International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

Participatory evaluation and demonstration of furrow irrigation systems with full irrigation application on Onion (*Allium cepa* L.) yield, yield component and water use efficiency at Docha Dembela in Demba Gofa woreda, South Ethiopia

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International Journal of Science and Research Archive, 2024, 12(02), 2571–2576

Publication history: Received on 07 July 2024; revised on 22 August 2024; accepted on 24 August 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.12.2.1530

Abstract

Poor irrigation water management is one of the major factors limiting crop production in Ethiopia. Field experiment was conducted at farmers filed at Docha Dambal kebele in Demba Gofa woreda, Gofa zone, South Ethiopia for two consecutive years (2019 & 2020) to evaluate and demonstrate the effect of furrow irrigation systems on onion yield and water use efficiency. The treatments consisted of three furrow irrigation systems (conventional, alternative and fixed). The irrigation treatments were laid out in randomized complete block design with six replications and participant farmers were used as a replication. Results indicated that highest mean value of marketable bulb yield (27758.2 kg ha-1) was brought under Conventional furrow system. However the lowest mean value of marketable bulb yield was recorded from the fixed furrow system (20482.5). However, Superior water use efficiency of 13.33kg/m3 was recorded from alternative furrow irrigation system. The lowest water use efficiency (7.78 kg/m3) was recorded from the Conventional furrow system. Therefore, It could be concluded that alternate furrow irrigation system maximized water use efficiency of onion with tolerable yield penalty at the study area. This result is important for farmers to irrigate supplemental lands with water saved, thus achieving a more efficient and rational use of land and water resources in the water limited area. If areas with no water scarcity, conventional furrow system could be a potential approach for promoting onion bulb yield under field conditions.

Keywords: Alternative furrow system; Fixed furrow system Conventional furrow system; Onion; Water use efficiency

1. Introduction

Water is the important but scarce resource for agricultural development and globally this resource is shrinking [1] Irrigated agriculture is the main solution to produce crop to feed and achieve the different needs for an ever-increasing world population. However, a growing competition for water from domestic and industrial sectors reduced its availability for irrigation. In this regards irrigation only based on crop water requirement is not an option especially in areas where water resource is limited [2]. Under this condition, the need to use the available water economically and efficiently is indubitable.

Water can severely restrict agricultural production and productivity unless it is carefully conserved and managed. There is a growing recognition that increases in food production will largely have to originate from improved productivity per unit water and soil. Increasing optimum water productivity, especially the value produced per unit of water, can be an important pathway for poverty alleviation [3]

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One more option to increase water productivity through deficit level is alternate and fixed furrow irrigation system. Alternate furrow irrigation system is irrigating only one of the neighboring two furrows during the consecutive irrigation time. But, fixed furrow irrigation system which means that irrigation is fixed to one of the two neighboring furrows. The studies of [4] improved by converting conventional furrow irrigation to alternate furrow irrigation (AFI) in order to increase water use efficiencies. Conventional furrow method is irrigating the entire neighboring furrow in two consecutive irrigation time leads to maximize yield under different crops

In the study area Onion is a major irrigated crop. However, water is the most limiting factor. Therefore, application of deficit irrigation could provide greater economic returns than maximizing yields per unit of water. The deficit irrigation could be considered as a way of maximizing water use efficiency (WUE) by applying a reduced amount of irrigation water, which has no significant impact on yield. Therefore, the present research designed to evaluate and demonstrate furrow irrigation systems on onion yield and water use efficiency

2. Material and methods

2.1. Description of the study area

This field experiment was conducted farmers filed at Docha Dambal kebele in the district of Demba Gofa, Southern Ethiopia during the dry cropping season for two consecutive years (2019 and 2020). The study site is located an altitude of 1193 meter above sea level, longitude of 037°02.628' and latitude of 06°25.136'.

2.2. Experimental Treatments and Design

The experimental treatments include three irrigation systems, viz.,the alternative furrow irrigation (AFI), fixed furrow irrigation (FFI) and conventional furrow irrigation (CFI) with irrigation of 100% ETc application. CFI, water was supplied to every furrow in every irrigation events. In AFI, water was applied to alternate furrows. However, during the subsequent event, irrigation water was applied to the alternate furrows that had been kept dry during the previous time while leaving previously wet furrows not irrigated. In FFI, irrigation water was supplied to the fixed furrows while the adjacent furrows kept dry from first to last irrigation events. The experimental design was Randomized complete block design (RCBD) with six replication and participant farmers were used as a replication. The farmers placed comparable fields that were the same soil texture, slope and productivity. Fields were planted to the same variety and planting dates.

2.3. Determination of Crop Water and Irrigation Requirements

There were no weather stations at the study sites. Thus, the New_Loclim: Local Climate Estimator, a public domain software program and database, developed by [5] was used to estimate the average weather variables for the study sites.

