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Evaluation of Furrow Irrigation Systems on Onion Yield and Water Use Efficiency in Melokoza Woreda, Southern Ethioipia

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Abstract

This experiment was conducted for the last two years to evaluate the effect of furrow irrigation systems on onion yield and water use efficiency in Melokoza woreda. Specifically to evaluate the effect of alternative, fixed and farmer practice irrigation system and identify the furrow irrigation type which allow achieving optimum onion yield and water use efficiency. The experiment had four level of treatments (alternative, fixed farmer practice and 50% of alternative irrigation system) and which were arranged in RCBD with four replications. Different data were collected and analyzed using SAS software in probability of 5% confidence level. The experiment result shown that alternative furrow irrigation system has highest yield and water use efficiency. The total yield obtained from alternative furrow irrigation was 25.4 t/ha and the minimum yield obtained from 50% of ETc with alternative furrow irrigation, which was 17.8 t/ha. The water use efficiency of alternative furrow irrigation was 3.3 kg/m^3 and fixed furrow irrigation had relatively highest water use efficiency than farmer practice, which were 2.6 kg/m^3. The lowest water use efficiency was obtained from farmers practice. From this experiment the result of alternative furrow irrigation is better in yield and water use efficiency in areas where there is water scarcity and laborer expensiveness.

Keywords: Onion; Alternative furrow; Fixed furrow; Water use efficiency; Farmer practice

Introduction

Background and justification

Much of an increase in the irrigated area had come because of the expansion of small-scale irrigation in the country. Yet, the existing irrigation development in Ethiopia, as compared to the resources the country has, is negligible [1].

Southern Peoples, Nations and Nationalities Regional State has exuberant resource endowment with respect to the natural resources for irrigated farming that accounts an estimated irrigable area of 700,000 hectare of land constituting about 19% of the estimated total irrigable area of the country, that is 3.7 million hectare [2]. This indicates the existing irrigation development in SNNPRS, as compared to the resources potential that the region has, is not significant.

Recently conducted survey results on identification of major production constraints in different agro-ecology of the region, pointed out that lack of improved small scale irrigation technologies, less irrigation water management practices and inadequate research supports are a major problem for efficient irrigation water use and agricultural production improvement.

Irrigation water management implies the application of suitable water to crops in right amount at the right time. Salient features of any improved method of irrigation is the controlled application of the required amount of water at desired time, which leads to minimization of range of variation of the moisture content in the root zone, thus reducing stress on the plants [3,4].

In the semi-arid areas of Ethiopia, water is the most limiting factor for crop production. In these areas where the amount and distribution of rainfall is not sufficient to sustain crop growth and development, an alternative approach is to make use of the rivers and underground water for irrigation. Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water [5,6]. Therefore, in an effort to improving water productivity, there is an increasing interest in therefore, the study is planned to evaluate the performance of types of furrow irrigation systems in tomato crop. Considering the scarcity of irrigation water in the Melokoza woreda and the sensitivity of onion to moisture stress, again it aimed at determining the water use efficiency of onion and evaluating the three furrow irrigation performance during which the crop (onion) and to identify furrow water application system which allow achieving optimum onion yield [7,8].

Materials and Methods

Description of the study area

This experiment was conducted in Melokoza woreda, salaysh mender one (1) kebelle. The study site is located at an altitude 900 m, longitude 036°28'07"N and latitude 06025'03'. Melakoza woreda located 661 km from Addis Ababa, 348 km from Arbaminch. The district has three agro ecologies Dega (21.73%) weyna, Dega (52.43%) and Kola (25.84%). The soil of the district is mainly clay-loam (50%), sand-loam (35%) and clay (15%). The district has two rain-seasons, 'Mehri' season (from July to Oct) and 'Belg' season (from last week of Jan to April). The maximum rainfall is 600 mm, minimum 400 mm and average annual rainfall 500 mm. The maximum temperature is 27.5°C and minimum temperature is 15.1°C. The Woreda total land coverage is 168,180.93 ha, annual crops 47103.897 ha, perennial crops 31884.093 ha, grazing land 6885 ha, natural forest 33687.15 ha, constitutional land 33087.15 ha, private land 1044.02 ha, other reserved land 180548.19 ha, totally 78987.99 ha and cultivable land for farther 14015.95 ha.

Potentialities that have been seen by agricultural sectors were**:** High water sources**,** Wide irrigation farm lands, Accessible farm land, Smart climatic condition, Huge forest coverage etc.

