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Development of Water - Yield Relation for Onion Production at Arba Minch, Southern Ethiopia

Alemnesh Ayza[1] Mekonen Ayana[2]
1South Agricultural Research Institute, Arbaminch Agricultural Research Center, Arbaminch, Ethiopia
2.School of Civil Engineering and Architecture, Adama Science and Technology University, Adama, Ethiopia

Abstract
In arid and semiarid areas where agricultural development is severely constrained by water scarcity and its mismanagement, the need to use the available water efficiently is unquestionable. This research was conducted aiming at development of water - yield relation for onion (Allium cepa L.) production. A field experiment was conducted at Arba Minch area district, Southern Ethiopia during 2017 dry cropping season. The experimental treatments consisted four irrigation levels (100, 75, 50 and 25% ETc) and three irrigation intervals (3, 5 and 7 days). The experiment was laid out according to randomized complete block design in factorial arrangement with three replications. Results of the analysis revealed that the interaction effects of irrigation levels and irrigation intervals showed highly ($P<0.01$) significant difference on marketable bulb yield and significant ($P<0.05$) difference on bulb diameter and bulb weight but non significant difference on unmarketable bulb yield. Maximum water productivity ($4.6 kgm^{-3}$) was recorded from treatment receiving 75% ETc at 3 days irrigation intervals; followed by treatment combination of 75% ETc and 5 days irrigation interval this recorded ($4.6 kgm^{-3}$). Treatment combination of 75% ETc with 3 days interval and 75% ETc with 5 days interval were save equivalent amount of irrigation water 155mm. This implies that it can bring 0.31 ha area of land in to production. no significant different on marketable bulb yield among them. In addition to that the highest number of irrigation event observed from treatment combination of 3 days interval with 75% ETc than treatment combination of 5 days interval with 75% ETc which leads to save labor cost, time and competition for irrigation water. Therefore, treatment combination receiving 75% ETc and 5 days irrigation interval seems economically productive when adopted by onion farmers in the study area. .
Keywords: water-yield relation, onion, Arba Minch

1. Introduction
The dominant sector, Agriculture, in Ethiopia mainly relay on rain fed which is becoming risky practice due to highly erratic and uneven distribution nature of rain in most area of the country both temporarily and spatially. Failure of a given seasonal rain leads to severe drought and widespread food insecurity. Even in good years, Ethiopia cannot meet its large food deficit through rain fed production (USAID, 2009).

Growing population pressure, rapidly declining natural resource base and rainfall variability (spatial and temporal) have secured irrigated agriculture a prominent position on the country's development agenda (Sisay *et al*., 2011). However, in Ethiopia irrigation efficiencies are generally low, of the order of 25 to 50%, and problems with rising water tables and soil salinisation are now emerging (EARO, 2002). Therefore, increasing water use efficiency in irrigation may be the most appropriate way of preserving our precious water resources.

The water productivity is "produced yields per unit of water used", often referred to as "crop per drop" (Kumar *et al.,* 2008). Determining crop yield response to irrigation is crucial for crop selection, economic analysis and for practicing effective irrigation management strategies. Furthermore, this enables to know the time of irrigation as well as to optimize yield, water use efficiency and ultimate profit (Payero *et al*., 2009).

Onion (*Allium cepaL.*) is the most important, widely grown vegetable crop throughout the world (Gambo *et al*., 2008). It occupies an economically important place among vegetables in the Ethiopia. The area under onion is increasing from time to time mainly due to its high profitability per unit area and ease of production, and the increases in small scale irrigation areas (Nigussie *et al.,* 2015). Also, onion is among the major vegetable crops grown in the study area under irrigation. However, the study area experiences water scarcity during the dry season from November to March, often resulting in conflicts. During this season onion supply is low while, its demand is high. Therefore, it is desirable to utilize the scarce water resource during this period to produce onion under irrigation for the ready market using an appropriate water saving technology. Development of crop yield - water relation was chosen for use in the study as it maximizes irrigation water productivity and maximum crop yields per meter cube. Therefore, the present research designed to develop and examine the yield-water relation.

