Effect of irrigation regimes (frequency and water depth) on yield of onion in Metema, western Amhara, Ethiopia

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Abstract

Farmers did not know how much and when to apply irrigation water for irrigating crops resulted in under or over-irrigation. They apply more water at one time and lost the water through deep percolation beyond the root zone and runoff. The study was conducted in 2017and 2018 at Gondar agricultural research center irrigation station. The objective of the study was to determine irrigation regimes for a better yield of onion. Treatments were a combination of irrigation interval (4, 7, and 10days) with (60%, 80%, 100%, and 120% of Etc. The experimental design was a split-plot design with three replications. Irrigation interval and depth were the main plot and subplot respectively. The combined result revealed that there were interaction effects and main effects on tested parameters at a=0.05. Irrigating every 4days gave the highest Bulb weight (61.18g), Bulb Diameter (52.41 mm), and total yield (22.93th^{-1}) followed by watering every 7days. On the other hand, 7days irrigation interval gave the highest water productivity (4.39 kg/m^{3}) than 4days with 10days irrigation interval. Applying 120%ETc provided the highest value concerning all yield components considered, while the lowest values were obtained from 60%ETc. The highest and lowest water productivity obtained from treatment 80%ETc with 120%ETc respectively. The interaction result revealed that the maximum total yield (27.66t/ha) and bulb weight (72.5g) obtained from 120%ETc with 4days intervals. This is statistically the same with 120%ETc with 7days intervals. Besides, the least amount of total yield (15.36 th^{-1}) and bulb weight (45.47 th$^{-1)}$ were recorded from 60%ETc with 10days intervals. In the area, there is no water scarcity for irrigation. Therefore, in the advantage of the less frequent watering day and minimizing of operational and labor cost, irrigating every 7 days with 120%ETc is more appropriate for the command area and others those have the same ecology and soil type.

Keywords: irrigation interval, Metema, water depth, water productivity, yield

Introduction

Onion is considered as one of the most important vegetable crops produced on small scale farming in Ethiopia. It also occupies an economically important place among vegetables in the country. The area under onion is increasing from time to time mainly due to its high profitability per unit area, ease of production, and the increases in small scale irrigation areas. In different areas of the country, the offseason crop (under irrigation) constitutes much of the area under onion production. Nigussie *et al.*, (2015) described that the range of altitude for onion production is between 500-2400 m.a.s.l. The best growing altitude so far known in Ethiopia is between 700-1800 m.a.s.l.

In Ethiopia, the crop is believed to be more intensively consumed than any other vegetable crops and a lion share of 95% of the vegetables and fruits produced in the country (Belay *et al.*, 2016). In most irrigable lands, the role of horticultural crops particularly Vegetables being cash crop with high nutritional value become important and irreplaceable to contribute the household food security and income. Higher profits can be achieved by increasing the production of a particular vegetable throughout the year when an efficient irrigation system is used. In Ethiopia, it contributes substantially to the national economy apart from overcoming local demand. Onion is among the largest production and highly commercialized vegetable crops in the Amhara region grown under irrigation. Currently, farmers in most irrigable areas of the Amhara region produce a large number of onion bulbs every year (Agumas, Abewa, and Abebe, 2014).

All crops require a certain amount of water during each stage of development mainly their initial stage, crop development stage, mid-growing, and maturity stage, and will transpire water maximum rate when the soil water is at field capacity. But the amount, intensity, duration, frequency, and distribution of rain needed to meet the actual water requirement of the crop to achieve full production potential is rarely realized in nature (Pejic, B. *et al.*, 2008).

Water management of onion is extremely important at all stages of plant development. Also, irrigation strategies with appropriate water restriction during mid and late-season growth stages are recommended in a way a significant amount of irrigation water could be saved without any significant decrease in onion yield and quality. The great challenge faces for the onion producers in achieving a high yield that meets the quality standards and market requirements with less water use (Zayton, 2007).

The interval between irrigations and the amount of water applying to each irrigation depends on how much water is held in the root zone and how fast the crop uses it. This is determined

by -soil texture, soil structure/water penetration, depth of effective root zone of the soil, the crop has grown and the stage of development of the crop. Proper irrigation scheduling will improve profitability and water use efficiency by - maximizing crop yield and quality, decreasing water loss through deep percolation and runoff and, optimizing pumping, and other costs.

