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Research Article

Pre - Extension Demonstration of Alternate Furrow Irrigation for Better Water Management Technologies at Dugda District

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Abstract

The agricultural sector is the main consumer of fresh irrigation water so any effort to improve WUE in this sector gets a lot of attention so, raising WUE through improved of modern irrigation techniques and increasing the capacity of soil output complementary to make better employ of irrigation water and saving water for other uses. The aim of this study was to demonstrate the most effective water-saving techniques and improve the water use efficiency of irrigated onions under limited agricultural water availability for better water management technologies. The treatment consists of conventional furrow irrigation and alternate furrow irrigation method with full crop water requirement in three replications on two farmers. Crop water requirement was estimated using actual daily climatic data. The result showed that conventional furrow irrigation method was the highest bulb yield and yield components when compared to alternate furrow irrigation method. Alternate furrow irrigation method produced total yield of 18.73 t/ha which was not significantly different with that obtained under every furrow irrigation (220.6 Qt/ha). It was also found that yield reduction may be low compared to the benefits gained by diverting the saved water to irrigate extra cultivated land. The result showed that decreasing WP with increased irrigation water from 50% crop water requirement (ETc) from alternate furrow irrigation (5.68 kg m^{-3}) to conventional furrow irrigation 100% Etc (3.6 kg m^{-3}). Increasing water deficit from 100 to 50% ETc led to an increase of onion WP up to 75%. For increasing marketable bulb yield of onion under no water stress scenario, irrigation of onion with conventional furrow irrigation methods could be used. However, under limiting irrigation water resource condition, irrigation of onion could be done with alternate furrow irrigation method to maximize water use efficiency of onion for similar agro-ecology and soil type.

Keywords

Alternate Furrow Irrigation, Water Management, Water Saved

1. Introduction

More than 40% of food production in the world depends on supplementary irrigation due to the widening gap between water availability and demand [2]. In case of not having a lot possibility of supplementary fresh water resources to be advanced or finding alternative water resources the only option is to Controlling available fresh water sources suitable for

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irrigation and optimal management to preserve them [9]. The agricultural sector is the main consumer of fresh irrigation water so any effort to improve WUE in this sector gets a lot of attention so, raising WUE through improved of modern irrigation techniques and Increasing the capacity of soil output complementary to making the better employ of irrigation water and saving water for other uses [3].

Surface irrigation is the most common executed irrigation system in Ethiopia as well as East Shewa of Oromia. This wide spread implementation might be due to its low capital cost, no special technical experience regarding operation and maintenance and no specific equipment are required as a result of long practical background among local farmers regarding the implementation of this irrigation system. Furrow irrigation is most widely used among the surface irrigation methods. In this system water is applied by means of small channels or furrows, which follow a uniform longitudinal slope. Furrow irrigation has low application efficiency because of its high water loss due to surface runoff, evaporation from water in the furrow, evaporation from the soil surface and percolation below root zone. Alternate furrow irrigation (AFI) is a system of irrigating only one side of the plant, i.e., half of the root system, is irrigated at first irrigation event, while the other side receives water on the next irrigation.

Alternate furrow irrigation (AFI) is one of the most common irrigation water management techniques, in which the irrigation water is applied to alternate furrows throughout the growing season; that is water was being applied to the alternate furrows which is dry in the previous irrigation cycle. Alternate furrow irrigation was proposed as a method to increase crop water productivity and area of water scarcity as compared to every-furrow irrigation and minimum yield losses were observed for different crops for example compared with fixed furrow irrigation systems [6, 8].

In semi-arid areas of Ethiopia, water is the most limiting factor for crop production [18]. To achieve sustainable irrigated agriculture with limited water resources; it is necessary to introducing different water saving technologies and guidelines for irrigation water users [10].

Limitation of water resources and low efficiency of irrigation are practiced in farmers' agricultural fields. The research was conducted on small-scale irrigation schemes in Ethiopia, and the observed application efficiency and overall efficiency was 56.05% and 43.54%, respectively [13]. This makes it necessary to investigate further alternative techniques to maximize crop water productivity. Although water-saving technologies are available, the installation cost is very high and limited in developing countries saving water consumption [17]. Therefore, finding alternative techniques of irrigation water management to improve sustainable crop water productivity is crucial all over the world, particularly in areas of water scarcity.

