International Journal on Food, Agriculture, and Natural Resources
Volume 05, Issue 04, Page 96-100
ISSN: 2722-4066
http://www.fanres.org

Original Paper

Verification of the Efficiency of Alternative Furrow Irrigation on Water Productivity and Onion Yield at Woleh Irrigation Scheme, Northern Ethiopia

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Received: 04 April 2024; Revised: 14 December 2024; Accepted: 27 December 2024
DOI: *https://doi.org/10.46676/ij-fanres.v5i4.408*

***Abstract*— In the semi-arid regions of Ethiopia, water is the most limiting factor for crop production. Meeting crop water demand maximizes productivity from a land unit but does not inherently increase revenue per unit of water. This has led to a growing interest in irrigation practices that improve water productivity by regulating the inappropriate use of irrigation water. The experiment was conducted in the Woleh irrigation Scheme, to verify the efficiency of alternative furrow irrigation on onion water productivity and yield. The treatments used a randomized complete block design with four replications. Alternating furrow irrigation (AFI), conventional furrow irrigation (CFI), and fixed furrow irrigation (FFI). Each method used 75% ETc of the irrigation water. The experiment showed that AFI had the highest yield and water productivity. The amount of irrigation water used for AFI and FFI was about half (3038 m3) of CFI (6078 m3). The water productivity obtained was 4.05 kg m-3 for AFI and 3.16 kg m-3 for FFI, almost double the 2.15 kg m-3 for CFI. Economic water productivity and marginal rate of return were greatest in AFI. Therefore AFI at 75% ETc was superior in yield and water productivity in areas with water scarcity and high labor costs.**

Keywords*— Conventional furrow, Deficit irrigation, Economic water productivity, Fixed furrow

I. Introduction

Several demand variables constrain water availability [1]. In arid and semi-arid regions, water resource efficiency through irrigation systems is becoming increasingly important. Irrigation water management is a key strategy for improving water productivity [2]. To meet the growing global demand for food, irrigation is the main source of water to increase agricultural productivity [3]. The most used irrigation technology in Ethiopia is furrow irrigation, but it is known to be ineffective. Alternate furrow irrigation can increase efficiency without noticeably reducing yields by reducing water use and pumping costs [4]. The onion has been known as one of the most important vegetable crops that have grown all over the world. It has grown mainly as a food source and is used as a cousin and value addition for different dishes. In Ethiopia, the consumption of the crop is very important in the food seasoning and daily stews as well as in different vegetable food preparation uses also the chemical flavonoids, anthocyanins, fructooligosaccharides, and organosulphur compounds found in the onion are considered as medicinal and health benefits to fight different diseases including cancer, heart, and diabetic diseases [5]. One of the most often consumed vegetables in Ethiopia is onion, which grows on 29,517.01 hectares of land and yields 2, 648,49.354 ton onion bulbs. In the Amhara region, onions are one of the most widely produced and highly marketed vegetable crops that are irrigated. Onion bulbs are being produced annually by farmers in the majority of the Amhara region's irrigable lands. For instance, 12,262.79 hectares of land were planted with onion crops in the region during the 2015/16 production year [6].

Efficient water use has become an important issue in recent years as water scarcity has become a serious problem in some areas. Over the past two decades, water-saving irrigation technologies such as deficit irrigation (DI), partial root-zone drying (PRD), or alternative furrow irrigation (AFI) have been developed and tested for field crops and fruit trees. Water-saving irrigation technologies such as (AFI) have been developed and tested for field crops and fruit trees. Water productivity should be improved by reducing leaf transpiration in alternative furrow irrigation system. Stomata control plant gas exchange and transpiration water loss door. Recent studies have shown that stomata may respond directly to water availability in the soil and that stomatal openings may decrease in response to water availability in the soil. Alternating furrow irrigation has been implemented in several crops, including potatoes, tomatoes, soybeans, and corn, to conserve water [7]. In the study on tomatoes at Orissa (India), alternate furrow irrigation gave the highest water productivity (5,140kgm-3) among several furrow treatments. Alternate furrow irrigation can prevent severe leaf water deficit, which develops in the shoots when irrigation has drastically reduced. It is well known that leaf growth and shoot elongation are inhibited when shoot, water deficit develops, and turgor is reduced as a result. Globally and more particularly in developing countries, changing water availability and quality pose complex problems and management options are not easy. The changing situation comes partly from increasing demands such as population, industry, and domestic requirements and partly from the consequences of climatic change [8].

