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Response of Onion (*Allium Cepa L.*) to Soil Moisture Stress Conditions at Different Growth Stages under Semi-Arid Area of Ethiopia

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Abstract

Soil moisture stress condition is the most critical factor affecting crop yield and water productivity. Under changing climate and increasing human population the evaluation of effect of soil moisture stress on crop production is critical issue for the increasing water scarcity. An experiment was conducted for three consecutive seasons to investigate the effect of water stress imposed at different growth stages on bulb yield and water productivity of onion (Allium cepa L.). Sixteen treatments were used depriving irrigation at different combinations of the four growth stages: at each growth stages, at two growth stages, at three growth stages, irrigated at establishment only and full irrigation (control). The treatments were replicated three times in a randomized complete block design. The study result indicated that onion bulb yield and water productivity were significantly ($p<0.05$) affected with soil moisture stress imposed at different growth stages. The maximum bulb yield (31.50t/ha) was obtained from fully irrigated onion at all stages (the control). Water stress imposed at combinations of initial and late season stage didn't affect bulb yield, but soil moisture stress imposed at combinations of development and bulb formation stage decreased bulb yield highly. Withholding irrigation at initial and late season stage increased onion water productivity and reduced yield response factor by saving 29.3% water. While withholding irrigation at development stage followed by bulb formation stage decreased water productivity to 3.41 Kg/m3 causing higher yield response factor of 1.19. Thus, moisture stress at mid-season stage should be avoided especially when combined with moisture stress imposed at development stage for higher bulb yield. Moreover, moisture stress imposed at initial and late season stages enhance water productivity without significantly reducing the yield from the control.

Keywords: Depriving irrigation • Growth stages • Onion • Moisture stress • Water productivity

Introduction

Fresh water scarcity is a main problem for agricultural crop production specially, in arid and semi-arid regions. Population increase and climatic change are aggravating the problem. Thus, achieving food security in the future while using water resources in a sustainable manner will be a major challenge in the future.

Many recent studies have tied water scarcity to agricultural water consumption. Irrigation agriculture is the largest freshwater consumer, using 70% of the total renewable freshwater resources (WWAP, 2014).

In Central Rift Valley of Ethiopia, water shortage is getting severe during dry season as the irrigation farms are expanding from time to time. Under scarce water condition adopting appropriate water saving practices to produce more food per drop of water will be a crucial strategy to address the challenge. Deficit irrigation and soil moisture stress can be used as alternate strategies to reduce irrigation water use as well as improve irrigation efficiency. In deficit irrigation, water applied at an irrigation time is less than the crop's actual need [1]. In soil moisture stress which is the main concern of this study irrigation water is deprived at respective growth stages. As a result of the two techniques, less water is used and more land can be cover by producing optimum yield [2].

Onion (Allium cepa L.) is one of the most important irrigable vegetable crops grown in Ethiopia. The area under onion production was about 48,443.36 hectares with a production of 3.75 million tons (CSA, 2018). The bulk of onion produced in the county comes from the central rift valley area where irrigated land under vegetables and other irrigated crops by state and private farms is expanding leading to water shortage. The great challenge of onion producers is achieving optimal yield with less water use. Most of the water saving studies conducted on onion is attached on evaluating effects of different deficit levels on yield and water productivity [3], but much study has not been done to evaluate the effect of depriving irrigation at some growth stages of crops, particularly for onion.

Therefore, this study aimed to evaluate the effect of soil moisture stress occurred at different onion growth stages on bulb yield and water productivity.

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Materials and Methods

Description of the experimental area

Field experiments were carried out for three consecutive years on dry season of 2014/15, 2015/16 and 2016/2017 at Gidara Research Sub-station of Melkassa Agricultural Research Center. The study site is found in the central rift valley of Ethiopia in Oromia Region, East Shoa Zone, in Fentale Woreda. Geographically the site is located at $08^0$44'55''N and $39^0$47'49" E with altitude of 1112m above sea level.

The long-term weather data collected from nearby metrological station, Nura Era, shows that the maximum and minimum monthly average temperature are 31.70°C and 16.80°C, respectively. July to September is the main rainy season whereas the mean annual rainfall is 615mm. The climate water balance (Figure 1) shows that there is Evapotranspiration deficit for longer duration which makes irrigation mandatory to the area.