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Experimental design and treatments arrangement

The experiment was laid out in randomized complete bock design with four treatments and four replications. The treatments were alternate furrow irrigation (AFI), fixed furrow irrigation (FFI), 50% of alternative furrow and conventional furrow irrigation (CFI) were applied. All cultural practices were done in accordance to the recommendation made for the area. The experimental field was divided into 16 plots and each plot size was 4 m by 4 m dimension. Space between plots been 1 m and between replication 1.5 m. Space between rows 40 cm and 10 cm between the plants was used. The experimental plot was pre-irrigated one day before transplanting or seedling. Before the commencement of treatment, two to three common light irrigations was supplied to all plots at two to three days interval to ensure better plant establishment.

Climate data

Meteorological parameters like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall was collected from climWat (Table 1).

Reference evapotranspiration (ETo): It was calculated by FAO reduced Penman-Monteith method [9]. Reference evapotranspiration of the growing season per four days (irrigation interval) was presented in the Table 1. It was used to calculate crop water requirement for the day of the interval. The reference evapotranspiration was increasing from June to January and as well as august to December. This was due to temperature increment.

Crop data

Maximum effective root zone depth (RZD) of tomato ranges between 0.3-0.6 m and has allowable soil water depletion fraction (P) of 0.25 [10]. Onion average Kc (crop coefficient) would be taken after adjustments have been made for initial, mid and late season stage to be 0.7, 1.05 and 0.95, respectively. Yield data like economical yield, unmarketable yield and total yield was measured in the field.

Soil data

Soil physical and chemical properties like textural class, bulk density, field capacity, permanent wilting point and infiltration rate, acidity organic electric conductivity, organic matter and organic carbon content of the soil was measured in laboratory.

Crop water determination

Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration [11]. For the determination of crop water requirement, the effect of climate on crop water requirement, which is the reference crop evapotranspiration (ETo) and the effect of crop characteristics (Kc) are important [12]. The long term and daily climate data like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall data of the study area were collected to determine reference evapotranspiration, crop data like crop coefficient, growing season and development stage, effective root depth, critical depletion factor of onion and maximum infiltration rate and total available water of the soil was determined to calculate crop water requirement using cropwat model.

$$ET_c = ET_o * K_c$$

Where, ET_c=crop evapotranspiration, K_c=crop coefficient, ET_o=reference evapotranspiration.

The time required to deliver the desired depth of water into each furrow will be calculated using the equation: $t = \frac{d * l * w}{6 * Q}$

Where:

d=gross depth of water applied (cm);

t=application time (min);

l=furrow length in (m);

w=furrow spacing in (m) and

Q=flow rate (discharge) (l/s).

The amount of irrigation water to be applied at each irrigation application was measured using Parshall flume.

Data collection

Climate like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours and rainfall data was collected to calculate crop water requirement. Soil moisture was determined gravimetrically. Amount of applied water per each irrigation event was measured using calibrated pareshall flume. During harvesting plant height, bulb weight, and bulb diameter were measured from the net harvested area of each plot.

Statistical analysis

Water balance and crop water use were estimated using volumetric calculations, based on the initial soil samples. Auger to collect the

Month	Min Temp (°C)	Max Temp (°C)	Humidity (%)	Wind (km/day)	Sun (hours)	ETo (mm/day)
January	11.5	20.4	60	95	7.7	3.52
February	11.1	21.3	63	104	8.1	3.87
March	11.5	21.3	68	181	6.1	3.81
April	11.6	19.6	72	130	7.3	3.76
May	11.6	18.4	76	112	5.3	3.13
June	10.5	16.6	76	104	5.4	2.95
July	10.1	15.1	62	95	5.3	3
August	10.3	15.9	59	104	3.6	2.88
September	10.6	17.1	62	86	5.4	3.21
October	10.6	17.9	78	95	6.8	3.24
November	10.7	19	57	78	8.1	3.48
December	11.1	19.2	67	69	8.3	3.31
Average	10.9	18.5	67	104	6.5	3.35

Table 1: The monthly mean value of climatic data of the study site for 2010 E.C these values were used as input for crop water determination.

soil sample and oven dry were used for soil moisture measurement. Agronomic water use efficiency was calculated as the lint yield (kg) per unit irrigation (m^3). All data were analyzed using SAS 9.0 at probability level of 5% using fisher unprotected test

