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Evaluation of Furrow Irrigation Systems on Onion Yield and Water Use Efficiency in Misrak Azernet Berbere woreda, Ethiopia

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Abstract: *Efficient use of water by irrigation system is becoming increasingly important in arid and semi-arid regions with limited water resources. Furrow irrigation is the most widely used system in Ethiopia and is characterized by low efficiency. The objective of this research study was to investigate the effects of alternative and fixed furrow irrigation system onion yield, WUE, irrigation water productivity, and economic return as compared with conventional method.This experiment was conducted for the last two years in Misrak Azernet Berbere woreda, Ethiopia. The experiment had three levels of treatments (alternative, fixed and conventional irrigation system) and which were arranged in RCBD with three replications. Different data were collected and analyzed using SAS software in probability of 5% confidence level. From the result water saved alternate furrow and fixed irrigation with 20% and 30% could save irrigation water applied. With respect to water use efficiency; alternative furrow irrigation results maximum values relative to fixed and conventional irrigation in both years. In the case of net return (NR) interaction of FFI and CFI, the highest was produced by alternate furrow AFI. Finally the finding indorses that farmers can practice alternate furrow irrigation (AFI) with 20% water saving as a best option, with maximum yield compared convectional furrow irrigation having full water application.*

Key Words: ET_c, Furrow irrigation, Misrak Azernet, Onion, Water use efficiency

1. INTRODUCTION

Efficient use of water by irrigation system is becoming increasingly important in arid and semi-arid regions with limited water resources. Furrow irrigation is the most widely used system in Ethiopia and is characterized by low efficiency. One way to improve efficiency is reducing water use and consequently pumping costs without significantly reducing yield through the use of alternate furrow irrigation [1].

To ensure food security it is must to use the water wisely in order to enhance food production while save water as much possible or in other words to increase water use efficiency of field crops. Besides the increasing demand of water for other purposes (industry and domestic use), degradation of water quality will also limit the water availability for agriculture sector in the coming future [2]. So the only tool to overcome this phenomenon is the enhancing of water use efficiency, it is also called water productivity. The largest sector of water consumption is agriculture, so increasing water use efficiency will not only increase agriculture production but will also save the water for other purposes.

In general, when water was insufficient for full irrigation relative onion yield (yield per unit water applied) under Alternative Furrow Irrigation was higher than Conventional Furrow Irrigation. In addition, [3]found that alternate furrow irrigation and fixed furrow irrigation techniques led to a higher reduction of transpiration than photosynthesis and thus increased water use efficiency (WUE). The economic and environmental benefits of using the Alternative Furrow Irrigation method are higher than conventional furrow irrigation methods because less water is applied and the economic return is higher [4].

Onion is one of the important vegetable crops, and it yield and grade are very responsive to careful irrigation scheduling and maintenance of optimum soil moisture [5]. The objective of this research study was to investigate the effects of alternative and fixed furrow irrigation system onion yield, WUE, irrigation water productivity, and economic return as compared with conventional method.

2. Methodology

2.1 Description of the study area

The research was conducted at farmers land located in the Misrak Azernet woreda to identify best furrow irrigation system on onion yield and water use efficiency which allow achieving optimum onion yield with economical water use and improve land productivity in onion cultivation by promoting year round cultivation using irrigation. The study site is located at an altitude 2483 m, longitude 007°51'17"N and latitude 038°02'45". The mean annual temperature ranges from a minimum of 9.3°C to a maximum of 25.7°C.

2.2 Treatments and experimental design

The experiments were conducted in the different field for the 2-year period. Transplanting dates were 25 December and 18 December and harvest dates were 29 April and 09 May, respectively, for 2016/17 G.C and 2017/18 G.C. The experimental design was a randomized complete bock design with three replications. The design consisted of three irrigation methods, (i.e. three treatments: T1=Alternative furrow irrigation (AFI); T2=Fixed furrow irrigation (FFI); T3=Conventional furrow irrigation (CFI)). 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. CFI was the conventional way where all furrows were irrigated for every irrigation. Each plot had 14.6m^2 (3.65m x 4.0m) areas. The space between plots and blocks were 1m and 1.5m respectively. As per the recommendation from Agricultural research centers, the spacing between onion plants and rows kept at 10 cm and 20 cm respectively.