Almost all of the irrigation schemes of East shewa zone, the eastern part of Ethiopia, are small scale and traditional. Farmers seem to have awareness about the benefits of irrigation and proven ability to organize themselves to manage small scale irrigation systems. However, it lacks scientific management; they either over or under irrigate their fields. At present situation water is a scarce resource due to use of water for different purposes. However, attention given to agricultural water management by the irrigators as well as the irrigation experts is very low. Therefore, efforts should be put in a place to develop water saving mechanisms which can minimize water lost during application of irrigation water [4]. If the amount of water lost due to poor water application method can be saved, irrigation command area of the scheme can be increased and accommodate the increased number of farmers. Saving unproductive losses creates opportunity for optimized use of a limited supply of irrigation water. Improved irrigation scheduling and water application methods are among the means of cutting losses and increasing efficiency.

The farmers of Dugda district of East Shewa Zone are using surface irrigation system in which water is applied to the field without determining amount of water required for the crop they are growing on that field and using indigenous knowledge for irrigation schedule. In this method water is applied to the field in excess amount and huge amount of water is lost in the form of surface runoff. On the other hand many farmers are left without irrigation water to produce crops during dry season due to shortage of irrigation water resulted from mismanagement of irrigation water by other farmers [5]. However, water resource is becoming scarce and limiting crop production during dry season in this area, whereas the number of farmers involved in crop production under irrigation is increasing from time to time. Nevertheless, no study was conducted in this area to improve water productivity and water use efficiency of crop under surface irrigation system. Alternating furrow irrigation practice is one of the possible irrigation water management techniques that may help farmers to apply limited amount of water to their crops in time and amount vital for optimum crop water productivity.

In Ethiopia, very few irrigation water management technologies have been developed through research for different areas. To make the situation worse, these technologies are kept in the research centers and the intended end-users did not get the chance to adopt them. Lack of organized dissemination mechanisms was one of the limiting factors. The other one is lack of focus on adoption and/or modification aspects of the technologies. It is usually understood as a work of development agents (DA), but much cannot be expected from that end.

So in Ethiopian context, the research side should play much role in this regard. Scaling-out of improved irrigation water management technologies is about taking out of relevant and efficient methods to the farmers so as to improve the irrigated agriculture. From experiences and field observations, it is believed that farmers are applying excess or less amount of irrigation water without considering crop demand (referred as “farmers’ practices”). On the other side, “improved” irrigation water management practice means the knowledge of applying the right amount of irrigation water at the right time i.e. “when” and “how much”.

According to our previous work done, 26.61% of water was saved with alternate furrow irrigation method as compared to every furrow irrigation. (252 and 264.7) Qt/ha yield was gained through AFI and CFI respectively. 0.23ha of extra land can be irrigated with the amount of water saved from AFI practice. Within additional extra land to be irrigated the same crop from amount of water saved by AFI can produce 67- 70.4 qt/ha than of CFI (Zelalem *and abay.*, 2022 unpublished document). In order to allocate the scarce water resources among competing users, identifying irrigation method which maximizes crop water productivity using available water is an obligatory work. The competition for freshwater often implies that, water for irrigation is not always available in the required quantity. Therefore, farmers often have to manage irrigation under moderate or severe water shortage. This experiment were proposed and executed with the hypothesis that irrigating alternate furrows, i.e., partial wetting of the root system alternatively could save water thereby increasing water productivity (WP) without causing a substantial drop in the yield of crop.

As a general objectives; this research will be planned and implemented to study the impact of alternate furrow irrigation (AFI) on crop yield and water productivity so as to get additional land and sustainable crop and water productivity. Therefore, this study specifically aim to evaluated the effects of different water application methods on yield and water productivity on farmers’ field and quantified the amount of water saved under each water application methods.

2. Materials and Methods

2.1. Description of Study Area

The demonstrations were conducted during irrigation season on four farmers’ fields at Dodota Denbel and Bekele Girisa kebeles of Dugda district. Onion variety of /Bombay Red/ were selected as test crops due to farmers’ preference and wide area coverage. Its altitude is about 1636 with latitude of 8 °9’7’’N and also longitude of 38 °49’16’’E. The average annual precipitation ranges from 712 to 1150 mm. the average monthly minimum and maximum temperatures between 13.4-14.2 ℃ and 27.5-28.7 ℃.