2. Materials and Methods
2.1. Site Description
Field data for this study were collected in 2017 at Shele Mela kebele in Arba Minch zuria woreda, Ethiopia. The area is located 500 km south of Addis Ababa at $6^{0}04'$ N and $37^{0}36'$ E at an altitude of 1285 masl. It experiences a bimodal type of rainfall with the first and second rainfall during April to May and September to October,

respectively. The mean annual temperature is 28 °C with a mean annual maximum and minimum temperature of 37 °C and 16 °C, respectively. The mean annual rainfall is about 800 mm.

2.2 Experimental Treatments and Design

The treatments consisted of a factorial combination of four irrigation levels (100, 75, 50 and 25% ETc) and three levels of irrigation intervals (3, 5 and 7 days). There were a total of 12 treatment combinations. The treatment combination and its descriptions are given in the Table 1.

Table 1. The experimental treatment combination and its descriptions

Treatments	Combination	Description
T1	100%ETC*3days	Full irrigation with 3 days interval throughout the crop stages
T2	100%ETC*5days	Full irrigation with 5 days interval throughout the crop stages
T3	100%ETC*7days	Full irrigation with 7 days interval throughout the crop stages
T4	75%ETC*3days	25 % deficit with 3 days interval throughout the crop stages
T5	75%ETC*5days	25 % deficit with 5 days interval throughout the crop stages
T6	75%ETC*7days	25 % deficit with 7 days interval throughout the crop stages
T7	50%ETC*3days	50% deficit with 3 days interval throughout the crop stages
T8	50%ETC*5days	50% deficit with 5 days interval throughout the crop stages
T9	50%ETC*7days	50% deficit with 7 days interval throughout the crop stages
T10	25%ETC*3days	75% deficit with 3 days interval throughout the crop stages
T11	25%ETC*5days	75% deficit with 5 days interval throughout the crop stages
T12	25%ETC*7days	75% deficit with 7 days interval throughout the crop stages

The experiment was laid out in randomized complete block design (RCBD) with three replications. The size of each plot was 3 m * 4 m (12 m^2) accommodating 10 rows with 30 plants per row. Seedlings were planted at one side of ridges of the furrow at the recommended spacing of10 cm between plants, 20cm between rows and 40 cm between furrows ridges for all plots. The distance between plots and blocks were 1 m and 1.5 m, respectively. The outer single rows at both sides of the plot and one plant at both ends of the rows were considered as border plants.

2.3 Experimental Procedure

Seeds were sawn on November 15, 2017 at 10cm distance between rows, lightly covered with soil and mulched with grass (until seedlings are emerged 2-5 cm from the soil). Seedlings were managed for 45 days and then after transplanted, to the main experimental plots on January 1, 2017 during transplanting only healthy, vigorous and uniform seedlings grown at the center of seedbeds were transplanted.

The experimental field was plowed three times using oxen. It was prepared again by human labor to break the clods, Plots were leveled and furrows and ridges were prepared at a spacing of 40 cm using hand tools. The experiment was conducted under furrow irrigation method.NPS and Urea was applied at the recommended rate of 100 kg/ha NPS at time of planting and 100 kg Urea with split application 50 kg at time of planting and 50 kg six weeks after planting. Irrigation applied up to March 24, 2017 then after it was discontinued 15 days before harvest which helps in reducing the rotting during storage.

All other cultural practices were followed as per the requirement of onion crop. Prior to the application of treatments equal amount of irrigation was applied one times for all experimental plots to favor uniform establishment of the seedlings.