The soil texture at the study site is sandy loam with pH of 8.4.

Treatment and experimental design

The experiment consisted 16 treatments randomized in blocks with three replications. The treatments are: 1) irrigated all stages (control-no stress), 2) depriving irrigation at initial stage only (DMdMt), 3) depriving irrigation

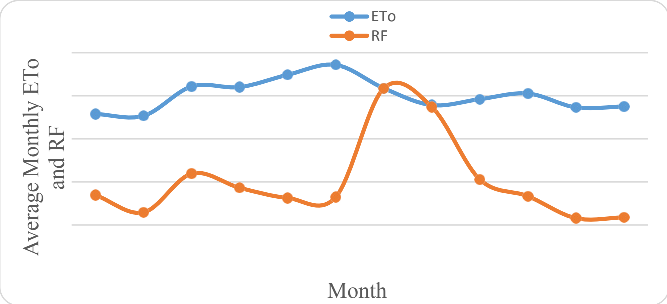

Figure 1. Climate water balance of the study area.

at development stage only (IMdMt), 4) depriving irrigation at mid season stage only (IDMt), 5) depriving irrigation at late season stage only (IDMd), 6) depriving irrigation at initial and development stages (MdMt), 7) depriving irrigation at initial and midseason stages (DMt), 8) depriving irrigation at initial and late season stages (DMd), 9) depriving irrigation at development and midseason stages (IMt), 10) depriving irrigation at development and late-season stages (IMd), 11) depriving irrigation at mid-season and late season stages (MdMt), 12) depriving irrigation at initial, development and mid-season stages (Mt), 13) depriving irrigation at initial, development and late season stages (Md), 14) depriving irrigation at initial, midseason and late season stages (D), 15) depriving irrigation at development, midseason and late seasons (I) and 16) with no irrigation.

Experimental procedure and management practice

Onion (*Allium cepa L.*), *Red Bombay variety,* seed was sown on well-prepared seedbed of 1 m x 5 m at seed rate of 70 grams per bed at early September of each year: 2014, 2015 and 2016. The seedling management practice was made as per the recommendation for the area until seedlings reached stage of transplanting. The seedlings were then transplanted at mid-October to experimental plots and planted on both sides of a ridge at row and plant spacing of 20 and 5 cm, respectively.

Each experimental plot had 3.0m length and 3.6m width with five ridges, 0.6m apart. All other agronomic practices were kept normal and uniform for all the treatments including pre-irrigation and two light irrigations for establishment.

Irrigation management

Depth of irrigation water applied was estimated using CROPWAT 8 model from daily climate data. The FAO Penman-Monteith method (Allen *et al*., 1998) was used to calculate the reference evapotranspiration ETo in the CROPWAT 8.0 Program. Crop water requirements or crop evapotranspiration (ETc) was determined from ETo according to the following equation using crop coefficient Kc:

ETc= Kc x ETo

Where: ETc is the crop water requirement, Kc is the crop coefficient and ETo is the reference evapotranspiration. Crop evapotranspiration was calculated by multiplying the reference evapotranspiration (ETo) values with the crop coefficients of onion given by Gobena et al. Since there was insignificant rainfall during the experimental period, net irrigation requirement was taken to be equal to ETc. Accordingly, the depth of irrigation water applied for each treatment is indicated in Table 1 below.

Parshall flume (3-inch throat width) was used to measure and adjust the water flow to the plots, as an equal quantity of water was supplied using furrow irrigation over all experimental plots (Kandiah, 1981). The amount of water discharged was then calculated by measuring the time of water flow into the plot in seconds with reading of the water height over the Parshall flume. Then return to the water discharge table to know the discharge rate in liters per second. Then the total volume of the water applied to each plot was counted from the discharge table. The gross irrigation was computed by adopting a field application efficiency of 60% [4].

Table 1. Average net irrigation depth applied (mm) for each growth period.

