Development of Optimum Irrigation Regime for Onion Production at Arba Minch, Southern Ethiopia

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Abstract
This research was conducted aiming at development of optimum irrigation regime 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 number of l eaves per plant and significant ($P<0.05$) difference on plant height, neck diameter and total bulb yield. The highest total bulb yield 34000 kgha^{-1} was obtained under control treatment which was statistically non significantly different with treatment combination of 100% ETc and 5 days interval. This study shows that shorter interval with higher level of irrigation had the better performance on all studied parameters, while the most stressed had low performance on all studied parameters. Therefore, application of 100% ETc at 5 days interval was economically productive when adopted by onion farmers in the study area when water was non limiting factor. However, 75% ET at 5 days interval can be an option in the study area when water was limiting factor.
Keywords: irrigation regime, onion, Arba Minch

1. Introduction
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 (Andarzian *et al*., 2011).
Irrigation scheduling is the process involved in deciding on the right time and the right amount of water a crop needs in order to maximize yield, quality and minimize water and nutrient leaching (Carr and Knox, 2011; Sammis *et al.*, 2012).Irrigation scheduling involves making a decision on how much and when to apply water.

Onion (*Allium cepa L.*) is one of the most important vegetables in the world. In Ethiopia, onion is produced in many parts of the country by small farmers, private growers and state enterprise (Lemma and Shimelis, 2003). The crop is produced both under rainfed in the "*Meher*" season and under irrigation in the off season. In the many area of the country the off season crop (under irrigation) constitutes much of the area under onion production (Nigussie, 2015).

Onion is among the major vegetable crops grown in the study area under irrigation. But it's productivity, is below national level due to, improper irrigation timing and amount. Flood irrigation is the major water application technique across smallholders' irrigation farmers in the study area to grow vegetable. However, the limited irrigation water availability along with unwise use of the available resource limits the area allotted for onion production. Therefore, it is desirable to utilize the scarce water resource using an appropriate water saving technology. As a result, this study was conducted to develop optimum irrigation regime for onion production in the study area.

2. Materials and Methods
2.1 Description of the Study Area
The field experiment was conducted at farmers' field at Shele Mela kebele in Arba Minch zuria woreda, Ethiopia during January to April, 2017. 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.The area 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 ^{o}C with a mean annual maximum and minimum temperature of 37 ^{o}C and 16 ^{o}C, respectively. The mean annual rainfall is about 800 mm.

2.2 Description of the Experimental Materials
Onion variety called adama red, which was well adapted and widely cultivated in the study area was used as a test crop for the experiment. It has deep red colour, circular shaped bulb and its yield potential is 35t ha^{-1} Full irrigation (100%ETc) with 3 days irrigation interval was used as standard check.

2.3 Experimental Treatments

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. Each four levels of irrigation water were applied throughout the crop growth stages with respective irrigation intervals.

Table 1. Treatment combinations of the amount of irrigation water and irrigation intervals throughout the growing season of onion

Levels of irrigation amount	**Levels of irrigation interval.**		
	3 days	**5 days**	**7 days**
25% ETc			
50% ETc			
75% ETc			
100% ETc			

2.4 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, when they reached 12-15 cm height stage, to the main experimental plots on January 1, 2017 and one day before transplanting the seedlings were irrigated for safe uplifting. During transplanting only healthy, vigorous and uniform seedlings grown at the center of seedbeds were transplanted and gap filling was done within a week after transplanting.

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.

2.5 Crop Water Requirement

The crop evapotranspiration (ETc) was estimated using reference evapotranspiration (ETo). The reference evapotranspiration (ETo) was estimated using climatic data such as; maximum and minimum temperature; relative humidity; sunshine hours and wind speed at 75% probability data obtained from Arba Minch University Metrological Station for the period 1971 to 2015, according to FAO Penman-Monteith method through the CROPWAT program. Then, ETc of onion was obtained by multiplying ETo with crop coefficient (Kc). The crop coefficient values were adopted from the FAO (2010), and using FAO crop coefficients for onions (0.7 for initial, 1.05 for mid, and 0.75 for end season) as suggested by Allen *et al.* (1998).

$$\mathrm{ETc} = ETo * kc \quad (1)$$

where,
ETc = crop evapotranspiration (mm/day);
ETo = reference evapotranspiration (mm)
Kc = crop factor

$$\mathrm{NIR} = \mathrm{ETc} - \mathrm{Pe} \quad (2)$$

where:
NIR = net irrigation water requirement (mm)
ETc = crop water requirement (crop evapotranspiration) (mm)
Pe = effective rainfall (mm)