2.4 Water Application

Diverted water from the river was brought to the field using filed channel that run adjacent to experimental plots. The flume was set on a straight section of the channel and used to estimate flow rate. The time required to deliver the desired depth of water into each plots using Parshal Flume was calculated from the following equation. Volume of the water required depth (d) in cm over an area of a s.qm

$$t = \frac{10*a*d}{q*60} minuts \quad (1)$$

where,

t = time

q = flow rate (l/s)

a = area of plot to be irrigated (m^2)

d = depth of water (cm)

2.5 Crop Water Productivity

Crop water productivity (CWP) was computed by dividing the mass of the product to the volume of water consumed (Zwart and Bastiaanssen, 2004).

$$\mathrm{CWP}\ (\frac{\mathrm{Kg}}{\mathrm{m}^3}) = \frac{Yt}{ETc}$$

(2)

where

CWP = crop water productivity (Kg/m^3)

Yt = the total crop yield (kg/ha) and

ETc = the seasonal crop water consumption (m^3/ha).

2.6 Data Collection

Data on bulb characters bulb diameter and bulb weight were recorded from ten randomly selected and pre-tagged plants in each experimental plots at harvesting period. Yield data marketable and unmarketable bulb yield data's were collected as per the procedures mentioned as follows. Marketable bulb yield ($kgha^{-1}$): marketable bulb yield was the yield recorded from all plants in the central eight rows per plot and was converted to yield of $kgha^{-1}$ which were greater than 3 cm in diameter (Morsy *et al*., 2012). Unmarketable yield ($kgha^{-1}$): was recorded as the total weight of damaged, discolored, splitted, thick necked and small bulbs (below 20g) (Lemma and Shemels, 2003 and Morsy *et al*., 2012).

2.7 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using SAS version 9.1.3. Treatment means were compared using the least significant difference (LSD) at 5% level of probability.

3. Results and Discussion

3.1 Amount of Water Applied

During the study period unexpected precipitation were occurred at different stages of the crop however, effective rainfall was nil. Therefore, total water supplied was equivalents to irrigation water supplied during the growth stages of the crop. The season irrigation depth of onion varied from 192 to 657 mm. In growing seasons, treatment combination of 100% ETc with 3, 5 and 7 days interval treatments received the largest irrigation depths which was 657 mm, followed by treatments combination of 75% ETc with 3 5 and 7 days interval which was 502 mm whereas the most stressed 25% ETc with 3, 5 and 7 days interval treatments got the smallest ones which was 192 mm followed by treatment combination of 50% ETc with 3, 5 and 7 days interval which was 347mm. According to Lemma and Shimelis (2003), the crop demands about 400-800 mm per growing season for the formation of large bulb size and high yield. Whereas, Ells *et al.* (1993) reported that furrow-irrigated onions required 1040 mm of water to obtain a yield of 59 t ha^{-1}.

3.2 Crop Yield and Yield Components

Results of the field experiment revealed that the interaction effect of irrigation levels and irrigation intervals on bulb diameter and bulb weight of onion plant were ($P<0.05$) significantly difference; Marketable bulb yield of onion plant were highly ($P<0.01$) significantly difference. However, unmarketable bulb yield was non significantly difference

3.2.1 Bulb diameter

Bulb diameter was significant ($P<0.05$) difference on the interaction of irrigation levels and irrigation intervals. The longest diameter (6.5 cm) was obtained from the treatment combination of 100% ETc and 3 days interval which was statistically at par with treatment combination of 100% ETc and 5 days interval. The shortest diameter (3 cm) was recorded from the treatment combination of 25% ETc and 7 days irrigation interval (Table 2).

Onion bulb diameter was determined as an indicator of size. Increased bulb equatorial diameter of onion by 3 days and 5 days interval with 100% ETc of irrigation may be attributed to optimum soil water- air- balance around plant root zone.. In line with this result, Rop *et al*. (2016) found that bulb diameter varied proportionally with the quantity of irrigation water applied. This finding was also in agreement with the finding of Bagali *et al.* (2012) who reported that Onion bulb sizes were affected by the level and timing of water stress.

3.2.2 Bulb weight

Bulb weight was highly ($P<0.01$) significant difference on the irrigation levels and irrigation intervals, and significant $P<0.05$) difference on their interaction. The highest bulb weight (70.5 g) was obtained from the combined effect of 100% ETc and 3 days irrigation interval which was statistically non significant difference with combined effect of 100% ETc and 5 days interval. The lowest bulb weight (38.5 g) was recorded from the combined effect of 25% ETc and 7 days irrigation interval which was statistically at par with treatment combination of 25% ETc and 5 days irrigation interval (Table 2).