2.3 Crop establishment and irrigation management

The recommended onion variety called bombayred to the area was selected and used as test crop. Onion seedling transplanted from nursery site to the experimental field after forty five days. Fertilizer rate used after transplanted was 200kg/ha NPS and 150kg/ha urea. Amount of irrigation applied in each irrigation event were measuring by partial flume. Amount of rain fall during cropping season in the experimental site was measured using plastic rain gauge.

2.4 Soil data

Disturbed mixture of soil samples were collected from experimental plots using auger for the analysis of soil moisture, texture, Bulk density (BD), field capacity (FC) and permanent wilting point (PWP). Soil textural class was analyzed by using hydrometric method from collected soil samples and it was determined using USDA textural triangle procedure. Bulk density (BD) is calculated as the dry weight of soil divided by its volume. This volume includes the volume of soil particles and the volume of pores among soil particles.

Bulk density is typically expressed in g/cm^3:

$$BD = \frac{Weight\ of\ dry\ soil(gm)}{Volume\ of\ the\ same\ soil(cm^3)} \qquad 2.1$$

The water content of the soil at field capacity and permanent wilting point were determined in the laboratory by using a pressure plate apparatus. The pressure plate was adjusted to 0.33bar to determine field capacity and 15bar to determine permanent wilting point to a saturated soil sample. The soil analysis was carried out at Ethiopian Construction Design Supervision Works Corporation (ECDSWC) Addis Ababa. The infiltration rate of the experimental site was measured at the field level by using double ring infitrometer.

2.5 Determination of Crop Water Requirement

Total available Water (TAW) in the root zone was computed as the difference in moisture content between FC and PWP. It is computed as follows:

$$TAW = \frac{(FC-PWP)*BD*Dr}{100} \qquad 2.2$$

Where: TAW= total available water (mm), Fc = Water content at filed capacity (%), PWP = Water content at permanent willing point (%), BD bulk density (g/cm^3) and Dr = effective depth of root zone of Onion (mm)

The term Maximum/management Allowable Deficiency (MAD) can be used to compute the amount of water that can be used by plants without adversely affecting the plants growth and can be expressed as a fraction of the TAW. The factor MAD or p is differs from crop to crop and it is possible to compute the net irrigation water requirement, IRn, necessary to restore the main root-zone (Dz) to FC. The factor MAD or p value is about 0.3 for shallow rooted plants e.g for onion p = 0.25 [6].

$$RAW = TAW*P \qquad 2.3$$

The optimal crop water requirement (ET_c) and irrigation scheduling were computed from models ET crop = ET_o x K_c [7] and CropWat model 8.0). The reference evapotranspiration was calculated from climate data using CROPWAT software. Such as: Rainfall, temperature, humidity, solar radiation and wind velocity data obtained from New locClim 1.10 model and Meteorological station of Hawassa district. Net and Gross irrigation were computed from from cropwat by considering application efficiency 60%.

The net irrigation(IRn) in each stage was computed from the following expression:

$$IRn = ETc - P\ eff \qquad 2.4$$

Where: Peff = Effective rain fall (mm)

The gross irrigation requirements (IRg) for each stage were obtained from the expression:

$$IRg = \frac{IRn}{Ea} \qquad 2.5$$

$$\text{Irrigation interval (days)} = \frac{IRn}{ETc} \qquad 2.6$$

The time required to deliver the desired depth of water into each plot as following:-

$$T = \frac{l*w*dg}{6*Q} \qquad 2.7$$

(Q=2.3l/s at parshall flume head h=6cm); the time to deliver has calculating at every irrigation period.