Different water application schedules on the growth and yield of onion, yield components, and morphological characteristics of the onion crop had significantly affected all the studied parameters, except for the fresh weight of leaves. Therefore to achieve a high production potential of onion, appropriate soil moisture should be maintained during the entire growing season (Pejic, B., et al., 2008).

The production of onion in the Metema district is mainly under irrigation but there were poor agronomic practice and water management skills. Farmers did not know how much and when to apply irrigation water for irrigating crops. Which lead crops under irrigation or over-irrigation. They apply more water at one time and lost the water through deep percolation beyond the root zone and the crop suffocates for some days. Therefore this study was initiated for the objective of determining the optimum irrigation water depth and irrigation interval for a better onion yield.

Materials and methods

The study area

The experiment was conducted in the lowland of western Amhara region **Metema** which is located 13°00′N and 36°15′E, it is one of the zones in the Amhara Region of Ethiopia named as “west Gondarzone administration”. Metema is bordered on the south by Quara, on the west by Sudan, on the north by Mirab Armachiho, on the northeast by Tach Armachiho, on the east by Chilga, and on the southeast by Takusa. Altitude ranges between 550 and 1600 meters above sea level. Rivers include the Atbarah, the GendaWuha, the Guang, and the Shenfa. Guang River is where the irrigation station of Gondar Agricultural Research center is situated.

The experimental site domain is one of the high potential areas for agriculture in the country. It can grow cash crops like sesame, cotton, soya bean, haricot bean, groundnut, and different horticultural crops (fruits: mango, banana, orange, onion, tomato). It has also a potential area for livestock. The soil is deep enough dominantly clay soil and it has a shallow groundwater table and surface water. Irrigation is very infant for the area but it is expanding in a short time. Generally, it is possible to grow three to four times within a year in the area.

The maximum and minimum temperature of the area was 35.88^{o}c and 19.48^{o}c respectively. The metrological information of the Metema district was average reference evapotranspiration of 5.21mm/day using *penman-monteith* and the total and effective rainfall were 885 mm and 636.5mm respectively by USDA S.C. Method.

Table 1. Climatic data for the study area

Month	T. Min [°C]	T. Max [°C]	Humidity %	Wind [km/day]	Sun [hours]	Rad [MJ/m²/day]	Eto [mm/day]	Rain [mm]	Eff rain [mm]
January	18.7	35	45	156	8.5	19.1	5.1	1	1
February	20.2	39	39	156	9.1	21.5	6.06	0	0
March	20.2	40	34	147	8.7	22.3	6.49	0	0
April	17.5	40.2	28	130	8.8	23.1	6.47	1	1
May	18.3	39	69	156	8	21.6	5.78	67	59.8
June	19.8	35.7	84	156	7.3	20.3	4.83	160	119
July	20.2	31.8	93	104	7	19.9	4.15	209	139.1
August	20.1	31.7	93	86	5.1	17.2	3.64	211	139.8
September	20.2	31.7	65	104	7.1	20	4.49	187	131
October	20.1	34.5	41	138	8.8	21.3	5.44	45	41.8
November	19.8	35.9	40	138	9.4	20.6	5.32	4	4
December	18.7	36	44	112	9.2	19.5	4.71	0	0
Average	19.5	35.9	56	132	8.1	20.5	5.21	885*	6.36.5*

Source: FAO-newLocclim; *total

Methodology

The experiment was performed in the 2017 and 2018 irrigation seasons from January 2017 to May 2017 at Metema irrigation station specifically Mender 6, 7, and 8. The experimental design was a split-plot with three replications in two factors. The first factor was irrigation interval consisted of three levels (i.e., four days, seven days, and ten days) and the second factor has consisted of four irrigation water depths (120%ETc, 80%ETc, 100%ETc, and 120%ETc). Generally, the experiment had twelve (12) treatment combinations. The spacing between blocks and plots was 1.5meter and 1meter respectively. The plot size was 3 meters by 3 meters. Crop spacing was 40*20*10, double row (i.e., 40 cm between ridge, 20 cm between rows, and 10 cm between plants). Fertilizer has been applied as the recommendation of EIAR (2007) which was 92kg/ha nitrogen. Data analysis was performed using SAS software window 9.0, and also multiple All-Pair wise Comparisons Test were done using LSD comparison method at 0.05 significant levels.

Water productivity in agriculture and landscape irrigation may be generically defined as the ratio between the actual crop yields achieved (Ya) and the water use, expressed in kg/m3 (Pereira, 2012).

