Research Article
Volume 11:6, 2022

Irrigation and Drainage Systems Engineering

ISSN: 2168-9768 Open Access

Response of Onion to Furrow Irrigation Methods under Different Deficit Irrigation Levels at Ziway Dugda District, Arsi Zone, Ethiopia

Samuel Lindi*, Bakasho Iticha and Mehiret Hone

Department of Irrigation and Water Harvesting, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

Abstract

This study was conducted to determine the response of onion to furrow irrigation method under different deficit irrigation levels on yield and water productivity. The experiment was laid out in RCBD with three replications. The treatments comprised alternate, fixed, and conventional furrow irrigation methods and 50%, 75%, and 100 % of Etc deficit irrigation levels. Onion bulb yield showed that, CFI method of 100% ETc had a significant difference over other treatments except the treatment receiving CFI 50% and 75% ETc. Maximum bulb yield of 18,022 kg/ha recorded from CFI receiving 100% of ETc and the minimum yield of 12,571 kg/ha was obtained from FFI 50% of ETc. The water productivity result showed that the maximum water productivity of 7.40 kg/m^3 was recorded from treatment receiving 50% ETc AFI method and the minimum value of 2.38 kg/m^3 was recorded from full irrigation (100% ETc CFI). Considering yield response (K_y) is a limiting factor, 50% ETc AFI treatment saves about 75% of irrigation water and has a yield penalty of 22.73% when compared with 100% ETc CFI. In conclusion, the association between 100% ETc and AFI method gave optimum bulb yield and water productivity and tolerable yield limit of 13.26%.

Keywords: Deficit irrigation • Furrow irrigation method • Water productivity • Onion

Introduction

Food production requires increasing to feed the growing world population [1]. This increase needs to be accomplished under a changing climate, so water shortages might increasingly materialize [2]. With the growing water shortage in developing countries, enhancing agricultural water management strategies is of paramount importance to reduce food insecurity [3]. In many developing countries like Ethiopia, water application intervals are mutually agreed upon and fixed among growers [4]. However, this method does not consider how and when to apply.

Deficit irrigation is needed where essential resources such as water, capital, energy, and labor are limited. Under deficit irrigation, crops are deliberately allowed to sustain some water deficit and yield reduction. The irrigator aims to increase Water Use Efficiency (WUE) by reducing the amount of water at irrigation or by reducing the number of irrigation [5]. The growth and yield of any crop are related to the amount of water used.

Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield [6]. In this method, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction (especially in water limiting situations) will be compensated by increased production from the additional irrigated area with the water saved by deficit irrigation [7].

Onion (*Allium cepa L.*) is considered as one of the most important and major irrigated vegetable crops produced on a large scale in Ethiopia. It is usually cultivated in the dry season from September to March in which there is typically little precipitation food and agricultural organization [8]. It is very responsive to the amount of irrigation water applied: good bulb yield when irrigation is sufficient and low bulb yield when not [9].

Onion (*Allium cepa L.*) is one of the most important horticultural crops worldwide. Many studies have been carried out regarding its water requirements and the effects of DI on yield [10-12]. Onion crop was found to be sensitive to water deficit during the whole growing season, and, therefore, it is better to partition the available water for the whole growing season to maintain moderate stress (regulated deficit irrigation, RDI) rather than creating a stress during the critical stages of plant growth [13,14]. For instance, Tsegaye, et al. found that DI given at 75% of ETc was economically recommended in his studied region, in southern Ethiopia.

***Address to Correspondence:** Samuel Lindi, Department of Irrigation and Water Harvesting, Ethiopian Institute of Agricultural Research, Addis Ababa ,Ethiopia, Tel: 913983305; E-mail: samuellindi5@gmail.com*

Received: 17 April, 2022, Manuscript No. IDSE-22-61073; **Editor assigned:** 20 April, 2022, Pre QC No. IDSE-22-61073 (PQ); **Reviewed:** 05 May, 2022, QC No. IDSE-22-61073; **Revised:** 17 June, 2022, Manuscript No. IDSE-22-61073 (R); **Published:** 27 June, 2022, DOI: 10.37421/2168-9768.2022.11.330

The majority of onion production is found in the Central Rift Valley (CRV) of Ethiopia; however, rainfall is unreliable and insufficient to support onion production that makes irrigation an indispensable practice. The rift valley area is a semiarid with limited water resources and increasing demand for water combined with high evapotranspiration rates limits the production and productivity of the crop. Hence, alternatives need to be explored for effective and efficient use of the existing water resources.