Therefore, great emphasis is placed on the area of crop physiology and crop management to make plants more efficient in water use under dry conditions [9]. Partial root-zone drying is a practice of using irrigation to alternately wet and dry (at least) two Spatially prescribed parts of the plant root system to simultaneously maintain plant water status at maximum water potential and control vegetative growth for prescribed parts of seasonal parts of plant development [10]. In northern Ethiopia, particularly in the Woleh irrigation scheme, water scarcity is a major constraint to agricultural production. Irrigated agriculture has expanded significantly due to the irrigation program in the scheme. However, water efficiency in agricultural production is extremely low since farmers irrigate their crops using conventional knowledge, which leads to nutrient leaching and serious water shortage issues in the research area. The absence of water-saving methods for growing key crops, such as alternative furrow irrigation and deficit irrigation, is one of the obstacles to the effective use of scarce water resources in irrigated agriculture. In over all poor crop water management techniques used by farmers in the Woleh irrigation scheme who have been engaged in irrigated agriculture. As a result, this study offered information for efficient water management of onions, the main crop. The objective of this study is to verify the efficiency of alternative furrow irrigation on water productivity and yield of onion.

II. Materials And Methods

A. Description of the study areas

The study was conducted during the 2017/18 growing season on four farmer test sites in the Woleh irrigation schemes Wag-himra zone. Geographically, it is located between latitudes 1384764°N and 505086°E, with an elevation of 2110 meters. The average annual maximum temperature ranges from 23.1 to 28.6 degrees Celsius. Average annual precipitation ranges from 329 mm to 799.5 mm [11]. Most of the rainfall occurs from the first week of July to the end of August. The rainfall pattern is uni-modal [12]. The area is intensively cultivated and production is subsistence agriculture. Rain-fed agriculture is the mainstay. Rainfall in the region starts late and ends early. The rainfall distribution is inconsistent and the effective season is short, resulting in a terminal dry season, prolonged droughts, and unstable rain-fed agriculture. The main crops grown in the area are, teff (Eragrostis tef), and wheat (Triticumaestivum L.), and cowpea grains. Horticultural crop such as mango (Manifera Indica), citrus fruits, pepper (Capsicum species), tomato (Solanum lycopersicum), and onion (Allium cepa L.) are also present. Topographically, there are plateaus, mesa, canyons, and ravines that have been covered by rivers and streams for thousands of years. In the study area the agricultural water management practice are flood and furrow irrigation methods. The livestock productions are beekeeping, cattle, sheep, goat, donkey, and poultry. Soil types are: Cambisols, Eutric Regosols, Nitosols, Vertisols, Leptosols and Orthic solonchaks. Among them Eutric Cambisols are the dominant for studay area [13].

B. Crop selection and crop agronomy in the study areas

The most important irrigable crops for the irrigation scheme were determined by the crop type, market potential, variety, and growing season. These varieties of Bombay red onions were selected. This cultivar was harvested and transplanted in a total of 115 days. The length of growth stages used was 20, 30, 40 and 25 days for initial, development, mid-season, and late season, respectively. A 10 m x 10 m double row planting experimental plot with 40 cm × 20 cm × 10 cm spacing (between rows including the furrow × between rows on the bed × between plants in a row) was used. The plots were separated by one meter. The experiment was fertilized with100 kgha-1 of NPS at transplanting and 200 kgha-1 of urea fertilizer half at transplanting and 45 days after planting. Disease and weed infestations were monitored regularly and proper management was timely.