Result and Discussion

Physical and chemical properties of soil

In order to characterize soils of the study site, soil physical and chemical parameters were measured in the field and laboratory. The laboratory results of the average soil physical and chemical properties of the experimental site were presented in table below. The result of the soil analysis from the experimental site showed that the average composition of sand, silt and clay percentages were 17%, 23% and 60%, respectively. Thus, according to the USDA soil textural classification, the percent particle size determination for experimental site revealed that the soil texture could be classified as clay soil. The top soil surface had bulk density of 1.23 gm/c m^3). In general, the average soil bulk density (1.23 g/c m^3) is below the critical threshold level (1.4 g/c m^3) and was suitable for crop root growth. Average moisture content at field capacity of the experimental site soils were 27% and at permanent wilting point had 15% through one meter soil depth. Soil pH was found to be at the optimum value (6.4) for onion and other crops. The value of EC (1.14 ds) was lower considering the standard rates in literature [13]. Generally, according to USDA soil classification, a soil with electrical conductivity of less than 2.0 dS/m at 25°C and pH less than 8.5 are classified as normal soil. Therefore, the soils of the study area are normal soils. The weighted average organic matter content of the soil was about 7.085%. The infiltration capacity was measured by using double ring inflitrometer and the recorded constant value was 6 mm/hours (Table 2).

Crop water requirement

The water requirement of onion crop for the specific site was calculated by using input data of climate and crop characteristics, thus based on the treatment set up and crop water requirement, the following amount of net irrigation was estimated and applied for each treatments. The amount of water applied for fixed, alternative and 50% of alternative and farmer practice were, 4786.3, 4786.3, 2393.2 and 5982.9 m^3 respectively. Table 3 shows in contrasts to farmer practice the amount of water saved from fixed, alternative and 50% of alternative is 1196.6 m^3, 1196.6 m^3, 3589.7 m^3 respectively.

Onion response to furrow irrigation system

In this experiment bulb yield was measured by harvesting onion yield on each plot distinctively and weighing them separately. The responses of unmarketable yield to different furrow irrigation system were insignificant in the first year. In this year highest mean plant height of 50.75 cm was observed at famer practice and the lowest mean of plant height was observed at 50% of alternative furrow. Again in this year the highest bulb diameter, 6.075 cm was observed in alternative furrow system and the lowest 5.325 cm from farmer practice.

In 2009 the highest single bulb weight (gm) was observed from fixed irrigation system and the lowest was from alternative furrow system. As the table shows the highest value of most important parameter economic yield of 27.86 ton/ha was observed from alternative furrow system, this is due to application of irrigation water alternatively by increasing the portion of wetting front and the lowest of 20.14 ton/ha was observed from farmer practice. From the first year result the highest water use efficiency (3.35 $kgm^{-3} ha^{-1}$) was observed from alternative and the lowest (1.475 $kgm^{-3}ha^{-1}$) from farmers practice.

In the second year (2010), single bulb weight, economic yield, total yield and water use efficiency have showed significant difference among the treatments. But plant height, bulb diameter and unmarketable yield has shown non significance in this year. As reported by Yemane, (2017), Unmarketable bulb yield of onion was not significantly affected ($P \leq 0.05$) by interaction of effect of furrow irrigation techniques and irrigation level. In this year the highest economic yield of (15.52 ton/ha) was obtained from alternative furrow irrigation system and the lowest (6.54 ton/ha) was from 50% of alternative furrow system. The highest total yield (29.071 ton/ha) was observed in alternative furrow system and the lowest (21.35 ton/ha) from farmer practice. Alternative furrow system has showed the highest water use efficiency in contrasts to other treatments, i.e. 2.742 $kgm^{-3}ha^{-1}$, 3.243 $kgm^{-3}ha^{-1}$, 2.733 $kgm^{-3}ha^{-1}$, 2.377 $kgm^{-3}ha^{-1}$, fixed furrow irrigation, alternative furrow irrigation, 50% of alternative furrow irrigation system and farmer practice respectively.

The combined result showed that application of irrigation water by different furrow systems significantly affect single bulb weight, economic yield, total yield and water use efficiency. In this study alternate furrow system saved irrigation water and increases water use efficiency. Alternate furrow irrigation system may supply water in a manner that greatly reduces the amount of surface wetted leading to less evapotranspiration and less deep percolation [14].

Generally in all parameters alternative furrow system with full irrigation application has shown the good mean results in contrasts to other treatments under normal irrigation water quality. This result shows the same trend as Abd El-Halim [15] reported Shifting irrigation practice from conventional irrigation (EFI) to alternate furrow increased corn yield to 8.9% (0.5 ton/ha) by approximately 8.9% and it is recommended to be practice by the farmers in the study area as well as areas with the same agro ecological patterns (Table 4a-4c).