The effective rainfall was determined based on the following empirical formula using CROPWAT Model.

$$\mathrm{Pe} = \frac{(P*0.5-5)}{3} \quad \text{if} \quad \mathrm{P} < \frac{50}{3} \quad (3)$$

$$\mathrm{Pe} = \frac{(P*0.7+20)}{3} \quad \text{if} \quad \mathrm{P} > \frac{50}{3} \quad (4)$$

where:
P = precipitation (mm/month)

The gross irrigation requirement was computed by adopting a field application efficiency of 60%. Furrow irrigation application efficiencies normally vary from 45-60% (Bakker *et al.*, 1999). Brouwer and Prins (1989) also indicated 60% as irrigation application efficiency for furrow irrigation. In this experimental setup, water was applied with accurate measurement; furrows were short and end-diked. As a result, there was no run-off and the only loss would be deep percolation which was expected to be not much in a deficit irrigation practice. Therefore, a higher value of application efficiency (60%) was adopted.

$$\text{GIR} = \frac{NIR}{\varepsilon} \quad (5)$$

where
GIR = gross irrigation requirement;
NIR = net irrigation water requirement; and
ε= water application efficiency.

2.6 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. Flow rate is the function of height of water measured in the Parshal Flume at the entrance section. The relationship is conventionally presented in the form of PF table. The time required to deliver the desired depth of water into each plots using Parshal Flume was calculated from the following equation.

$$\text{t} = \frac{10*a*d}{q*60} minuts \quad (6)$$

where,
q = flow rate (l/s)
a = area of plot to be irrigated (m^2)
d = depth of water (cm)

2.7 Data Collection
Data on growth parameters:, plant height, leaf number and neck diameter were recorded at physiological maturity and expressed as average of ten randomly selected and pre-tagged plants in each experimental plots.
Total bulb yield ($kgha^{-1}$): total bulb yield was measured as the total weight of bulbs produced by all plants at central eight rows per plot. The total weights of the bulbs were measured using digital balance and it was converted into $kgha^{-1}$.

2.8 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
Results of the field experiment revealed that the interaction effect of irrigation levels and irrigation intervals on plant height, neck diameter and total bulb yield of onion plant were ($P<0.05$) significantly difference. However, leave number per plant of onion plant was highly ($P<0.01$) significantly difference.

3.1 Plant height
The longest plants (48 cm) were obtained from the treatment combination of 100% ETc with 3 days interval which was not significantly different with treatment combination of 100% ETc and 5 days irrigation interval. The shortest plants (27 cm) were recorded from the treatment combination of 25% ETc and 7 days irrigation interval is presented in Table 1.

The reason for the better performance of this growth parameter due to the shorter interval with higher level of irrigation may be attributed to optimum soil water- air- balance around plant root zone. The result of the current study is in agreement with the result of Bagali *et al*. (2012) reported that scheduling of drip irrigation onion at shorter interval with higher level of irrigation recorded significantly higher plant height. The finding of this study is also in line with the result of Metwally (2011) reported that the higher water supply resulted in higher plant height. This result is in contradicted to Enchalew *et al.* (2016) reported that plant height was not affected by the level of deficit irrigation.

3.2 Number of leaves per plant
The mean number of leaves per plant was highly significant ($P<0.01$) difference by irrigation levels and irrigation intervals, and their interaction. The highest number of leaves per plant (11) was obtained from the treatment combination of 100% ETc and 3 days irrigation interval which was statistically at par with treatment combination of 100% ETc and 5 days irrigation interval. The lowest number of leaves per plant (3.6) was recorded from the treatment combination of 25% ETc and 7 days irrigation interval (Table 1).

The increase in number of leaves per plant at higher irrigation level and shorter irrigation interval was obviously due to maintenance of soil moisture regime in the root zone closer to field capacity. When moisture in the root zone is closer to field capacity, the nutrient availability is high and the plant does not experience moisture stress at any stage of growth and development.

This finding is also in line with Youssef and Taha (2016) reported vegetative growth parameters of onion crop including plant height, number of leaves per plant were significantly decreased by increasing soil moisture stress. The result of the current study is in agreement with the result of Bagali et al. (2012) reported that scheduling of drip irrigation onion at shorter interval with higher level of irrigation recorded significantly higher number of leaves. This finding is also in line with Metwally (2011) and Enchalew (2016).