C. Crop water requirement of onion

The climate, soil, and crop data inputs were used to determine the crop water demand, the net irrigation requirement, and the water application timetable. The CROPWAT model for the performing of an operation has been implemented. To calculate water requirements, the required data were first entered and the standard evapotranspiration was determined using the penman-monteith equation of the CROPWAT model. The required data were input and determined using the penman-monteith equation of the CROPWAT model [14]. Composite soil samples were collected from the field plots and soil texture classes were determined from the soil texture triangles. Undisturbed soil samples were taken at a depth of 0-30 cm and 30-60 cm based on crop root depth by using a core sampler to evaluate physical properties, including field capacity, permanent wilting point and bulk density. Total available moisture (TAM) and readily available moisture (RAM) in the soil for the crop during the growing season were calculated using the following equations (1) [15]:

$$TAM = \frac{1000(FC-PWP)}{100} \quad (1)$$

where, TAM = total available moisture (mm/m), FC = field capacity and PWP = permanent wilting point . Readily Available Moisture (RAM) will be calculated as TAM*P, Where P is the depletion fraction as defined by the crop coefficient (Kc) files. The estimated crop water requirements will be converted into the field irrigation water requirement. The net irrigation requirement (NIR (mm/period)) will be determined based on the equation:

$$NIR = CWR - Peff \quad (2)$$

where, CWR = crop water Requirement (mm/period), Peff = Effective precipitation. The total volume of water needed to fulfill the irrigation water requirement throughout the growing season will be calculated using the equation below [16].

$$GIR = \frac{NIR}{ea} \quad (3)$$

where, GIR = Gross irrigation requirement (mm) and ea = Application efficiency. The crop water productivity (WP), expressed as kg m^{-3} of water, AFI, FFI, and CFI was determined using the relationship [17]:

$$WP\left(\frac{Kg}{m^3}\right) = \frac{[Y]}{[\sum ETC]} \quad (4)$$

Where, Y is the total yield of onion in Kg, WP is water productivity, ETc is the total amount of water delivered up to harvesting in m^3 Water has been applied directly to the plot. 60% of irrigation application efficiency was taken [18].

D. Experimental setup

The farmer conducted four replications of the RCBD design pilot. Three crop furrow irrigation application techniques were used in the field experiment. Fixed furrow irrigation (FFI), conventional furrow irrigation (CFI), and alternating furrow irrigation (AFI), with a recommended irrigation rate of 75% ETc. Irrigation was applied every 5 days, so all plots were irrigated 20 times during the growing season. Before planting, the same amount of water was applied to each plot throughout the field. Weeding and other agricultural practices were performed on time and in the same manner in each treatment. The amount of water entering each furrow was adjusted using a portable watering cane.

E. Treatment arrangement

1. 75 % ETc with Alternate furrow irrigation (AFI) at 5-day intervals.
2. 75 % ETc with Conventional furrow irrigation (CFI) at 5-day intervals.
3. 75 % ETc with Fixed furrow irrigation (FFI) at 5-day intervals.

F. Irrigation and field management

A watering can with a specified volume was used to regulate the amount of irrigation water given to each furrow of the experimental plot. There was no tail water loss because the water was solely sprayed in the furrows. Since the water was solely used to replenish soil moisture in the root zone, deep percolation was thought to be minimal. The following formula was used to determine how much water was applied to the field [19]:

$V = A\ X\ D$ ....(5)

Where, V = volume water in litter, A = irrigated plot (m^2), D = depth of application (mm)

G. Data collection

Agronomic parameters such as planting date, spacing, fertilizer application timing, pesticide application, emergence, growth, yield, and yield components (including plant height, bulb diameter, marketable yield, unmarketable yield, and total yield) were collected according to the schedule.

H. Data analysis

Data analysis was conducted using appropriate statistical software, including SAS version 9.1. Crop yield (Y) and other data from plot-to-plot were analyzed with a suitable statistical package. The means of different treatments were compared using the Least Significant Difference (LSD) test to verify the efficiency alternative furrow irrigation on yield and water productivity of onion.