Therefor water productivity was determined by the equation (Pereira, 2012)

$$WP = \frac{Ya}{TWU} \text{ ---------- (1)}$$

Where, Ya is bulb yield (kg/ha) and TWU is total water used (m^3)

Table 2. The crop has four stages and its kc values (Science, 2015)

Growth stages	Growth length	Crop coefficient (kc)
Initial stage	15	0.6
Developmental stage	25	0.6
Mid stage	40	1.1
Late stage	30	0.9

Materials used

During the experiment execution materials were used as; a Siphon tube which was used to deliver water from the tanker to the plot field, and this was also used as the water measurement by calibrating flow rates. The weighing balance was also used as a weighing of harvested bulb samples and soil samples which were collected by plastic bags. Besides tape meter and caliper were important for measuring the experimental area and plot dimensions, plant height, and diameter of bulbs.

Results

Determination of irrigation regimes for better yield of onion in Matema district tested for its interaction effect and main effects. The result revealed that there were interaction effects and main effects on tested parameters at a 0.05 level of significant difference. Analysis of variance table (3) showed that there was a highly significant difference in total yield, bulb weight, bulb diameter, and water productivity among irrigation intervals. Moreover, irrigation water depths affected highly significantly total yield, bulb weight, bulb diameter, and also significantly affect water productivity. On the other interaction between irrigation interval and water, depth affected total yield and bulb weight significantly. However, there were no differences in bulb diameter and water productivity among treatment interactions.

Table 3. Analysis of variance (ANOVA) for total yield, bulb weight, bulb diameter, and water productivity.

Source	DF	Total Yield	Bulb weight	Bulb diameter	Water productivity
REP	4	38.15*	156.59*	9.89*	1.24*
Interval(IN)	2	240.60**	718.86**	67.61**	10.07**
REP*IN(Error)	8	31.15	165.92	19.01	1.1
Water depth(D)	3	238.26**	1146.04**	114.1**	2.12*
IN*D	6	22.76*	90.15*	6.33	0.58
Error (pooled)	0	8.47	34.49	4.58	0.35

*significant, **highly significant, DF= degree of freedom, REP= replications

Table 4 showed that irrigating onion every 4 days gave the highest Bulb weight (61.18g), Bulb Diameter(52.41 mm), and Total yield(22.93 th^{-1}), followed by a 7days irrigation interval with the Bulb weight (59.33g) Bulb Diameter (51.97mm), and Total yield (22.3th^{-1}). 7days irrigation interval gave the highest water productivity (4.29 kg/m^3) and water productivity (4.39 kg/m^3). However, there was no statistical difference between 4days with 7days irrigation intervals. 10-day irrigation interval provided the lowest value for all variables.

On the other hand application of 120%ETc, provided the highest result on bulb weight (64.61 g), bulb diameter (54.09 mm), and total yield (24.07 th^{-1}). The lowest values for bulb weight, bulb diameter, and total yield obtained from treatment 60% ETc. The highest and lowest water productivity was obtained from treatment 80% ETc with 120% ETc respectively.

Table 4. Effects of irrigation interval and depth on the mean of bulb weight (gram), bulb diameter (mm), total yield (t h^{-1}), and water productivity (kg/m^3)

Irrigation Interval	*Bulb weight*	Bulb diameter	Total yield	Water productivity
4days	61.18^{a}	52.41^{a}	22.93^{a}	4.29^{a}
7days	59.33^{ab}	51.97^{ab}	22.30^{a}	4.39^{a}
10days	50.89^{b}	49.33^{b}	17.16^{b}	3.23^{b}
LSD*(0.05)*	8.58	2.90	3.72	0.7
depth				
120%ETc	64.61^{a}	54.09^{a}	24.07^{a}	3.53^{b}
100%ETc	61.97^{a}	51.66^{b}	22.83^{a}	3.93^{ab}
80%ETc	55.31^{b}	51.23^{b}	20.48^{b}	4.27^{a}
60%ETc	46.65^{c}	47.97^{b}	15.81^{c}	4.15^{a}
LSD*(0.05)*	3.97	1.45	1.97	0.40
CV*(%)*	10.28	4.18	14.0	14.95

Values with the same letters have no significant difference

According to table 5, the interaction result revealed that the maximum total yield (27.66t/ha) and bulb weight (72.5g) obtained from 120%ETc with 4days intervals. Which is statistically the same with 120%ETc with 7days intervals. Also, the least amount of total yield (15.36 th-1) and bulb weight (45.47 th-1) were recorded from 60%ETc with 10days intervals.