3.3 Neck diameter

The mean neck diameter was highly (P<0.01) significant difference by the effect of irrigation levels and irrigation intervals, and their interaction effect (P<0.05). Neck girth is one of the important growth parameters which indicate vigor of the plant. The highest neck diameter (2.5 cm) was obtained from the treatment combination of 100% ETc and 3 days irrigation interval which is statistically at par with treatment combination of 100% ETc and 5 days irrigation interval. The lowest mean neck diameter (1 cm) was recorded from the treatment combination of 25% ETc and 7 days irrigation interval (Table 1).

Increased neck diameter of onion by 3 days and 5 days interval with 100% ETc of irrigation may be due to the better performance of growth parameters like plant height and number of leaves. The result of the current study is in agreement with the result of Bagali *et al.* (2012) reported that scheduling of drip irrigation onion at shorter interval with higher level of irrigation recorded significantly highest neck diameter. The growth characteristics yield and yield components of onion generally improved with the increased in total water applied during growing period (Abdul Qados and Hozayn, 2010).

3.4 Total bulb yield

The mean total bulb yield was highly (P<0.01) significant difference on the irrigation levels and irrigation intervals, and significant (P<0.05) difference on their interaction effect. The highest total bulb yield (34000 kg ha^{-1}) was obtained from the combined application of 100% ETc and 3 days interval which was statistically at par with combined effect of 100% ETc and 5 days irrigation interval. The lowest value (6500 kgha^{-1}) was recorded from the treatment combination of 25% ETc and 7 days irrigation interval (Table 1).

The result of the current study is in agreement with the result of Rop *et al.* (2016) who reported that yield decreased with increasing water stress significantly. Also, Bagali *et al*. (2012) reported that scheduling of drip irrigation onion at shorter interval with higher level of irrigation recorded significantly higher bulb yield.

Table 1. Interaction effect of irrigation levels and irrigation intervals on Plant height (cm), leave number per plant, neck diameter (cm) and total bulb yield of onion

IL (%ETc)	II (days)	PH (cm)	LN	ND (cm)	TBY (kgha^{-1})
100	3	48^{a}	11^{a}	2.5^{a}	34000^{a}
	5	47.2^{a}	10.7^{a}	2.4^{a}	33000^{a}
	7	44^{b}	9.5^{b}	2.3^{b}	31200^{b}
75	3	41.7^{c}	8.4^{c}	2.1^{bc}	30500^{bc}
	5	40.9^{c}	8.1^{c}	2^{cd}	29700^{c}
	7	38^{d}	7.5^{d}	1.9^{de}	27400^{d}
50	3	37.3^{de}	6.4^{e}	1.75^{ef}	18100^{e}
	5	36^{e}	6^{e}	1.65^{f}	16700^{f}
	7	32^{f}	5^{f}	1.4^{g}	14200^{g}
25	3	29^{gh}	.4^{g}	1.2^{hi}	7500^{h}
	5	28^{g}	.4.3^{fg}	1.1^{h}	7600^{h}
	7	27^{h}	3.6^{h}	1^{i}	6500^{h}
Average		37.43	7.08	1.77	188.25
CV(%)		2.74	5.10	5.48	2.58
LSD (5%)		1.73	0.61	0.16	4.98

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, PH (cm)=plant height in centimeter, LN=number of leave per plant, ND (cm)= neck diameter in centimeter, TBY (kgha^{-1})=total bulb yield in kilogram per hectare, LSD (5%)=least significant difference at five percent probability, CV (%) = coefficient of variation in percent.

3.5 Yield Reduction, Water Saved, Calculated Yield and Extra Land from Saved Water

The highest total bulb yield 34000 kgha^{-1} was obtained under treatment combination of 100% ETc and 3 days interval which was statistically non significantly different with treatment combination of 100% ETc and 5 days interval. The treatment combination of 75% ETc and 3 days irrigation interval consumed 25% less water as compared to treatment combination of 100% ETc and 3 days irrigation interval ; this leads 10.3% (3500 $kgha^{-1}$) yield reduction. If the saved water is used to produce onion at the same irrigation regime, it will produce bulb yield 9417 $kgha^{-1}$ this exceeds the loss of onion bulbs occurred due to deficit irrigation by 5917 $kgha^{-1}$. There were non significant different between treatment combination of 75% ETc with 3 days and 75% ETc with 5 days interval. In addition to that equal amount of water was saved. This implies that it can bring the same area of land in to production.