Where: T = time in minute d = depth in cm

L = furrow length in meter Q = flow rate in l/s

W = furrow width in meter

2.6 Water Productivity

In crop production water productivity is defined as the ratio of the yield produced from crops to the volume of water required to produce those yield. Definitions of water productivity are varies with the background of the researcher. [8] Give a number of strategies for enhancement of agricultural water productivity by integrating varietal improvement and better resource management at plant level, field level and agro climatic level.

$$CWP = \frac{Yield\ (kg)}{ETc(m3)} \qquad 2.8$$

ETc= Seasonal crop water requirement, CWP= Crop water productivity

2.7 Agronomic Data Collection

The field data such as unit bulb weight and bulb yield weight were taken from each plot. Unit bulb weight was taken by random selection of plants from each plot by excluding the border rows and border plants. At the end of the season the amount of bulb yield produced was harvested and weighted from each plot. The harvested yield was grouped based on its quality for market according to the size and degree of damage [10].

2.8 Economic Analysis

Economical evaluation of furrow irrigation systems is analyzing the cost that invested during growing season and benefit gained from yield produced by application of water. Marginal Rate of Return (MRR) was used for analysis following the CYMMYT method [10]. Economic water productivity was calculated based on the information obtained at the study site: the size of irrigable area, the price of water applied and the income gained from the sale of onion yield by considering the local market price. Yield and economic data was collected to evaluate the benefits of application of different levels of water in deficit irrigation treatments. Economic data includes input cost like cost for water (water pricing) and other costs. However, cost of water pricing and yield sale price were the only cost that varies between treatments

The difference between net income of a treatment and its next higher variable cost treatment termed as change in net income (ΔNI). Higher net benefits may not be attractive if they require very much higher costs [8]. Hence, it is required to calculate marginal costs with the extra marginal net income. The marginal rate of return (MRR) indicates the increase of the net income, which is produced by each additional unit of expenditures and it is computed as follows:

$$MRR = \frac{\Delta NI}{\Delta VC} \qquad 2.9$$

Where: MRR= marginal rate of return

ΔNI= change in net income

ΔVC= change in variable cost

2.9 Data Analysis

Data was subjected to ANOVA using SAS statistical soft ware based on randomized complete block design. Least Significant Difference (LSD at P=0.05) was employed to identify different level of deficit irrigation that were significantly different from other treatments.

3 Result and discussion

3.1 Soil Field And Laboratory Result For Experimental Field

The soil samples were taken from two different fields in each experimental season and the soil field and laboratory result is presented below in table:

Table 3.1: Soil laboratory and field result

Soil parameters	Results
Moisture content (%)	8.91
Sand (%)	35.23
Clay (%)	36.23
Silt (%)	28.54
Textural class	Clay loam
Bulk density (gm/cm3)	1.01
Field capacity (%)	28.93
Permanent wilting point (%)	14.02
Soil Infiltration rate (mm/day)	11.4

3.2 Applied irrigation water

In the two growing season the amount of irrigation water applied on each treatment and amount of irrigation water saved was presented in the discussion: The amount of irrigation water saved and amount of applied water (Wa) for each treatment are shown in Table. The seasonal amount of applied water in 2016/17 and 2017/18 respectively were 396.3mm (3963m^{3}ha-1), 346.8mm (3468m^{3}ha-1), and 495.4 mm (4954m^{3}ha-1) and 331.4mm (3314m^{3}ha-1), 290.0mm (2900m^{3}ha-1), and 414.3 mm (4142m^{3}ha-1) for alternative, fixed and conventional furrow irrigation systems respectively. This indicates that the AFI and FFI treatments saved water by approximately 20%, 30% respectively, as compared to conventional Furrow Irrigation.

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Table 3.2: Water applied, water saved and seasonal rain fall with respect furrow irrigation application levels in 2016/17G.C

Trts	rain fall (mm)	Water applied (mm)	Water saved(%)	water saved(mm)
AFI	133	396.3	20	99.2
FFI	133	346.8	30	148.6
CFI	133	495.4	-	-

AFI= alternative furrow irrigation; FFI= fixed furrow irrigation; CFI= conventional furrow irrigation

Table 3.3: Water applied, water saved and seasonal rain fall with respect deficit irrigation application levels in 2017/18 G.C

Treatments	rain fall (mm)	Water applied (mm)	Water saved (%)	water saved(mm)
AFI	176	331	20	82.9
FFI	176	290	30	124.3
CFI	176	414	-	-

AFI= alternative furrow irrigation; FFI= fixed furrow irrigation; CFI= conventional furrow irrigation

3.3 Onion response to furrow irrigation system

In the first year (2016/17), irrigation methods showed significant difference on unit bulb weight and water use efficiency. But, irrigation methods has shown non-significance difference total yield in this year. In this year the maximum yield of (9.93 ton/ha) was obtained from alternative furrow irrigation system and the minimum (7.08ton/ha) was from conventional furrow system. Alternative furrow system has showed the highest water use efficiency in contrasts to other treatments, as shown table.