This result was also in agreement with the result of Shahi *et al*. (2015b) reported that water is the main limiting factor for production of many crops including onion in the arid and semiarid regions; fresh and dry mass production of crop reduce due to the adverse effect of water stress. The result of the current study is in agreement with the result of Bagali et al. (2012) reported that the mean onion bulb weight was affected by the level and timing of water stress.

3.2.3 Marketable bulb yield

The mean marketable bulb yield of onion plant was highly (P<0.01) significant difference on irrigation levels and irrigation intervals, and their interaction. The highest marketable bulb yield (27540 kg ha^{-1}) was obtained in treatments which received the combined application of 100% ETc with 3 days irrigation interval which was statistically at par with treatment combination of 100% ETc and 5 days irrigation interval. The lowest marketable bulb yield (3200 $kgha^{-1}$) was recorded from the treatment combination of 25% ETc and 7 days irrigation interval which was statistically at par with treatment combination of 25% ETc with 3 and 5 days irrigation interval (Table 2).

This result is in accord with Enchalew *et al*. (2016) reported that marketable bulb yield had highly affected by deficit irrigation. The different irrigation levels applied has significant effect on onion yield and yield components (Ebtisam *et al*., 2015; Sabreen *et al*., 2015). Pejic *et al.* (2014) cleared that onions yield and quality decreased with increasing soil-water stress.

Table 2. Interaction effect of irrigation levels and irrigation intervals on bulb diameter (cm), bulb weight (g) and marketable bulb yield ($kgha^{-1}$) of onion

IL (%ETc)	II (days)	BD (cm)	BW (g)	MBY ($kgha^{-1}$)
100	3	6.5^{a}	70.5^{a}	27540^{a}
	5	6.3^{a}	69.4^{a}	26400^{a}
	7	5.8^{b}	65.7^{b}	24650^{b}
75	3	5.5^{bc}	63^{bc}	23100^{c}
	5	5.2^{c}	62.5^{c}	22310^{c}
	7	4.65^{d}	57.5^{d}	20200^{d}
50	3	4.5^{d}	54^{e}	12850^{e}
	5	4.3^{d}	52.5^{e}	11690^{e}
	7	3.8^{e}	48^{f}	10000^{f}
25	3	3.5^{ef}	42^{g}	3800^{g}
	5	3.2^{fg}	39.5^{gh}	3870^{g}
	7	3g	38.5^{h}	3200^{g}
Mean		4.69	55.26	15.81
CV(%)		4.65	3.08	5.15
LSD (5%)		0.37	2.87	1.37

Means followed by the same letter are not significantly different at P< 0.05, IL (%ETc)=irrigation level in ETc percent, II (days)=irrigation interval in days, BD (cm)=equatorial bulb diameter in centimeter, BW (g)=bulb weight in gram, MBY ($kgha^{-1}$)= marketable bulb yield in kilogram per hectare, LSD=least significant difference at five percent probability; CV (%)= coefficient of variation in percent.

3.2.4 Unmarketable bulb yield

Unmarketable bulb yield was highly (P<0.01) significant difference on the irrigation levels but non significant difference on irrigation intervals and interaction. Considering the independent effect of irrigation levels alone, the highest and lowest unmarketable bulb yields were recorded from 100% ETc and 25% ETc treatments, respectively. However, 100% ETc treatment gave the lowest percentage (22%) of unmarketable bulb yield and while 25% ETc treatment gave the highest percentage (49%) of unmarketable bulb yield (Table 3). From the result, it can be observed that up to 25% water deficit was marginal to obtain the least unmarketable bulb yield.

The current study result is in agreement with the result of Enchalew *et al*. (2016) observed that the highest and lowest percentage of unmarketable onion bulb yields were recorded from the control and 50% ETc treatments, respectively.