The reference evapotranspiration (ET_0) was computed from minimum and maximum air temperatures, wind speed, relative humidity, sunshine hours, and solar radiation using the FAO CROPWAT 8.0 model. The onion crop water requirement was estimated from reference crop evapotranspiration (ETo) and crop coefficient (Kc) using equation (1). Since there were no site specific K_C for onion in the study area, the values set by FAO for the four crop development stages were adopted for this study:

$$\text{ETc} = \text{ETo x Kc} ----------------------1$$

Where, ETc- crop evapotranspiration (mm day^{-1}), ET_0-reference evapotranspiration (mm day^{-1}) and Kc-crop coefficient

After the determination of crop evapotranspiration using the above relation, the net irrigation requirement (I) was estimated using

$$\text{NIR(mm)} = (\text{ETc}_{\text{mm}} - \text{Peff}_{\text{mm}}) ------------- 5$$

Where, NIR represents the net irrigation requirement (mm), Pe represents the effective rainfall (mm).

The gross irrigation requirement was obtained from the expression:

$$\text{GIR} = \frac{\text{NIR}}{\text{Ea}} ------------------------6$$

Where, GIR represents gross irrigation requirement (mm), NIR represents net irrigation requirement (mm) and Ea represents application efficiency (%)

The field application efficiency considered for the method of irrigation used in this study was 60%

The field application efficiency of furrow irrigation was 60% for properly constructed water distribution and proper prepared land water over the irrigated field.

2.4. Irrigation Water Management

The amount of irrigation water supplied to the plots was measured using calibrated three inch Parshall flume. The flume was installed at a leveled surface 2 meters before the experimental site. The fixed partial flume was aligned straight with the field canal and leveled laterally and longitudinally to allow free flow of water. The water supply to each furrow within each plot was switched off when the time allotted to each furrow ended indicating the delivery of the calculated amount irrigation water to each plot.

The time required to deliver the desired depth of water into each furrow will be calculated using the equation:

$$t = \frac{A * dg}{6Q} ------------------------7$$

Where: - dg- gross depth of water applied (cm), t-application time (min), A-area of plot size (m^2), and Q-flow rate (discharge) (l/s).

The same amount of irrigation water was supplied just after transplanting to all plots. Thereafter, the irrigation water was applied according to the treatment setup.

2.5. Crop Management

All experimental plots were transplanted with onion crop variety of Adama Red on 25 November in 2019 and 2 December in 2020 with the spacing of 40cm, 20cm and 10cm between furrows, rows and plants respectively. The optimum rate of 100kg DAP /ha and 100 kg urea/ha was used for onion crop equally for all treatments. Urea split application after 20days of transplanting were the same for all treatments.

2.6. Data Collection

Data collected during the experimental period were number of leaves per plant, plant height, total yield, marketable yield, and water use efficiency.

Plant height (cm): Plant heights of ten randomly selected ten plants were measured from the soil surface to the top of the longest leaf at physiological maturity, and the mean values were computed for further analysis.

Number of leaves per plant: Number of leaves of ten randomly selected plants per plot were counted at physiological maturity, and the mean values were computed for further analysis.

Bulb diameter (cm): The mean sizes of the bulb at harvest from each plot were computed by measuring the diameters of ten randomly selected bulbs using caliper.

Marketable bulb yield (t ha-1): Bulbs which were free of mechanical, disease and insect pest damages, uniform in color and medium to large in size (20 - 160 g) were considered as marketable.

Unmarketable bulb yield (t ha-1): under (160g), misshaped, decayed, discolored, diseased and physiologically disordered bulbs were considered as unmarketable. The weight of such bulbs obtained from the net plot area were measured and expressed as ton per hectare.

Total bulb yield (t/ha): Total yield of onion were obtained by adding marketable and unmarketable bulb yields

Water Productivity

Water productivity (WP) is the amount of onion bulb yield per irrigation water applied.

$$wp = \frac{\text{harvested bulb yield (kg/ha)}x}{\text{total water used}(m^3/ha).} --------------8$$

Where, WP is crop water productivity (kg/m^3), harvested bulb yield (kg/ha) and total water used is the seasonal crop water consumption by evapotranspiration (m^3/ha).

2.7. Statistical Analysis

The data collected was subjected to the standard analysis of variance (ANOVA) using the SAS software 9.1. Treatment means were compared using the least significant difference (LSD) at 5% level of probability.

3. Results and discussion

3.1. Texture of experimental soil

Composite soil sample was collected from depth of onion root zone before planting to analyze soil texture. The result of the soil analysis from the experimental site showed that the average composition of sand, silt and clay percentages were 64%, 11.5% and 24.5%, respectively. Thus, according to the USDA soil textural classification, the soil is classified as sandy clay loam.

3.2. Crop water requirements

Onion was planted on December, 2019 and 2020 at dry cropping season. Total precipitation during the months of December to March in both years was insignificant. As a result throughout the growing period of the test crop, the only source of water was irrigation. In the study area there was no well-established weather stations. Therefore, New Loc Clim 1.10 was used for database to generate climatic parameters for the determination of irrigation regimes. “CROPWAT version 8.0” was used to determine the amount of irrigation water required to meet the irrigation water requirements of the onion.