Table 5. Interaction effects on bulb weight (gram) and total yield (th^{-1})

Water Depth	Bulb Weight			Total Yield		
	Irrigation interval- days					
	4	7	10	4	7	10
120%ETc	72.50^{a}	66.27^{ab}	55.05^{de}	27.66^{a}	25.84^{ab}	18.71^{d}
100%ETc	68.38^{ab}	63.80^{bc}	53.73^{de}	25.66^{ab}	24.17^{bc}	18.65^{d}
80%ETc	58.05^{cd}	58.55^{cd}	49.32^{ef}	22.24^{c}	23.28^{bc}	15.91^{d}
60%ETc	45.80^{f}	48.68^{ef}	45.47^{f}	16.17^{d}	15.9^{d}	15.36^{d}
Cv*(%)*	10.78			14.00		
Lsd*(<0.05)*	6.88			3.41		

ETc= crop evapotranspiration*; values with the same letters have no significant difference*

Discussion

Yield, individual bulb weight, and individual bulb diameter are the important criterion to be considered when a plan to produce an onion bulb. Before planting and growing the crop under irrigation, irrigation interval and water depth should be decided.

Yield

Irrigation interval and water depth interaction result displayed in table 5, which showed interactions effect on yield of onion crop. The result revealed that the maximum bulb yield was recorded from 120%ETc with 4day irrigation intervals (**27.66**t ha^{-1}**)** followed by 120%ETc with 7day irrigation intervals (**25.84**t ha^{-1}). Increasing the Application of water from 60%, 80%, 100% to 120%ETc will increase the total bulb yield. This is in line with (Kumar, Imtiyaz, Kumar, & Singh, 2007) who reported that irrigating onion from 60%ETc, 80%ETc, 100%ETc to 120%ETc increased onion yield. The same result was also obtained by Tsegaye *et al.*, (2016), who reported that increasing irrigation water from 25%ETc to 50%ETc, 75%ETc, and 100%ETc increase marketable yield from **15.48 to27.59**tha^{-1}. Patel and Rajput, (2013) also found that irrigation from 60%, 80% deficit to full irrigation had increase yield from 39.2 to 44.4tha^{-1}. In the same trend Enchalew *et al.*, (2016) found that an increase in water depth from 50 to 60, 70, 80, 90 to 100%ETc has been increased in marketable(**10.9**t ha^{-1}) and total bulb yield(**15.69**t ha^{-1}).

Bulb weight

Irrigating onion at increasing of 4 to 7 and 10-day irrigation interval (main plot) has been decreased bulb weight from 72.5 to 66.27 and 55.05g. Beyond the 7day interval, bulb weight

had significantly affected by water stress. On the other hand, increasing of application of water from 60%ETc, 80%ETc, 100%ETc, and 120%ETc water depth (subplot) will increase the bulb weight. The application of water below 100%ETc of crop water requirement significantly decreases the individual weight of the bulb. A similar result on bulb size was observed by Kumar et al. (2007). The maximum bulb weight (**72.5g)** lied on the interaction of 4-day and 120%ETc, which is statistically identical with 4day with 100%ETc (**68.38g)** and 7 days with 120%ETc (**66.27**g).

Water productivity

Increasing water depth from 80%ETc to 100%ETc and 120%ETc would decrease water productivity from 4.27 to 3.93 and 3.53 kg/m3. Independent of water depth, irrigating every 7 days (4.39kgm^3) is optimal for the water productivity of the onion. than 4days (4.29kg/m^3) and 10days (3.23kg/m^3).

Conclusion and recommendation

Production of onion under irrigation in Metema district and the same ecology, application of water every 4-day irrigation interval with 120%ETC water depth followed by 7day with 120%ETc is appropriated. Moreover, there is no yield and quality penalty among them. Independence of water depth irrigating every 7 days is best in terms of water productivity but it is in contrast on the point of water depth that will prefer 80%ETc. however, in the area, there is no water scarcity for irrigation.

Therefore, in the advantage of the less frequent watering day and minimizing of operational and labor cost, irrigating every 7 days with 120%ETc water depth with a net amount of seasonal water of **664**mm will more appropriate for the command area and others those have the same ecology and soil type.

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