had better performance for increasing WUE. Mansouri-Far et al. (2010) reported that irrigation water can be conserved and yields maintained (as a sensitive crop to drought stress) under water-limited conditions.

CONCLUSION AND RECOMMENDATION

Many investigations have been conducted to gain experiences in irrigated crops to maximize the performances, efficiency, and profitability. However, investigations in water-saving irrigation still are continued. Full irrigation is used by farmers in non-limited or even water-limited areas. In this method, crops receive full evapotranspiration requirements to result in the maximum yield. Nowadays, full irrigation is considered a luxury use of water that can be reduced with minor or no effect on profitable yield (Kang and Zhang, 2004). Water-saving irrigations are used to improve water productivity (WP) in recent years.

The experiment was conducted at farmer's field for the evaluation deficit irrigation under furrow irrigation method for the promotion of this technology for small scale farmers, and to create awareness on the benefits of deficit irrigation practices and optimize water productivity under irrigated agriculture. Two types of furrow irrigation methods (100% ETc alternate furrow and 100% ETc conventional furrow) and farmer irrigation practice was used as a control in a plot size of 10mx10m. The comparison of the experiment shows that the maximum and minimum 15.78 and 14.15 ton/ha were obtained at conventional and alternate furrow irrigation methods, respectively. On the other hand, the maximum and minimum water productivities of 6.81 kg/m3 and 3.59kg/m3 were obtained at 100% ETc alternate and 100% ETc conventional Furrow irrigation method respectively. 100% ETc AFI treatment saves about 50% of irrigation water than 100% ETc CFI for the production of potato tuber yield. A deficit of irrigation water by 50% recorded yield loss of 10.33%.

Therefore, in areas having enough irrigation water farmers can use 100%ETc CFI for maximum potato yield production, nonetheless under limited irrigation water resource 100% ETc AFI method is an appropriate method, which can save about 50% of irrigation water for the cultivation of another irrigation land.

ACKNOWLEDGMENT

The authors are would like to give thanks to the Ethiopian Institute of Agricultural Research (AGP-II) for funding this research and providing necessary facilities. Finally, thanks to Mr. Mengistu M. and Dawit T. for their technical assistance during the experiment.

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