3.3. Irrigation water applied throughout the growth stages

The amount of applied water for Conventional, Alternative and fixed furrow system were 375mm, 178.5mm and 178.5mm respectively.
This indicates that the alternative furrow system and fixed furrow systems saved water by 50% compared to conventional furrow system. From (Table 2) water saved from AFI and FFI with 100% ETc levels were 50% of total net volume of irrigation water applied.

Table 1 The amount of net irrigation water applied and water saved for each treatment per a hectare of land

S.no	Treatment	Water applied (m3 /ha)	Water saved (%)	Additional area could be irrigated (ha)
1	Conventional furrow system	3570	0	0
2	Alternative furrow system	1785	50	1
3	Fixed furrow system	1785	50	1

3.4. Effect of irrigation system on onion bulb yield

Onion bulb yield collected from each treatment was further differentiated to total yield, marketable yield and unmarketable yields.

Marketable bulb yield (kg/ha): The two years' combined statistical analysis resulted that marketable bulb yield was significantly ($P<0.05$) affected by irrigation system (Table 2). Highest mean value of marketable bulb yield (27758.2 kg/ha) was brought under Conventional furrow system. However the lowest mean value of marketable bulb yield was recorded from the fixed furrow system (20482.5 kg/ha)

Unmarketable bulb yield: Statistical analysis resulted that unmarketable bulb yield was significantly ($P<0.05$) affected by irrigation system (Table 2). The highest mean value of unmarketable bulb yield (146.5a kg/ha) was obtained from the fixed furrow system and the lowest (56 kg/ha) observed at the conventional furrow system (Table 2).

Total bulb yield (kg/ha): Statistical analysis resulted that total bulb yield was significantly (P<0.05) affected by irrigation system (Table 2). The highest mean value of total bulb yield (27814.2 kg/) was obtained from conventional furrow system but, lowest (20629.0 kg/ ha) observed at the fixed furrow system (Table 2).

3.4.1. Effect of irrigation system on onion yield components

The two years' combined statistical analysis revealed that plant height and number of leaves per plant were not significantly (P<0.05) affected by furrow irrigation system. But bulb diameter of onion was significantly influenced (P<0.05) by furrow irrigation system (Table 2). The largest diameter was recorded as 18.3 cm by conventional furrow system, followed by alternative furrow system and fixed furrow system as 16.88cm and 14.7cm respectively (Table 2)

Table 2 Combined onion yield and yield components (2019 and 2020) results at Docha Dambala, Demba Gofa woreda

Treatment	MYLD (kg/ha)	UMYLD (kg/ha)	TYLD (kg/ha)	BD/cm	Ph(cm)	Number of leaves per plant
Conventional furrow system	27758.2^{a}	56.0^{c}	27814.2^{a}	18.3^{a}	51.00	9.5
Alternative furrow system	23796.0^{b}	76.5^{b}	23872.5^{b}	16.88^{ab}	52.23	7.94
Fixed furrow system	20482.5^{c}	146.5^{a}	20629.0^{c}	14.7^{b}	54.3	8.00
Mean	24012.23	93	24105.22	16.65	52.51	8.48
LSD (5%)	1335.4	14.24	1336.8	2.63	NS	NS
CV (%)	5.27	14.52	5.26	14.99	6.17	12.12

Data share different letter indicate significant difference. MYLD (kg/ha) = Marketable bulb yield (kilo gram per hectare), UMYLD (kg/ha)= Unmarketable bulb yield (kilo gram per hectare), TYLD (kg/ha)= Total bulb yield (kilo gram per hectare), BD/cm= bulb diameter (centimeter). Ph (cm)= plant height (centimeter), CV (%) coefficient of variance by percentage and LSD (5%) list significant difference

3.5. Water use efficiency

Superior water use efficiency of 13.33kg/m^3 was recorded from alternative furrow irrigation system. The lowest water use efficiency (7.78 kg/m^3) was recorded from the Conventional furrow system. The tolerable yield reduction in this experiment was obtained from alternative furrow irrigation system of the crop water application which showed 14.27% yield reduction and also saved 50% irrigation water as compared to CFI.

Therefore, this showed an application using alternative furrow perform well in accordance with water use efficiency of onion with saving of more water with tolerable yield reduction. Alternative furrow system was save 50% applied water as compared to the conventional furrow irrigation system. This finding is similar to finding states that, applied water was used more efficiently in the alternate furrow irrigation treatment [6]. [6] reported that lower amount of irrigation water received, could higher the water use efficiency

Table 3 Water use efficiency (kg/ m^3) of onion

Treatment	MYLD (kg/ha)	Water applied (m^3 /ha)	Water use efficiency (kg/ m^3)
Conventional furrow system	27758.2	3570	7.78
Alternative furrow system	23796.0	1785	13.33
Fixed furrow system	20482.5	1785	11.47

4. Conclusion

The results of this study showed that alternate furrow irrigation system maximized water use efficiency of onion with tolerable yield penalty in the study area. This result is important for farmers to irrigate supplemental lands with water saved, thus achieving a more efficient and rational use of land and water resources in the water limited area. If areas with no water scarcity, conventional furrow system could be a potential approach for promoting onion bulb yield under field conditions.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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