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Evaluation of Alternate and Conventional Furrow Irrigation Method on Yield of Onion and Water Use Efficiency in Humbo Woreda, Ethiopia

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Abstract

Water resources were subjected to ever-increasing supply constraints due to extensive agricultural water demand for irrigated lands. Therefore, it is important to develop water-water-saving irrigation strategies to solve the problem. This experiment was conducted for three years to evaluate the effect of furrow irrigation systems on onion yield and water use efficiency at Humbo Woreda. The experiment had six treatments [Appling 100% crop water requirement with Alternate, 100% crop water requirement with Conventional, 75% crop water requirement with Alternate, 75% crop water requirement with Conventional, 50% crop water requirement with Alternate, and 50% crop water requirement with Conventional furrow irrigation] that were arranged in randomized complete block design with three replications. Yield and yield component data were collected and analyzed using Statistical Analysis System at the probability of a 5% confidence level. The experiment result showed that increasing deficit irrigation level significantly affects the yield of onion. Maximum onion yields were obtained under 100% crop water requirement with Alternate, 100% crop water requirement with Conventional, and 75% crop water requirement with Conventional furrow irrigation method without statistical difference. 50% crop water requirement with conventional furrow irrigation and 100% crop water requirement with alternative furrow irrigation were gives maximum water use efficiency of 6.56kg/m^3 and 6.11kg/m^3 respectively. But 50% crop water requirement with conventional furrow irrigation significantly reduces the yield. Therefore, 100% crop water requirement with Alternative Furrow Irrigation systems is recommended in water scarcity areas to increase water use efficiency without yield reduction.

Keywords: Alternate conventional • Deficit • Water use efficiency

Introduction

Onion [*Allium cepa L.*] is an important bulb crop, belonging to the family Alliaceae [1]. In Ethiopia, the consumption of onion is very important in food seasoning and in daily stews as well as in different vegetable food preparation uses. Also, the chemical flavonoids, anthocyanins, fructooligosaccharides, and organo-sulfur compounds found in the onion are considered medicinal and health benefits to fight different diseases including cancer, heart, and diabetic diseases [2]. 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 [3].

Southern Peoples, Nations, and Nationalities Regional State have an exuberant resource endowment concerning the natural resources for irrigated farming that accounts for an estimated irrigable area of 700,000 hectares of land constituting about 19% of the estimated total irrigable area of the country that is 3.7 million hectares [4]. This indicates the existing irrigation development in SNNPRS, as compared to the resource potential that the region has, is not significant.

Irrigation water management implies the application of suitable water to crops in the right amount at the right time. The salient features of an improved method of irrigation are the controlled application of the required amount of water at the desired time, which leads to minimization of the range of variation of the moisture content in the root zone, thus reducing stress on the plants [5].

In these areas where the amount and distribution of rainfall are 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 [6]. Therefore, this research evaluates alternate and conventional furrow irrigation methods, and is designed to alleviate the problem of irrigation water shortage and has a significant role to play in increasing onion production and water productivity.

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Materials and Methods

Description of the study area

The study was conducted at Humbo woreda, Wolaita zone of southern nation nationality and peoples of Ethiopia. Humbo Woreda is located 327 km south of Addis Abeba. Geographically located at an altitude 1611m, longitude 037°48'26"N and latitude 06'43'48" [Figure 1].

Experimental Treatments and Design: The experiment has six treatments with three replications, which were arranged in a randomized complete block design. The treatments were 100%ETc alternate furrow irrigation [AFI], 100%ETC conventional furrow irrigation [CFI], 75%ETC of alternative furrow[AFI] and 75%ETC conventional furrow irrigation [CFI] 50%ETC of alternative furrow[AFI] and 50%ETC conventional furrow irrigation [CFI]. The experimental field was divided into 18 plots and each plot size was 4 m by 4 m in dimension. Space between plots been 1 m and between blocks 1 m. Space between row plants on the different ridges was 40 cm, and space between row plants on the same ridges was 20cm and 10 cm between the plants was used respectively.