Disregarding the effect of irrigation intervals, the highest and lowest unmarketable bulb yields were recorded from 3 days and 7 days intervals, respectively. However, the highest and lowest percentage of unmarketable bulb yields was recorded from 3 days and 7 days intervals, respectively (Table 3).

Table 3. Effect of irrigation levels and irrigation intervals on unmarketable bulb yield (kg ha^{-1})

IL (%ETc)	UMBY (kg ha^{-1})	%
100	7270[a]	22
75	6430[b]	22
50	4880[c]	30
25	3560[d]	49
II (days)		
3	5680[a]	25
5	5670[a]	26
7	5250[b]	27
Mean	5.53	
LSD (5%)	0.21	
CV (%)	6.33	

IL (%ETc)=irrigation level in ETc percent, II (days)=irrigation interval in days, LSD=least significant difference at five percent probability; CV (%)= coefficient of variation in percent

3.3 Water Supply–Yield Relationship

The relationship between marketable bulb yield and seasonal water applied for onion is shown in Table 4. Water supply-yield relationship was known as crop water productivity. The seasonal water applied for onion ranged from 192 to 657 mm, whereas marketable bulb yield ranged from 27540 to 3200 $kgha^{-1}$.Crop water productivity (CWP) in terms of marketable bulb yield was estimated by dividing marketable bulb yield (kg/ha) to the total irrigation water applied (m^3/ha). The water productivity for onion ranged from 1.67 to 4.6kgm^{-3}. The highest water productivity (4.6kgm^{-3}) was recorded from treatment receiving 75% ETc at 3 days irrigation intervals; followed by treatment combination of 75% ETc and 5 days irrigation interval this recorded (4.6kgm^{-3}). Treatment combination of 75% ETc with 3 days interval and 75% ETc with 5 days interval were save equivalent irrigation water 155mm. This implies that it can bring 0.31 ha area of land in to production. no significant different on marketable bulb yield among them. In addition to that the highest number of irrigation event observed from treatment combination of 3 days interval with 75% ETc than treatment combination of 5 days interval with 75% ETc which leads to save labor cost, time and competition for irrigation water. Therefore, treatment combination receiving 75% ETc and 5 days irrigation interval seems economically productive when adopted by onion farmers in the study area. .

Table 4. Water productivity, yield reduction %, water saved, calculated yield and extra land from saved water under the different treatment combinations against yield obtained at control

IL/ %ETc	II/ days	AW/m^3/ ha	MBY ($kgha^{-1}$)	WP/kg/ m^3	YR/ %	WS/ mm	CY/kg/ ha	EL/ha
100	3	6570	27540	4.19	0	0	0	0
	5	6570	26400	4.02	4	0	0	0
	7	6570	24650	3.75	10.5	0	0	0
75	3	5020	23100	4.6	16	155	7132.47	0.31
	5	5020	22310	4.44	19	155	6888.55	0.31
	7	5020	20200	4.02	26.7	155	6237	0.31
50	3	3470	12850	3.7	53.3	310	11479.8	0.89
	5	3470	11690	3.37	57.6	310	10443.5	0.89
	7	3470	10000	2.88	63.7	310	8933.7	0.89
25	3	1920	3800	2.00	86	465	9203	2.4
	5	1920	3870	2.02	86	465	9372.65	2.4
	7	1920	3200	1.67	88.4	465	7750	2.4

IL/%ETc=irrigation level in ETc percent, II/days)=irrigation interval in days, AW/m^3/ha=applied water in meter cub per hectare, MBY ($kgha^{-1}$)= marketable bulb yield in kilogram per hectare, WP/kg/m^3=water productivity in meter cub per hectare, YR/%=Yield reduction in percent, WS=saved water in millimeter, CY=calculated Yield from saved water, EL=Extra land irrigated from saved water in hectare.

5. Conclusions

Treatment combination receiving 75% ETc and 5 days irrigation interval seems economically productive when adopted by onion farmers in the study area. .

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