Treatments		Stage*				Total
		I	D	Md	Mt	
T1	no stress (IDMdMt)	60.9	140.4	208.4	83.8	493.5
T2	DMdMt	-	140.4	208.4	83.8	432.6
T3	IMdMt	60.9	-	208.4	83.8	353.1
T4	IDMt	60.9	140.4	-	83.8	285.1
T5	IDMd	60.9	140.4	208.4	-	409.7
T6	MdMt	-	-	208.4	83.8	292.2
T7	DMt	-	140.4	-	83.8	224.2
T8	DMd	-	140.4	208.4	-	348.8
T9	IMt	60.9	-	-	83.8	144.7
T10	IMd	60.9	-	208.4	-	269.3
T11	ID	60.9	140.4	-	-	201.3
T12	Mt	-	-	-	83.8	83.8
T13	Md	-	-	208.4		208.4
T14	D	-	140.4	-	-	140.4
T15	I	60.9	-	-	-	60.9
T16	No-irr	-	-	-	-	-

*Growth stage: I = initial stage, D = development stage, Md = bulb formation stage and Mt = maturity stage

The time required to deliver the desired depth of water into each plot was calculated using the equation below.

$$t = \frac{I_g \times A}{60 \times q}$$

Where: Ig = gross depth of water applied (mm), t = application time (min), A = plot area, q= flow rate (l/s) at specific Parshall flume head and 60 (sixty) is unit adjusting figure.

Data collection

From the total of five both side plated rows the interior three rows were harvested. Data on onion bulb yield and other parameters were collected.

Water Productivity

Water productivity (WP) in this study was determined by dividing the marketable onion bulb yield to the net amount of irrigation water used by the crop as indicated by the following equation [5]:

WP =(Y/ET)

Where, WP is water productivity (kg/m³), Y crop yield (kg/ha) and ET is the seasonal crop water consumption by evapotranspiration (m³/ha).

Water Productivity

The yield response factor was calculated according to the procedure mentioned by Vaus and Pruitt (1983) as follows:

$$1 - \frac{Y_a}{Y_m} = K_y \left[1 - \frac{ET_a}{ET_m}\right]$$

Where: Ky is yield response factor, Ya is the marketable bulb yield obtained from each deficit treatments (t/ha), Ym is marketable bulb yield obtained from the control treatment with full irrigation (t/ha), ETa is the net depth of irrigation applied for each deficit treatments (mm), ETm is the net depth of irrigation water applied for the control treatment with full irrigation (mm), $(1 - \frac{Y_a}{Y_m})$ is the decrease in relative yield due to deficit water application and $(1 - \frac{ET_a}{ET_m})$ is the relative water saved (decrease in relative crop water consumptive) due to deficit irrigation.

Table 2. Bulb yield, water productivity and yield response factor analysis.

Treatments	Bulb yield (ton/ha)	WP (kg/m³)	Relative yield reduction (%)	Relative ETc deficit/ water saved (%)	Yield response factor (K_y)
Fully irrigated (IDMdMt)	31.50^{a}	$_{6.38}g$	0.0	0.0	-
DMdMt	31.32^{a}	7.24^{ef}	0.6	12.3	0.05
IMdMt	25.02^{b}	7.08^{f}	20.6	28.4	0.72
IDMt	23.64^{c}	8.29^{b}	25.0	42.2	0.59
IDMd	31.07^{a}	7.58^{de}	1.4	17.0	0.08
MdMt	18.67^{d}	6.38^{g}	40.7	40.8	1.00
DMt	18.09^{d}	8.80^{bc}	42.6	54.6	0.78
DMd	30.72^{a}	8.80^{a}	2.5	29.3	0.08
IMt	4.94^{g}	3.41^{i}	84.3	70.7	**1.19**
IMd	16.76^{e}	6.23^{g}	46.8	45.4	1.03
ID	11.46^{f}	5.68^{h}	63.6	59.2	1.07
Mt	1.81^{h}	2.16^{k}	94.3	83.0	1.14
Md	11.24^{f}	5.39^{h}	64.3	57.8	1.11
D	10.86^{f}	7.73^{cd}	65.5	71.6	0.92
I	1.84^{h}	3.02^{j}	94.2	87.7	1.07
No-irr	1.29^{h}	-	95.9	100.0	0.96
CV (%)	12.2	13.5			
LSD0.05	0.81	0.37			

Data Analysis

A randomized complete block design with three replicates was used. Analysis of variance and mean separation using the least significant difference (LSD) at 5% probability level was applied for the analysis of significance, as stated by Gomez and Gomez [6].