An important adaptation of furrow irrigation is Alternate Furrow Irrigation (AFI) in which furrows are irrigated alternately rather than consecutively during irrigation water application. This is a form of Partial Root-zone Drying (PRD) system which has been found to increase the production of various vegetables in the ASAL areas as well as saving irrigation water. Furthermore, studies have shown that water deficit occurs during certain stages of the growing season improves fruit quality, although water limitations may determine fruit yield losses [15-17]. Therefore, the objectives of this study were to determine the response of onion to furrow irrigation method under different deficit irrigation levels which can allow to achieving optimum onion yield and water productivity.

Materials and Methods

Description of the study area

The study was conducted in Shelled PA, Ziway Dugda district, Arsi Zone of Oromia Regional State, Ethiopia. Ziway Dugda is 180 km far from Addis Ababa capital city of Ethiopia. The study is geographically located at latitude of 08˚02'19" and longitude of 39˚00'59" and situated in an average elevation of 1700 m a.s.l.

The study area is characterized by semiarid environment with mean monthly maximum and minimum temperature of 26.3˚C and 12.3˚C, respectively. The area has unmoral low and erratic rainfall pattern with average annual rainfall of 689 mm. Soil type of the experimental site is classified as silt clay texture and has field capacity, permanent wilting point and total available water and bulk density of 31%, 15%, 16% and 1.25 g/cm, respectively.

Field experimental layout and design

The study was carried out in RCBD with three replications. Bombay red onion variety was us as experimental crop and plant to field plots having a dimension of 4.0 x 5.0 m and furrow spacing of 0.5 m apart. Onion was planted on both side of a ridge in row and plant spacing of 0.3 and 0.07 m, respectively.

Nine treatments of different deficit irrigation level were factorially combined and randomized in plots as described below in Table 1.

Treatment	Treatment combinations
T_1	Alternative Furrow (AF) irrigated at 100% ETc
T_2	Alternative Furrow (AF) irrigated at 75% ETc
T_3	Alternative Furrow (AF) irrigated at 50% ETc
T_4	Fixed Furrow (FF) irrigated at 100% ETc
T_5	Fixed Furrow (FF) irrigated at 75% ETc
T_6	Fixed Furrow (FF) irrigated at 50% ETc
T_7	Conventional Furrow (CF) irrigated at 100% ETc
T_8	Conventional Furrow (CF) irrigated at 75% ETc
T_9	Conventional Furrow(CF) irrigated at 50% ETc

Table 1. Combination of the experimental treatments.

All experimental plots were irrigated with uniform amount of water before planting to make the soil workable during planting. To ensure the plant establishment common irrigations was provided to all plots at two days interval before commencement of the differential irrigation. Irrigation water was applied at allowable soil moisture depletion (p=0.25) of the total available soil moisture throughout crops growth stage. All experimental plots were fertilized with recommended fertilizer rate of Nitrogen and P_2O_5 150 kg/ha and 112 kg/ha, respectively. Phosphorus fertilizer was applied to all plots as basal dose at planting, while split application was conducted for nitrogen fertilizer. Measured depths of irrigation water were delivered to each plot according to the treatment arrangements and irrigation schedule through a water measuring device, namely two inch parshall flume, which was installed 3 m far away from the experimental plots.

Crop Water Requirement (CWR) for the CFI method 100%ETc was calculated using CropWat version 8.0 software and soil moisture was monitored by gravimetric method. Based on the calculated CWR, Irrigation water was applied according to the treatment percentage and the method of furrow irrigation. FFI and AFI treatments were received half of conventional furrow irrigation method. Soil samples before and after irrigation was taken from control treatment plots to check soil moisture content before and after irrigation at field capacity and below allowable moisture depletion level.

Data collection and statistical analysis

Bulb and biological yield data were measured using digital weighing balance. Bulb diameter was measured by caliper. These data were subjected to ANOVA analysis.