Conclusion and Recommendation

Conclusion

Alternate-furrow irrigation with appropriate irrigation intervals

Woreda	kebelle	%OC	%OM	PH	EC (ds)	% sand	% clay	% silt	Textural class	BD (gm/cm³)	Fc (%)	PwP (%)
Melokoza	*Salaysh-3*	7.085	12.21	6.4	1.14	17	60	23	clay	1.23	27	15

Table 2: The average soil physical and chemical properties analyzed in laboratory.

S.no	Treatments	Water applied (m^3/ha)	Water saved in contrast to farmer practice (m^3)	Water saved (%)
1	Fixed furrow system	4786.3	1196.6	19
2	Alternative furrow system	4786.3	1196.6	19
3	50% alternative furrow system	2393.2	3589.7	60
4	Farmer practice	5982.9	0	0

Table 3: The average amount of irrigation water applied for each treatment per a hectare of land.

(a) 1st Year (2009) parameters affected by furrow irrigation system.							
Treatments	**PH (cm)**	**BD (mm)**	**BW (gm)**	**EY (ton/ha)**	**UNMY (t/ha)**	**TY (t/ha)**	**WUE (kg/ha^{-1}m^{-3})**
Fixed	49.5^{b}	5.645^{ab}	104.98^{a}	23.47^{ab}	1.183	24.653^{b}	2.399^{b}
Alternative	50.42^{ab}	6.075^{a}	77.34^{cb}	27.86^{a}	1.211	29.071^{a}	3.35^{a}
50% alternative	48.95^{c}	5.165^{b}	70.05^{c}	21.19^{b}	1.302	22.492^{c}	2.27^{ab}
Farmer practice	50.75^{a}	5.325^{b}	95.32^{bc}	20.14^{b}	1.201	21.35^{b}	1.475^{c}
LSD (5%)	1.211	0.747	18	1.764	NS	4.166	0.808
CV	1.5	8.4	12.9	8.9	25.5	13	21.3
(b) 2nd year (2010) parameters affected by furrow irrigation system.							
Fixed furrow	46.65	5.17	78.5^{b}	13.12^{b}	5.889	19.01^{b}	2.742^{b}
alternative furrow	51.95	5.415	103^{a}	15.52^{a}	6.183	21.70^{a}	3.243^{a}
50% of alternative furrow	49.65	5.295	100.75^{a}	6.54 ^{c}	6.162	12.70^{c}	2.733^{b}
Farmers practice	49.35	5.685	95.25^{a,b}	14.22^{b,a}	6.092	20.32^{a,b}	2.377^{c}
LSD (5%)	NS	NS	21.8	1.764	NS	1.861	0.3118
CV	10.8	6.5	14.4	8.9	4.7	6.3	7
(c) Combined result of parameters of two years (2009 and 2010).							
Fixed furrow	48.08^{a}	5.407^{a,b}	77.75^{b}	18.3^{b}	3.535	21.83^{a,b}	2.571^{b}
alternative furrow	54.54^{a}	5.745^{a}	102.62^{a}	21.69^{a}	3.699	25.39^{a}	3.299^{a}
50% of alternative furrow	37.86^{b}	5.425^{a,b}	77.75^{b}	14.02^{c}	3.732	17.75^{b}	2.501^{b}
farmers practice	50.29^{a,b}	5.31^{b}	96.69^{a}	17.18^{b}	3.647	20.83^{a,b}	1.926^{c}
LSD (5%)	15.19	0.6126	22	15.8	NS	4.798	0.5127
CV	20.7	7.6	16.4	4.124	8.9	21.7	19.3

[a,b,c]Data with different letters indicate significant differences.

PH: Plant Height (cm), BD: Bulb Diameter (mm), BW: Bulb Weight (gm), EY: Economic Yield (ton/ha), UNMY: Unmarketable Yield (ton/ha), TY: Total Yield (tone/ha), WUE: Water Use Efficiency (kg/ha/m^3).

Table 4: (a-c) Year wise parameters affected by furrow irrigation system.

with four day interval can be used as an efficient method for onion production in arid areas like Melkoza Woreda. From this experiment it could be concluded that the alternative furrow irrigation treatment controlled stress irrigation without the risk reduced economic yield and total yield of yield of onion increase production and productivity of the society. Moreover, it increased the water use efficiency and saved irrigation water. Besides it also saves the energy and time for farmers to irrigate the whole land in turn it saves the cost for water of irrigation.

Recommendation

Therefore, it is recommended that using alternative furrow irrigation system in areas where there is water scarcity as well as labor expensiveness is the best options to increase the production of onion and other vegetables.

Further research work is needed to give the appropriate irrigation interval with alternative furrow irrigation system.

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