Results and Discussion

Effect of soil moisture stress on onion bulb yield and water productivity

Onion bulb yield

The analysis of pooled mean indicated that soil moisture stress imposed at different growth stages of onion had a significant effect ($p<0.05$) on bulb yield as indicated in Table 3. The result showed that the maximum bulb yield of 31.50 t/ha was obtained from the control (fully irrigated plot) with no significant difference from the treatment for which irrigation was withheld either at initial or maturity or both. The minimum bulb yield of 1.29 t/ha was obtained from treatment with no irrigation except during establishment. Depriving water at bulb formation stage was noticed to result in lower bulb yield compared with the other stages. The result is in agreement with Zayton finding, where depriving irrigation at bulb formation stage is observed to reduce bulb yield significantly.

Water productivity (WP)

Soil moisture stress occurred at different growth stages of onion had a significant ($p<0.05$) impact on onion water productivity as indicated in Table 3. Higher water productivity with a value of 8.80 Kg/m³, was attained when moisture stress was occurred at both initial and maturity stages. The minimum water productivity was obtained when irrigation water was given at either initial or late stage or both, depriving the development and bulb formation stages. The study revealed that irrigating onion at development stage gave higher water productivity compared with other stages.

The study showed that low soil water content at initial and late growth stages could increase water productivity. It might be due to low water demand during these stages, and the irrigation was withheld after irrigation was given during establishment and bulb formation stage as a result the residual moisture could have helped the plant to skip the stage without irrigation and WUE was increased consequently. Similar effect of soil moisture stress on water productivity was observed by Gobena et al.

Yield response factor (Ky)

The analysis of yield response factor is presented in Table 3. The highest Ky was 1.19 attained at T9 (irrigated at initial and late season only) and the lowest Ky obtained was 0.05 for T2, followed by 0.08 obtained from T5 and T8, respectively. The result revealed that reduction in water applied at development and bulb formation stage resulted in pronounced decrease in yield compared to the other stages. Irrigating onion at two stages only (development and bulb formation stages) resulted in 29.3% water saving with 2.5% yield reduction with minimum yield reduction. Moreover, depriving irrigation at initial and late season stage had no significant impact on bulb yield (Table2).

Means followed by the same letters in column are not statistically different at 5% level for Least Significant Difference Test.

Conclusion and Recommendation

The results of the study revealed that soil moisture stress imposed at some growth stages enhance water productivity of onion without significantly reducing the yield. Stressing onion at development and mid-season crop growth stage while irrigating the rest of growth stages will lead to wastage of water decreasing the productivity of water in relation with the yield obtained. To enhance onion crop productivity in water limited areas, application of the available irrigation water at bulb formation stage is very important. Moisture availability at development stage has great influence on water productivity. Keeping optimal moisture at development and bulb formation stage while depriving irrigation at initial and late stage results in higher water saving with invisible yield reduction. Moreover, combined moisture stress at development and bulb formation stage critically reduces onion bulb yield and water productivity but increases yield response factor. In generally, it can be concluded that the critical sensitive stages are the combined development and mid-season stages. Moreover, to enhance the water productivity without affecting the bulb yield, irrigation could be deprived at initial and late season stage.

References

1. Fereres, Soriano. “Deficit irrigation for reducing agricultural water use” *J. Exp. Bot* (2007) 58: 147-159.

2. Ali, Hoque, Hassan, Khair. (2007) “Effects of deficit irrigation on yield, water productivity, and economic returns of wheat” *Agric. Water Manag. J.* (2007) 92: 151-161.

3. Gobena, Abreham, Tilahun. “Effect of Deficit Irrigation at Different Growth Stages on Onion (Allium CepaL.) Production and Water Productivity at Melkassa Central Rift Valley of Ethiopia *Acad. Res. J Agri Sci Res* (2017)5:358-365.

4. Bakker, Raine, Robertson. “A preliminary Investigation of Alternate Furrow Irrigation for Sugar Cane Production” (1999).

5. Heydari. “Water productivity in agriculture: challenges in concepts, terms and values” *Irrig and Drain* (2014) 63: 22-28.

6. Gomez, Gomez. “Statistical Procedures for Agricultural Research” *John Willey sons. New York. USA* (1984) 680.

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