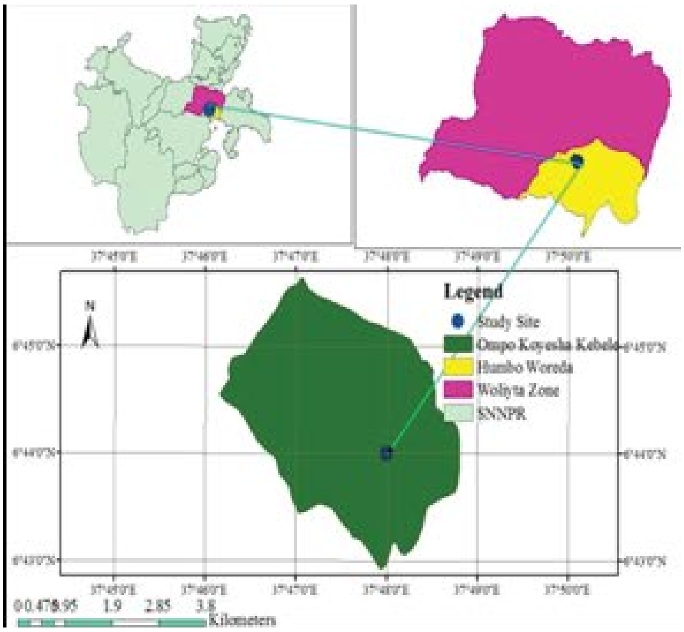

Figure 1. Study area map.

Climate data: Meteorological parameters like maximum and minimum air temperature, relative humidity, wind speed, sunshine hours, and rainfall were collected from Wolaita Sodo metrological station [Table 1].

Crop data: The maximum effective root zone depth [RZD] of onion ranges between 0.3-0.6 m and has an allowable soil water depletion fraction [P] of 0.25. Onion average Kc [crop coefficient] would be taken after adjustments have been made for initial, development; mid and late season stage to be 0.6, 0.8, 1.1, and 0.9, respectively [FAO 33]. Yield data were measured in the field.

Soil data: Auger and core sampler are used to collect the soil sample and oven dry were used for soil moisture measurement. Soil physical and chemical properties like textural class, bulk density, field capacity, permanent wilting point, acidity, electric conductivity, organic matter, and organic carbon content in the soil were measured in the laboratory.

Crop water and irrigation water requirement

Daily weather data, including daily maximum and minimum temperature, rainfall, wind speed, and relative humidity were obtained from the nearest Wolaita Sodo meteorological station. The daily reference evapotranspiration of study areas was estimated by using FAO CROPWAT 8 program by using daily weather data. Kc for every growth stage was adopted from [7]. and then, crop water requirement was calculated using the following equation:

$$\mathrm{ETc} = ETo * kc$$

Where ETc is crop evapotranspiration [mm/day]; ETo is reference evapotranspiration [mm/day] and Kc is crop coefficient [Fraction]

The net irrigation requirement was calculated using the following equation.

$$\mathrm{NIR} = \mathrm{ETc} - \mathrm{Pe}$$

Where NIR is net irrigation water requirement [mm]; ETc is crop evapotranspiration] [mm/day] and Pe is effective rainfall [mm]

The amount of water applied during an irrigation event is gross irrigation and obtained by dividing the net irrigation required by application efficiency, which was assumed as 60%.

$$\mathrm{GIR} = \frac{NIR}{\mathrm{Ea}}$$

Where GIR is gross irrigation requirement [mm]; NIR is net irrigation water requirement [mm] and Ea is application efficiency [%]

Irrigation water application methods: Irrigation water was applied to each plot using furrow irrigation systems. Measured depths of irrigation water were delivered to each plot according to the treatment arrangements through a 3-inch partial flume. Irrigation was started just after planting based on the arrangement of the treatment.

The following formula was used to calculate the time for a specific depth of water application.

$$\mathrm{t} = \frac{a * d}{q * 6}$$

Where T is time [min]; q is the flow rate [l/s]; a is an area of the plot to be irrigated [m^2] and d is the depth of water [cm]

Water Use Efficiency [WUE]: Water use efficiency for the different treatments was computed following the equation below.

$$\mathrm{WUE} = \frac{Y}{ETc}$$

Where WUE is crop water use efficiency [kg/ha-mm]; Y is crop yield [kg/ha] and ETc is = crop evapotranspiration [mm].

Data collection: Climate data, soil data, and harvesting yield and yield component data [plant height, bulb weight, bulb diameter, marketable and unmarketable yield] were collected and analyzed. Statistical analysis

Data were analyzed using SAS 9.0 statistical software package following the standard procedures applicable for RCBD. When the treatment effects were found significant, mean differences were identified using LSD to compare the statistical difference among treatment means.

Result and Discussion

Physical and chemical properties of soil: The laboratory results of the average soil physical and chemical properties of the experimental site were presented in the table below. The result of the soil analysis from the experimental site showed that the average composition of sand, silt, and clay percentages were 30%, 11.5%, and 58.5%, respectively. Thus, according to the USDA soil textural classification, the percent particle size determination for the experimental site revealed that the soil texture could be classified as clay soil. The average bulk density of the experimental site is 1.27-1.45 gm/cm^3. The average moisture content at field capacity of the experimental site soils was 21.6% and at the permanent wilting point had 16.08% through one-meter soil depth. Soil pH was at the optimum value [6-6.02] for onion and other crops. The value of EC [0.91ds/m] is low considering the standard rates in literature [8]. Generally, according to USDA soil classification, 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 **[**Table 2].