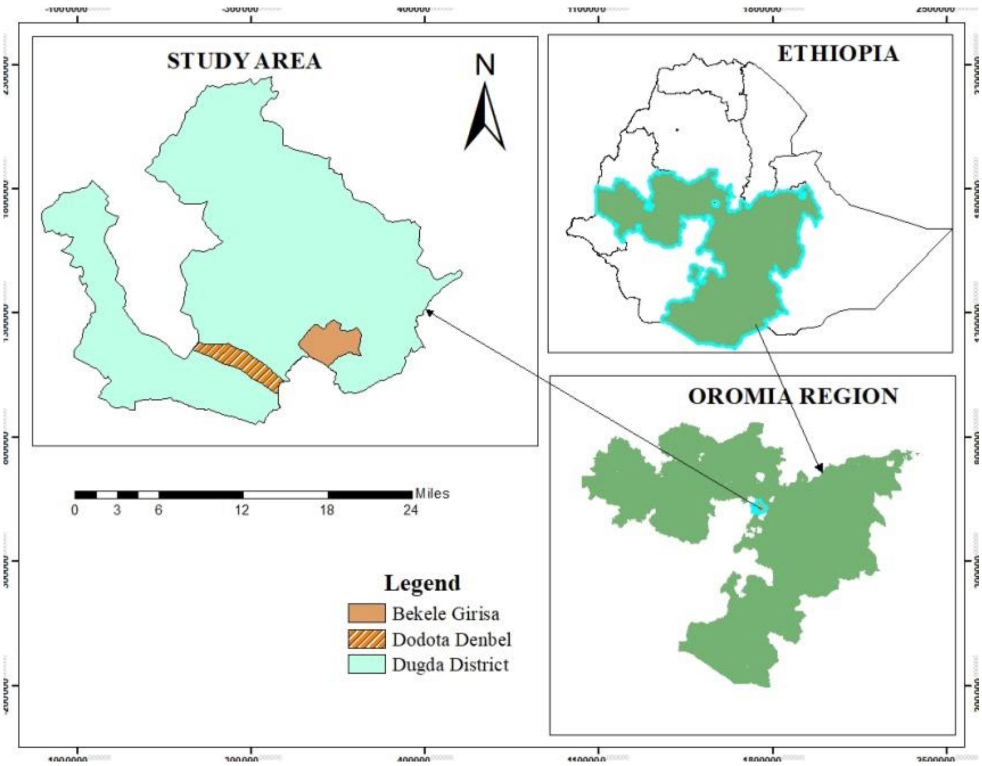

Figure 1. *Location map of the study area.*

2.2. Experimental Treatment and Design

Two treatments were applied alternate furrow irrigation and conventional furrow irrigation (farmers practice). Equal plot sizes were prepared with in each farmer’s field. Onion were raised and transplanted to the prepared 400 m^2 (20m×20m) area of plots, from seedbed at each location. (10 and 50) cm spacing between plants and furrows were used and it was planted on a furrow length of 10m.

Irrigation water depth for demonstration plots were determined based on effective root depths of the crops and monthly average evapo-transpiration (mm/day) of the area throughout growing stages. For the first two months, 30 cm were considered for the crop, then after 45 and 60 cm root depths were considered for onion (Allen et al., 1998).

The amount of water applied by farmers to their fields were measured and recorded. Application and measurement of water for the demonstration and farmers' plots were started just after transplanting the crop. To measure the amount of water applied to the demonstration and farmers' plots, three-inche Parshall-flumes were installed at the entrances of plots in each site. Simple comparisons were made between the two practices based on depths of water given and yields obtained.

2.3. Technology Demonstration and Evaluation Approaches

Two FRG were formed in selected district, which had 20 members. Group discussion, about the objectives of the demonstrations, with that of formed FRG farmers, development agent (DA) and farmers' representatives of the area were taken. Training was given for farmers, DA and experts on improved irrigation water management technologies. Then, from two test sites and two willing farmers were selected. Farmers' selections were carried out based on; availability of land, access to irrigation water, individual interest and acceptance of the farmer by the society. Supporting guidelines on how to determine; "when" and "how much" to irrigate and how to measure the amount of water passing through the Parshall flume were prepared and measured accordingly.

One development agent was assigned to measure the amount of water that was applied at each irrigation event for the demonstration and farmers plots. On other hand, our experts were closely followed up the trial. During the study period several farmers were invited to observe the activities and on job technical explanations (for instance "how to measure irrigation water") were given by the ATARC experts and DAs. In the absence of ATARC experts and DAs, while farmers were irrigating and measurements were taken and recorded by respective trained farmers.