III. Results And Discussion

The findings of the experiment indicate that when 75% ETc of irrigation water was applied to alternative and Conventional furrow irrigation systems, there was no statistically significant difference in the plant height, marketable and unmarketable, and total yield of onions (Table I). However, the bulb diameter and water productivity were significantly different (Tables 1 and 2). As compared with CFI, AFI system enables more effective use of irrigation water associated with any water stress. However, the irrigation technique study's findings indicated that, except for bulb diameter, applying an alternate form of furrow irrigation differs statistically significantly from fixed furrow in all parameters. It is evident that traditional furrow irrigation requires a lot of work and time; each furrow needs to be irrigated at each irrigation event. While alternating irrigation uses half the labor, time, and water needed for irrigating. This corresponds with the findings of [20] that alternative furrow irrigation systems are the best way to increase onion production in areas where water is scarce and labor costs are high.

Table I. Plant Height, Bulb Diameter, Marketable, Unmarketable, And Total Yield Of Onion

Treatment	PH (cm)	BD (cm)	MY (ton ha^{-1})	UNMY (ton ha-^{1})	TY (ton ha^{-1})
AFI	50.4^a	4.31^b	12.003^a	0.289	12.22^a
CFI	50.3^a	4.68^a	12.95^a	0.313	13.26^a
FFI	47.01^b	4.32^b	9.28^b	0.334	9.63^b
CV (%)	1.11	1.9	5.08	15.82	5.15
LSD(0.05)	0.95	0.14	10.03	NS	10.45

Where, PH = plant height, BD = bulb diameter, MY = marketable yield, TY = total yield, UNMY = unmarketable yield

The marketable bulb yields of AFI (12.00 ton ha^{-1}) and CFI (12.95 ton ha^{-1}) were substantially different from FFI (9.28 ton ha^{-1}), as (Table I) showed. There was no discernible difference between the yields produced by CFI and AFI. However, the output of AFI is somewhat lower when compared to CFI. This was also noted by [21]. It is also consistent with the findings of [22], on the production of sorghum and soybeans using alternative furrow irrigation methods. This is also supported by [23], who found that AFI could result in the negligible output of cotton yield with little water is applied, particularly when evaporative rates are very high. The AFI method may have partially wetted the onion root system, resulting in reduced stomatal conductance and transpiration. However, this partial closure of the stomata has little effect on photosynthesis or dry matter accumulation [24] and even the roots on the irrigated side of the furrow (wet soil) will continue to take up water to try to satisfy the plant's needed water demand [25]. [26], reported that under alternating dry and wet cycles, plants with two separate root systems showed a decrease in stomatal opening, but not much increase in leaf water deficit.

This may be why AFI does not result in a significant reduction in crop yield. Higher grain yields of corn were observed when irrigation water was reduced by half, AFI has also been proposed to [10], improve fruit quality and crop water productivity in areas with limited water supply. The highest water productivity was 4.05 kg m^{-3} in AFI, followed by 3.16 kg m^{-3} in FFI and the lowest was 2.15 kg m^{-3} in CFI. The difference in water productivity in both treatments is quite significant and shows the advantages of the irrigation method. Crop water productivity and irrigation water productivity were highest in AFI compared to CFI; water productivity and irrigation water use efficiency increased significantly in AFI and FFI, and water application was 50% less in AFI compared to CFI, Agree the AFI method provides the large amount of water productivity compared to the CFI method. [22], they also reported that AFI contributed to a slight decrease in crop yield, but improved water productivity. [21], have explained, that AFI allows irrigation water to be used more effectively, but with a lower crop yield compared to CFI associated with some water stress. The amount of water applied in the AFI treatment was halved compared to the CFI treatments, this agrees with the finding of [27]. In other words, the amount of water required to irrigate 1 ha of the CFI system is 6076 m^3, which is sufficient to irrigate 2 ha of the AFI system. Thus, AFI could have saved almost 50% of CFI's water [28]. The amount of water saved by the AFI system doubles the irrigated area and therefore doubles the yield produced. This is also consistent with the reports of [29]. It also agrees in the finding of [30], alternative irrigation systems improve the quality of water productivity and field water use efficiency in sugar cane cultivation. Alternative furrow irrigation with 75% ETc improved water productivity [31].