Amount of water applied [Table 3]

Onion response to the furrow irrigation system: The table shows that onion yield was significantly reduced when the deficit irrigation level increased. Better onion production was obtained under 100%ETc with CFI, 100%ETc with AFI, and 75%ETc with CFI which is 16115kg/ha, 15641kg/ha, and 14395kg/ha respectively. There is no significant difference between them. There is no significant difference between all treatments on plant height, bulb diameter, and bulb weight. The minimum yield [8398kg/ha] was obtained under 50%ETc with AFI. Conventional furrow irrigation reduces the water use efficiency significantly as compared to alternative furrow irrigation systems. The highest water use efficiency [6. 56kg/m^3] was obtained under 50%ETc with AFI [Table 4].

Table 1. Climate data of the study area.

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/day
January	14.8	29	48	173	8	20	4.88
February	14.8	30	43	181	8	21	5.39
March	14.7	30	50	156	7	20.3	5.04
April	14	28	64	121	6	18.7	4.18
May	14.2	26	73	104	6	18.1	3.7
June	14.1	24	74	121	4	14.7	3.13
July	14.2	23	78	95	3	13.4	2.74
August	14.4	24	76	95	4	15.3	3.09
September	14	25	71	95	5	17	3.46
October	14.1	26	65	121	7	19.6	4
November	15.1	27	53	181	8	20.1	4.65
December	15.3	28	49	190	8	19.6	4.81

Table 2. Soil data.

Soil property over depth		Soil Depth				
		0-20(cm)	20-40(cm)	40-60(cm)	60-80(cm)	average
Particle size	sand	30	28	28	34	30
	Silt	12	8	10	16	11.5
	clay	58	64	62	50	58.5
Textural class		clay	Clay	clay	clay	clay
Bulk density		1.15	1.26	1.32	1.34	1.27
Ph		6.15	5.98	5.84	6.12	6.02
EC(ds/m)		0.8	1.08	1	0.76	0.91

Table 3. The water applied for each treatment**.**

Growth stages	Depth of water applied(mm) for Treatments					
	100% ETc with AF	100% ETc with CF	75% ETc with AF	75% ETc with CF	50% ETc with AF	50% ETc with CF
Initial	19.95	39.9	14.9625	29.925	9.975	19.95
Dev	57.3	114.6	42.975	85.95	28.65	57.3
Mid	83.2	166.4	62.4	124.8	41.6	83.2
Late	96.35	192.7	72.2625	144.525	48.175	96.35
Total(mm)	256.8	513.6	192.6	385.2	128.4	256.8

Table 4. Onion response to deficit level with different furrow irrigation methods.

Treatment	PH(cm)	BD(cm)	BW(cm)	Yield(kg/ha)	WUE(kg/m3)
100%ETc with AFI	43ab	3.17b	108.11	15641a	6.11a
100%ETc with CFI	43.2ab	3.33ab	123.11	16115a	3.15c
75%ETc with AFI	41.7b	3.34ab	130.94	8270b	4.3b
75%ETc with CFI	43.17ab	3.12b	109.44	14395a	3.75bc
50%ETc with AFI	40ab	3.62a	118.39	8398b	6.56a
50%Etc with CFI	48.3a	3.42ab	124.67	7941b	3.1c
CV(5%)	14.9	13.9	33.6	20.16	22.2
LSD	NS	NS	NS	2259.9	0.949

Conclusion and Recommendation

The result shows that the deficit level with different furrow irrigation method was not affected the yield component [plant height, bulb diameter, and bulb weight] of onion. But onion yield significantly reduced as the deficit level increased from 0% to 50%. The highest water use efficiency is obtained under 50%ETc with AFI. The maximum yields of 16115kg/ha, 15641kg/ha, and 14395kg/ha were obtained at treatments T2, T1, and T3 respectively and there are no significant differences among the yield of these treatments. The minimum yield of 7941kg/ha, 8270kg/ha, and 8398kg/ha was obtained from treatments T6, T3, and T5 respectively and there are no significant differences among yields of these treatments. Treatment 5 [50%ETC CFI] and Treatment 1[100%ETC AFI has maximum water use efficiency of 6.56kg/m^3 and 6.11kg/m^3 respectively. Therefore, applying 100%ETc with alternative furrow irrigation systems is recommended to obtain maximum water use efficiency and the highest onion yield [9,10].

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