2.4. Water Application

Diverted water from the river was brought to the field using field channel that run adjacent to experimental plots. The flume was set on a straight section of the channel and used to estimate flow rate. Flow rate is the function of height of water measured in the Parshal Flume at the entrance section. The relationship is conventionally presented in the form of PF table. The time required to deliver the desired depth of water into each plots using Parshal Flume was calculated from the following equation.

$$t = \frac{A \text{ x dgross}}{Q}$$

where: dg - gross depth of water applied (mm)

t - Application time (sec), A - Plot Area (m^2) and

Q - Flow rate (l/s)

2.5. Data Collection and Analysis

The sources of data for this research were both primary and secondary. Daily climatic data such as rainfall, maximum and minimum temperature, relative humidity, sunshine hours and wind speed were obtained from Hawassa branch National Meteorological Agency. These data were used to determine reference evapotranspiration (ETo) and effective rainfall by CROPWAT 8.0 software.

Representative soil samples were taken to investigate selected soil properties like field capacity (FC), permanent wilting point (PWP), bulk density (ρb), organic matter (OM), texture, electrical conductivity (ECe) and pH of the study area. The soil samples were taken at 30 cm depth intervals within the effective root zone and used to determine the total available water content of the soil.

Plant growth parameters: - plant height, width and neck diameter were recorded at physiological maturity and expressed as average of ten randomly selected and pre-tagged plants in each experimental plots. Total bulb yield ($kgha^{-1}$): total bulb yield was measured as the total weight of bulbs produced by all plants at central two rows per plot. The total weights of the bulbs were measured using digital balance and it was converted into $kgha^{-1}$.

Onion bulb characteristics used as input parameters was mainly length of the growth cycle, bulb factors, rooting depth, critical depletion factor, yield response factor for each growth stages specified in table 1 below. The basal bulb coefficients, Kc, for non-stressed, well-managed plant in sub humid climates (RHmin ≈ 45%, u2 ≈ 2 m/s) for use with the FAO Penman Monteith ETo (Allen et al., 1998).

***Table 1**. Kc values, critical depletion and yield response factors for onion.*

Kc and Yield Factors	Growing stages (days)			
	Initial season	Development	Mid-season	Late- season
Growing Periods (120 days)	20	30	45	25
Kc values	0.45	0.75	0.99	0.86
Critical Depletion Fraction	0.15	0.24	0.29	0.32
Yield Response Fraction (Ky=1.1 ave.)	0.9	1.0	1.3	1.2
Maximum Crop height (m)	0.4			
Maximum Root Depth (m)	0.6			

2.6. Statistical Analysis

Data collected were analyzed using SAS 9.2 software. Whenever treatments effect were found significant, treatment means were compared using the least significant difference (LSD) method.

3. Result and Discussions

3.1. Soil Physio-Chemical Analysis

***Table 2**. Soil physical and chemical properties of the experimental site by two soil depths interval.*

Soil properties	Soil depth (cm)		Mean
	0-30	30-60	
Sand (%)	75	77	76
Silt (%)	15	13	14
Clay (%)	12	11	11.5
Textural class	Sandy loam	Sandy loam	Sandy loam
Bulk density (gcm^{-3})	1.21	1.23	1.22
pH-water (1:2.5)	7.7	7.1	7.4
EC (ds/m)	0.122	0.1	0.11
OC (%)	1.0	0.8	0.9
FC (%)	16.1	12.22	14.12
PWP (%)	10.31	8.02	9.16
TAW (mm/m)	78.00	82.20	80.10

The selected soil physico-chemical properties of the experimental site were presented in table 2. Percent of particle size determination revealed that the soil texture of the study area is sandy loam. The mean bulk density of soil of the study area was 1.22 g/cm^3. The mean pH, EC and OC of soil of the study area were 7.4, 0.111 ds/m and 0.9% respectively. The moisture content at field capacity, permanent wilting point and total available water were 14.12%, 9.16% on and 80.10 mm/m respectively. The basic infiltration rate was about 5 cm/hr.

3.2. Comparison of Yield, Yield Component and Water Productivity

As shown in Table 3, the higher plant height (50.4 cm), bulb diameter (54.2 mm), bulb height (50.2 mm), marketable yield (191.9 qt/ha) and total yield (220.6 qt/ha) were observed from conventional furrow irrigation method. While the lower plant height (47.5 cm), bulb diameter (51.5 mm), bulb height (46.8 mm), marketable yield (106.7 qt/ha) and total yield (187.3 qt/ha) were recorded from alternate furrow irrigation method. The smaller water productivity (3.2 kg/m^3) were recorded from conventional furrow irrigation system and the higher water productivity (5.6 kg/m^3) was obtained from alternate furrow irrigation method.

Table 3. Results of yield, yield component and water productivity of onion.