TABLE II. EFFECT OF APPLIED WATER AND FURROW IRRIGATION METHOD ON WATER PRODUCTIVITY

Treatment	Number of irrigation	Irrigation water (m^3 ha^{-1})	Total yield (ton ha^{-1})	Water productivity (kg/m^3)
75%AFI	20	3038	12.29^a	4.05^a
75%CFI	20	6076	13.26^a	2.15^c
75%FFI	20	3038	9.62^b	3.16^b
CV (%)	_	_	5.15	10.07
LSD	_	_	10.45	0.45

Field experiments confirmed that conventional furrow irrigation is labor- time-intensive and requires irrigating each furrow at each irrigation frequency, while alternate furrow irrigation requires only half the labor, time, and irrigation volume. The economic water productivity (WP (e)) of onion under AFI, FFI, and CFI irrigation was the highest at 36.41birr m-3 under AFI irrigation, followed by the lowest at 27.81birr m-3 under FFI and19.68 birr m-3 under CFI irrigation ((Table III)). The maximum economic water productivity recorded at AFI compared with others, agrees with reported by [32]. (Table IV) shows that farmers, including 1.27 Ethiopian birr, loosened every birr 1.00 spent in conventional furrow irrigation and received an additional 7.85 Ethiopian birr after recovery from alternative furrow irrigation. Since MRR>100% AFI adoption is economically feasible, it agrees with that of [33]. The total cost mainly included operating and variable costs. The operating costs (land preparation, seeds, fertilizer, and chemicals) were dependent on the area cultivated.

TABLE III. ECONOMIC WATER PRODUCTIVITY OF ONION UNDER AFI, FFI, AND CFI IRRIGATION METHOD

Treatment	Total Gross benefits (TB) birr ha^{-1}	Irrigation water (m^3 ha^{-1})	Economic water productivity (WP(e)) birr m^{-3}
AFI	110610	3038	36.41
FFI	84510	3038	27.81
CFI	119610	6076	19.68

Therefore, the operating costs of the AFI process were the same as CFI and FFI. However, the variable cost difference, which depended on irrigation frequency and water unit cost, was important. Based on the irrigation water prices of the Awash River Basin Authority, the unit cost of water was estimated at 3.5 birr 1000 m^{-3} [34]. The total water cost for each season was determined by multiplying the water unit price by the total amount of irrigation water needed for the onion production. Therefore AFI and FFI, 10.63 birr 3038m^{-3}, while for CFI, 21.27 birr/6076m^3. The labor cost due to irrigation events is 12480 birr for AFI and FFI but for CFI, 24960 birr. The results of the partial budget analysis show that AFI offers a higher marginal rate of return, which is consistent with the findings of [35]. This showed that CFI had higher labor costs and water prices than all of them.

TABLE IV. PARTIAL BUDGET ANALYSIS

Treatment	**UY (t ha^{-1})**	**AY (t ha^{-1})**	**TGB (birr ha^{-1})**	**TCV (birr ha^{-1})**	**NB (birr ha^{-1})**	**MRR**
AFI	12.29	11.061	110610	12490.63	98119.37	785.543
FFI	9.39	8.451	84510	12490.63	72019.37	D
CFI	13.29	11.961	119610	24981.27	94628.73	-27.946

Where, D= stands for domination, UY =unadjusted yield, AY=adjusted yield by 10%, TGB=total Gross benefits, TCV=total costs that vary, NB=net benefits

IV. CONCLUSION AND RECOMMENDATIONS

In the factory's supply chain analysis, the highest priority risk is the humidity level in the warehouse. The improper temperature and humidity levels, as well as less thorough employee mitigation, are prioritized risk factors at the factory. The priority control strategy that needs to be carried out is to create a standard operating procedure (SOP) for the proper maintenance management of production and storage facilities.

V. ACKNOWLEDGMENT

The authors would like to thank the Amhara Agricultural Research Institute and Sekota Dry Land Agricultural Research Center for the financial support and guidance for the successful accomplishment of the research.

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