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Evaluation of Irrigation Regime on Onion Yield in Konta Special Woreda, Ethiopia

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Abstract

Irrigation scheduling (when and how much to apply) is the primary tool to improve water use efficiency, increase crop yields, increase the availability of water resources, and contribute positive effect for the quality of soil and ground water. Field experiment was conducted for two consecutive years to determine appropriate scheduling of onion production. The experiments were arranged in randomized complete block design (RCBD) with four treatments (T1 = 125% manageable allowable depletion [MAD], T2 = 100% MAD, T3 = 75% MAD, and T4 = farmers practices) and replicated four times. The result shows that there is no significant yield difference between treatment of 100% MAD (12311.6 kg/ha) with 445.2 mm seasonal amount of irrigation water and 75% of MAD (12931.4 kg/ha) with 333.9 mm seasonal amount of irrigation water. The highest total yield (12931.4 kg/ha) was obtained from 75% of MAD by applying 333.9 mm of irrigation water and the lowest yield (9824.2 kg/ha) was obtained at farmers practice by applying 484.5 mm depth of irrigation water. The highest water use efficiency of 4.66 kg /m^3 was recorded at 75% MAD and the lowest water use efficiencies of 2.36 kg/m^3 and 2.03 kg/m^3 were recorded at 125% MAD and farmers practice, respectively. For onion production, applying irrigation water at long intervals reduces the yield and water use efficiency. Therefore, applying irrigation water at 75% MAD increases onion yield and water use efficiency.

Keywords: Efficiency, interval, manageable allowable depletion (MAD), onion, scheduling

INTRODUCTION

Agriculture has been the basis of the Ethiopian economy for centuries. Agricultural productivity was growing continuously in the past two decades. The ever-increasing world population and the demand for additional water supply by industrial, municipal, and agricultural sectors exert a lot of pressure on renewable water resources forcing the agricultural sector to use the available irrigation water efficiently to produce more food to meet the increasing demand [1].

Determining crop yield response to irrigation is crucial for crop selection, economic analysis and for practicing effective irrigation management strategies [2]. Furthermore, this enables to know the time of irrigation as well as to optimize yield, water use efficiency and ultimate profit [3, 4].

Under limited irrigation water supply, irrigation scheduling is also very useful in determining irrigation strategies. Irrigation scheduling is one of the most important tools for developing best management practices for irrigated areas [5].

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Irrigation scheduling is the technique of applying water on a timely and accurate basis to the crop, and is the key to conserving water and improving irrigation performance and sustainability of irrigated agriculture [6]. Hoffman et al. [7]. referred to irrigation scheduling as “a planning and decision making activity that the farm manager or operator of an irrigated farm is involved in before and during most of the growing season”.

Irrigation scheduling involves making a decision on how much and when to apply it. Three factors influence the decision: water needs by the crop (evapotranspiration), water availability, and water holding capacity of the soil [8]. Applying irrigation water at the right amount and time increases the yield. Short irrigation interval and long irrigation interval reduce the yield of tomato [9].

Modern scientific irrigation scheduling uses a single approach or combination of weather, soil or plant-based approaches. This may involve estimating the earliest date to permit efficient irrigation or the latest date to avoid the detrimental effects of water stress on the crop [10]. Generally, the field experiment is planned to evaluate the responses of onion to irrigation regime (when and how much) and to identify water productivity under optimal irrigation regime.

METHODS

Description of the Study Area

The experiment was conducted in Konta Special District for two consecutive years. The experimental site is located latitude range between 6°10'30" and 7°23'00" North, longitude range between 36°13'30" and 37°05'00" East, and an altitude range of 800 to 2625 m.a.s.l. The area is characterized by bimodal rainfall pattern with a short rainy season (belg) and (kirmet). The soil textural class of the experimental area is clay with pH of 5.65 to 5.96.

Treatment Setup and Experimental Design

The experiment has four treatments with four replications and arranged in randomized complete block design (RCBD). The treatments were T1 (125% manageable allowable depletion [MAD]), T2 (100% MAD), T3 (75%MAD), and T4 (farmers practices). The size of each individual plots had kept at 4 m × 4 m. The spacing between plots and blocks were 1 m. The spacing between onion plants and rows was kept at 10 cm, 20 cm, and 40 cm, respectively. Each plot has 6 ridges of onion plants with double row on each ridge and 40 plants in each row with a total plant population of 480 in each plot. Each experimental treatment was fertilized with recommended fertilizer application, that was 200 kg/ha and 100 kg/ha of Nitrogen, Phosphorus, and Sulfur (NPS) and urea, respectively. The full dose of NPS was applied at transplanting, whereas urea was applied by splitting into two parts, half first three weeks after transplanting and the rest just at mid-stage. All cultural practices were done to all treatments in accordance to the recommendation made for the area.

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 Allen et al. [11] and then, crop water requirement was calculated using the following equation:

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

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%.

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

where GIR is gross irrigation requirement (mm); NIR is net irrigation water requirement (mm), and Ea is application efficiency (%).

The number of days between two subsequent irrigations, irrigation scheduling, was determined by using the following equation:

$$\text{Irrigation interval (II)} = \frac{\mathrm{NIR}}{\mathrm{ETc}}$$

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:

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

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 productivity (WP) is the amount of onion bulb yield per irrigation water applied:

$$\mathrm{WP} = \frac{\text{Harvested bulb yield}}{\text{Total water used}}$$

where WP is crop water productivity (kg/m^3), harvested bulb yield is in kg/ha, and total water used is the seasonal crop water consumption by evapotranspiration (m^3/ha).