Treatments	PH (cm)	BD (mm)	BH (mm)	MY (Qt/ha)	TY (Qt/ha)	WP (kg/m^3)
CFI	50.4	54.2	50.2	191.9	220.6	3.2
AFI	47.5	51.5	46.8	106.7	187.3	5.6

*CFI = Conventional Furrow irrigation, AFI = Alternate Furrow Irrigation, PH = plant height, BD =Bulk Density

Therefore alternate furrow irrigation system is a water application method that minimizes moist surface which reduces evapotranspiration and deep percolation losses [11]. This system saves substantial amount of water and is incredibly important in areas of water scarcity and salt problems [15]. Alternate furrow irrigation maintained high grain yield with up to 50% reduction in irrigation amount, while Fixed Furrow Irrigation resulted in a considerable yield decrease [11]. Therefore, alternate furrow irrigation is an effective water-saving irrigation method in moisture stress areas [12]. AFI tender opportunity for minimizing irrigable area and then shorten irrigation time with a given amount of water; a water saving mechanism which results in improvement of the irrigation water use efficiency.

3.3. Training Provided for Stakeholders

The training was given on irrigation water management and knowledge, skill and experience sharing and technology transfer approaches. Accordingly, a total of 40 farmers (33 males and 7 female), 3 DAs and 4 experts participated during the training organized in the target areas.

Table 4. Number of participants during training at Dugda district.

Participants	Male	Female	Total
Farmers	33	7	40
DAs	3	-	3
Experts	3	1	4
Total	39	8	47

3.4. Farmers' Evaluation and Selection of the Technologies

The farmers group consisting of male and female evaluated the performance of onion and the technologies. As shown in table 5, farmers selected AFI ranked as their first and conventional furrow irrigation secondly preferred. The farmers selected AFI as a best and ranked first because of its ability to water saving, no water logging in their field, labor cost reduced, less cost incurred for production for example less fuel cost required for pump and additional area irrigated.

According to the research of [14], AFI saved irrigation water by 35 to 38% for irrigation levels up to 80 and 100% water level, compared to the conventional furrow respectively. Mehari H et al. [16] also concluded that the minimum amount of irrigation water and labor costs were required for the AFI technique and could maintain statistically the same grain yield of maize to full irrigation or conventional furrow irrigation.

Second selection was conventional furrow irrigation though high yield, water logging problem in their field, large amount of water used for growing, high labor cost, absence of additional area irrigated because of no irrigation water saved.

Du T, Kang S *et al.* [7] reported that AFI with 100% crop evapotranspiration (ETc) could observe the possibilities of increasing additional net irrigable land up to 0.868 ha per hectare of irrigation water as compared to conventional furrow irrigation systems (control). AFI has not only saved water but also produced a maximum yield [1]. Therefore, compared to conventional furrow irrigation systems, AFI was the best technique of irrigation water management to improve crop water productivity in areas of water scarcity.

Generally; based on overall mean score observed against the weight attaches for each of the traits set and listed for evaluation and selection, AFI was ranked and selected as the best where there is a limited water availability and input cost of fuel for pump of water from the source and also save time.

Table 5. Farmer's preferences and selecting of the technologies in the study area.

No	Criteria	Conventional Furrow Irrigation (CFI)		Alternate Furrow Irrigation (AFI)	
		No	%	No	%
1	Yield performance	34	85	6	15
2	Water saving	2	5	38	95
3	Cost incurred	12	30	28	70
4	Water logging problem	5	12.5	35	87.5
5	Labor cost	18	45	22	55
6	Additional area irrigated	0	0	40	100
7	Time consuming	15	37.5	25	62.5

4. Conclusion and Recommendations

From two Dodota Denbel and Bekele Girisa from Dugda district of East Shewa Zone, and two Furrow irrigation technologies, demonstration groups were established and two representative trial farmers from farmer groups was selected purposively, and improved water management technologies were demonstrated on farmers plots in the off season. The water management technologies were implemented with full recommended onion production and management packages. Farmers' preference and yield data were collected and analyzed using descriptive statistics. Based on farmers' preference, after evaluation, farmers preferred and selects the promising water management technologies as compared to traditional practice across the sites.

Therefore, for increasing marketable bulb yield of onion under no water stress scenario, irrigation of onion with conventional furrow irrigation methods could be used. However, under limiting irrigation water resource condition, irrigation of onion could be done with alternate furrow irrigation method to maximize water use efficiency of onion for similar agro-ecology and soil type.

Abbreviations

WP	Water Productivity
DAs	Development Agents
EC	Electric conductivity
OC	Organic Caron
FC	Field Capacity
PWP	Permanent Wilting Point
TAW	Total Available Water

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Conflicts of Interest

The authors declare no conflicts of interest.

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