Table3.4: Effects of irrigation treatments on total yield, unit bulb weight and water productivity of onion in 2016/17 G.C and 2017/18 G.C

Year	Irrigation Treatment	Total Yield (t/ha)	Unit b UBW (gm)	Water WP (kg/m3)
	AFI	9.93	73.33^{a}	2.50^{a}
	FFI	7.19	58.33^{b}	2.10^{a}
2016/17	CFI	7.08	64.66^{a}	1.43^{b}
	CV (%)	19.03	7.78	16.57
	LSD	NS	11.54	0.75
	AFI	13.04	77.16	3.90
	FFI	11.89	64.16	4.10
2017/18	CFI	12.67	73.16	3.06
	CV(%)	12.95	8.80	12.40
	LSD	NS	NS	NS

AFI, FFI and CFI are alternate, Fxed and conventional furrow irrigation, respectively. CV- coefficient of variance, LSD($p<0.05$)- least significant difference and NS-non-significant.

In the second year (2017/18), irrigation methods showed non-significance on total yield, unit bulb weight and water use efficiency. It may affected by rain fall contribution in the study area.

Table 3.5: Combined effects of irrigation treatments on total yield, unit bulb weight and water productivity of onion

Treatment	Yield (t/ha)	UBW (gm)	WP(kg/m3)
AFI	11.49	75.25^{a}	3.20^{a}
FFI	9.54	61.25^{b}	3.10^{a}
CFI	9.87	68.91^{ba}	2.25^{b}
CV (%)	15.71	9.02	14.31
LSD	NS	7.94	0.52

3.4 Economic analysis

The total cost mainly includes operating and variable costs. Operating costs (labor, land preparation, seeds, and fertilizers and implement costs) were based on the planted area. Variable costs depended on the water unit price. But, assumption was made to the operating costs was constant for all irrigation treatments. The indigenous farmers in the study area do not pay for irrigation water of their farms. However, drinking water price was used which was estimated to be 5 ETB m-3. Total water cost for season was calculated by multiplying the water unit price by the total amount of irrigation water required for onion production. Gross revenue has been calculated by multiplying total yield in kg ha-1of onion market price per kilogram at time of harvesting. The farm-gate price for onion in this study was 11 ETB/kg.

Table 3.6: Net income generated and marginal rate of return from each treatment per hectare of onion crop.

Trt	AW M^3/ha	TY kg/ha	AY kg/ha	GI	VC	NI	MRR
CFI	4548	9874	8887	97757	22740	75017	0
FFI	3184	9543	8589	9448	15920	7856	D
AFI	3638	11484	10336	113696	18192	95504	75

NB: AW=Applied water, OY= observed yield, GI= gross income, VC= variable cost, NI= net income, MRR= marginal rate of return and D = dominant treatment

The result in the economic analysis indicated that the alternative furrow irrigation was feasible economic advantage having net income of 95504.1 ETB and high value marginal rate of return.

4 Conclusion and Recommendation

This study advocates that the technique of alternate furrow irrigations were substantially saved water than convectional furrow irrigation method in field conditions under water application level. From the result water saved alternate furrow and fixed irrigation with 20% and 30% could save irrigation water applied. With respect to water use efficiency; alternative furrow irrigation results maximum values relative to fixed and conventional irrigation in both years. In the case of net return (NR) interaction of FFI and CFI, the highest was produced by alternate furrow AFI. Finally the finding indorses that farmers can practice alternate furrow irrigation (AFI) with 20% water saving as a best option, with maximum yield compared convectional furrow irrigation with full water application. Another alternative option was observed CFI method in terms of total yield indicates non-significant difference between treatments in both years.

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