Statistical Analysis

Analyses of variances for the data recorded were conducted using SAS 9 statistical software carried out using least significant difference (LSD) test at 5% probability used for mean separation when the analysis of variance indicated the presence of significant treatment differences.

RESULTS AND DISCUSSION

Soil Result of the Study Area

The result of the soil analysis from the experimental site showed that the average composition of sand, silt and clay percentages were 22.5%, 46.5%, and 31%, respectively. Thus, according to the US Department of Agriculture soil textural classification, the percent particle size determination for experimental site revealed that the soil texture could be classified as clay soil. Moreover, the pH value of the experimental site was 5.76 to 5.86 and this value falls in the pH range that is conducive for onion production. The total available water (TAW) that is the amount of water that a crop can extract from its root zone is directly related to variation in field capacity (FC) and permanent wilting point (PWP) and its root depth. Onion root depth extends only to 60 cm (Table 1).

Climatic Characteristics

The average climatic data (maximum and minimum temperature, relative humidity, wind speed, and sun shine hours) on monthly basis of the study area were obtained from meteorological station. The potential evapotranspiration, ETo was estimated using CROPWAT software version 8 (Table 2).

Table 1. Soil characteristics of the study area.

Soil properties		Soil depth			
		0–20 (cm)	*20–40 (cm)*	*40–60 (cm)*	*Average*
Particle size	Sand%	22	22	26	23.3
	Silt%	32	32	28	30.7
	Clay%	46	46	46	46.0
Textural class		Clay	Clay	Clay	Clay
Bulk density		1.04	1.03	1.32	1.1
pH		5.65	5.96	5.68	5.8
Electrical conductivity EC (dS/m)		1.45	1.59	1.6	1.5

Table 2. Climatic data of the study area.

Month	Min temp (°C)	Max temp (°C)	Humidity (%)	Wind (km/day)	Sun hours	Eto (mm/day)
January	10	29	77	95	7	3.64
February	11	29.7	80	104	6.4	3.8
March	11.8	29.2	86	173	6.3	3.98
April	12.6	28.1	88	130	6.6	3.88
May	12.6	27.3	93	104	6.2	3.54
June	12.3	25.8	92	104	5.3	3.18
July	12.3	24.2	88	95	3.6	2.79
August	12.3	24.6	88	104	4.1	2.98
September	11.6	25.7	91	86	5.1	3.22
October	11	27.7	99	95	6.7	3.49
November	10.3	28.1	89	69	7.2	3.5
December	10.3	28.3	85	69	7.5	3.46
Average	11.5	27.3	88	102	6	3.45

Table 3. The total amount of irrigation water applied in each growing season for each treatment.

Growth stages	Depth of irrigation water (mm)			
	125% MAD	*100% MAD*	*75% MAD*	*FP*
Initial	45.0	36	34	76.5
Dev	124.4	99.5	95	127.5
Mid	175.5	140.4	130	127.5
Late	211.6	169.3	160	153
Total	556.5	445.2	419	484.5

FP, farmers practice; MAD, manageable allowable depletion.

Irrigation Water Requirement of Onion

The crop water requirement of the tested crop is calculated by multiplying the ETo with crop coefficient (Kc). According the seasonal irrigation water requirement of onion for 100% ASMDL (allowable soil moisture depletion level), 125% ASMDL, 100% ASMDL, and 75% ASMDL was 445.2 mm, 556.5 mm, 445.2 mm, and 419 mm respectively (Table 3).

Onion Response to Different Irrigation Regimes

Analysis of variance has shown non-significant ($p < 0.05$) difference in plant height, bulb diameter and bulb weight of onion and there is a significances differences of total yield and water use efficiency among treatments. Irrigation scheduling have significant effect on bulb diameter, total yield and water use efficiency of onion, but plant height and bulb weight have not affected by irrigation scheduling.

Table 4. Onion response to scheduling

Treatment	PH (cm)	BD (cm)	BW (gm)	TY (kg/ha)	WUE (kg/m^3)
125% MAD	32.8	3.56a	25.75	10873.3bc	2.36c
100% MAD	33.9	3.53a	25.64	12311.6ab	3.35b
75% MAD	34.6	3.36b	26.38	12931.4a	4.66a
Farmers practice	33.4	3.44ab	24.54	9824.2c	2.03c
CV (%)	8.68	6.67	15.04	18.12	20.11
LSD (0.05)	NS	0.1645	NS	1474	0.4421

PH, plant height; BD, bulb diameter; BW, bulb weight; TY, total yield; WUE, water use efficiency; MAD, manageable allowable depletion; CV, coefficient of variation; LSD, least significant difference.

Total yield of farmer practice and 125% MAD reduce the yield significantly. The highest total yield and the highest water use efficiency was obtained under 75% MAD (Table 4).

CONCLUSION AND RECOMMENDATION

From the analyzed results, there is no significant difference between yields of treatment 100% MAD (12311.6 kg/ha) with 445.2 mm seasonal amount of irrigation water and 75% of MAD (12931.4 kg/ha) with 333.9 mm seasonal amount of irrigation water. The highest total yield (12931.4 kg/ha) was obtained from 75% of MAD by applying 333.9 mm of irrigation water. The lowest yield (9824.2 kg/ha) was obtained at farmers practice by applying 484.5 mm depth of irrigation water. The highest water use efficiency of 4.66 kg/m^3 was recorded at 75% MAD and the lowest water use efficiencies of 2.36 kg/m^3 and 2.03 kg/m^3 were recorded at 125% MAD and farmers practice, respectively. Therefore, the longer watering interval reduces onion yield, so proper on the right day and amount, frequent but less amount application increases onion production.

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