Table 2 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)	Applied water (m^3ha^{-1})	TBY ($kgha^{-1}$)	Yield reduction (%)	Saved water (mm)	Calculated Yield from Saved water ($kgha^{-1}$)	Extra land irrigated from saved water (ha)
100	**3**	**6570**	**34000**	**0**	**0**	**0**	**0**
	5	**6570**	**33000**	**2.9**	**0**	**0**	**0**
	7	**6570**	**31200**	**8.2**	**0**	**0**	**0**
75	**3**	**5020**	**30500**	**10.3**	**155**	**9417**	**0.31**
	5	**5020**	**29700**	**12.7**	**155**	**9170**	**0.31**
	7	**5020**	**27400**	**19.4**	**155**	**8460**	**0.31**
50	**3**	**3470**	**18100**	**46.8**	**310**	**16170**	**0.89**
	5	**3470**	**16700**	**50.9**	**310**	**14919**	**0.89**
	7	**3470**	**14200**	**58.2**	**310**	**12686**	**0.89**
25	**3**	**1920**	**7500**	**77.9**	**465**	**18164**	**2.4**
	5	**1920**	**7600**	**77.7**	**465**	**18406**	**2.4**
	7	**1920**	**6500**	**80.9**	**465**	**15742**	**2.4**

3 Conclusions

75% ET at 5 days interval can be an option in the study area when water was limiting factor. However, application of 100% ETc at 5 days interval was economically productive when adopted by onion farmers in the study area when water was non limiting factor.

Reference

Abdul Qados, Amira M. S. & M. Hozayn. (2010). Magnetized Water Technology, A Novel Toolto Increase Growth, Yield, and Chemical Constituents of Lentil (*Lens Esculenta*) Under Green House Condition American-Eurazian. *Journal of Agricultural and Environmental Science*, 7(4): 457-462.

Allen, R.G., Pereira,L.S., Raes, D. & Smith, M. (1998). Crop Evapotranspiration Guidelines for Calculating Crop Water Requirements. FAO Irrigation And Drainage Paper 56.FAO, Rome, Italy

Andarzian, B., Bannayan, M., Steduto, P., Mazraeh, H., Barati, M. E., Barati, M. A. & Andrahnama, A.(2011). Validation and Testing of The Aqua Crop Model Under Full and Deficit Irrigated Wheat Production In Iran. *Agricultural Water Management, 100*: 1-8. Http://Dx.Doi.Org/10.1016/J.Agwat.2011.08.023

Bagali, A.N., Patil, H.B., Guled, M.B. & Patil, R.V. (2012). Effect of Scheduling of Drip Irrigation on Growth, Yield and Water Use Efficiency of Onion (Allium Cepa L.).Karnataka. *Journal of Agricultural Science,* 25(1) :116-119.

Bakker, M., Raine, R., & Robertson, M. (1999). A Preliminary Investigation of Alternate Furrow Irrigation for Sugarcane Production. [Online] Http://Www.Usq.Edu.Au/Users/Raine/Index Fiels/ASSCT /Pdf. [Accessed On 24,May,2009].

Brouwer, C & Prins K. (1989). Irrigation Water Management: Irrigation Scheduling. Training Manual No. 4. Food and Agricultural Organization Of The United Nation, Rome, Itally.

Carr, M.K.V. & Knox, J.W. (2011). The Water Relations and Irrigation Requirements of Sugarcane (*Saccharum Officinarum*). A *Review. Experimental Agriculture*, 47(1): 27-51

David, K. Rop, Emmanue,C., Kipkorir & John, K. Taragon. (2016). Effects of Deficit Irrigation on Yield and Quality of Onion Crop. Canadian Center of Science and Education. *Journal of Agricultural Science*;. 8(3); 2016

Enchalew, B., Gebre, S.L., Rabo M, Hindaye B, & Kedir M. (2016). Effect of Deficit Irrigation on Water Productivity of Onion (*Allium Cepa*l.) Under Drip Irrigation. *Irrigation Drainage System Engineer,* 5: 172. Doi: 10.4172/2168-9768.1000172.

Lemma, D. & Shimelis, A. (2003). Research Experience In Onion Production. Research Report Number 55. EARO, Addis Ababa, Ethiopia.

Metwall, A.K. (2011). Effect of Water Supply on Vegetative Growth and Yield Characteristics in Onion(*Allium Cepa L.*). *Australian Journal of Basic and Applied Sciences*, 5(12): 3016-3023.

Nigussie A, Kuma Y, Adisu A, Alemu T & Desalegn K. (2015). Onion Production for Income Generation in Small Scale Irrigation Users Agro-Pastoral House Holed of Ethiopia. *Journal of Horticulture, 2:145.*

Sammis, T., Sharma, P., Shukla, M.K., Wang, J. & Miller, D. (2012). Water-Balance Drip-Irrigation Scheduling Model. *.Agricultural Water Management,* 113:30–37.