Water productivity and yield response factor

Water productivity and effect of water stress on crop performance were quantified by equation 1 and 2, respectively. Estimation of water productivity was carried out as a ratio of total bulb yield to the total water applied as follows:

Water productivity (kg/m^3)=Total Bulk Yield (kg)/Crop Water Use (m^3) Equation (1)

The yield response factor (K_y) was estimated from the relationship.

$$\text{Yield response factor (Ky)} = \left[1-\left(\frac{Y_a}{Y_m}\right)\right] = K_y\left[1-\left(\frac{ET_a}{ET_m}\right)\right] \qquad \text{Equation (2)}$$

Where, Y_a=Actual harvested yield

Y_m=Maximum harvested yield

K_y=Yield response factor

ET_a=Actual evapotranspiration

ET_m=Maximum evapotranspiration

The K_y values are crop specific and vary over the growing season according to growth stages with:

K_y>1: crop response is very sensitive to water deficit with proportional larger yield reductions when water use is reduced because of stress.

K_y<1 the crop is more tolerant to water deficit and recovers partially from stress exhibiting less than proportional reductions in yield with reduced water use.

K_y=1: yield reduction is directly proportional to reduced water use.

Statistical data analysis

The collected data were subjected to analysis of variance using the Statistical Analysis System (SAS) software version 9.0 with the General Linear Model (GLM) procedure. Mean separation was employed using the Least Significant Difference (LSD) at 5% probability level to compare the differences among the treatments means.

Results and Discussion

The statistical analysis of variance showed that a highly significant (P<0.01) differences were received by above ground biological yield, bulb yield and water productivity. However, bulb diameter of the onion was not significantly affected by deficit irrigation and furrow methods at (p<0.05) level. The data on Tables 2 and 3 provide analysis of variation for bulb diameter, above ground biological yield, bulb yield and water productivity [18].

Acquisition of yield and yield component of onion

Above ground biological yield of onion: The result showed that above ground biological yield of onion was significantly affected at p<0.01 level. The highest 4816 kg/ha of above ground biological yield was recorded from the control treatment and this treatment was significantly difference from other treatment except the treatment receiving CFI method of 75% ETc. The lowest above ground biological yield of 2210 kg/ha were obtained from treatment receiving AFI method of 50% ETc (Table 2) [19]. Statistically there were no significant difference among treatments receiving AFI of 100% and 75% ETc and FFI methods of 100%, 75% and 50% of ETc at p<0.05 level [20].

Yemane M, et al. also reported that the furrow irrigation techniques were significantly different from each other in number of leaf per plant. Significantly higher number of leaf per plant was recorded with conventional furrow irrigation technique followed by AFI and FFI. There were no significance difference between AFI and FFI of irrigation. Similarly, Biswas, et al. also reported that onion bulbs of irrigated treatments gave highest leaves number per plant than the non-irrigated one, whereas onion grown without supplemental irrigation gave lower number of leaves. This indicated that when plants respond to water stress by closing their stomata to slow down water loss by transpiration, gas exchange within the leaf is limited, consequently, photosynthesis and growth was slow down. The obtained result was also in agreement with the findings of Wien who recorded that leaf number had a linear correlation with the availability of soil moisture [21-24].

Onion bulb diameter: The result of the study show that onion bulb diameter was not affected by deficit irrigation water application at (P<0.05). The highest bulb diameter of 5.55 cm was recorded from the control treatment CFI method of 100% ETc and the least bulb diameter of 5.32 cm was recorded by FFI method receiving 100% ETc (Table 2). The recent study of Yemane M. et al, 2018, confirmed that, the analysis of variance revealed that the interaction effect of furrow irrigation techniques and irrigation level showed no significant difference (P<0.05) [25]. The least bulb diameter was recorded for fixed furrow irrigation and the largest onion bulbs were recorded for 100%ETc (full irrigation) amount of irrigation water applied. The result might be because of the reason that high irrigation levels increased photosynthetic area of the plant (height of plants and number of leaves), which increased the amount of assimilate partitioned to the bulbs and increased bulb diameter. This result is closely related to that of Kumar, et al. who observed that bulb size decreased with the decrease of irrigation amount. In the same way, Al-Harbi and Biswas, et al. indicated that bulb diameter of onions were increased at higher levels of irrigation [26,27].

Marketable onion bulb yield: The statistical analysis of variance revealed that, deficit irrigation water applications affected the bulb yield of onion. The control treatment CFI 100% ETc was significantly different from all treatments except treatment receiving CFI 75% and 50% ETc and 100% Etc AFI at p<0.05. The highest bulb yield of 18,055 kg/ha was recorded by treatment receiving CFI of 100% ETc and the lowest 12,571 kg/ha was obtained from treatment receiving FFI of 50% ETc (Table 2). The previous study by confirmed that the highest marketable bulb yield was recorded from the control treatment of 100% ETc. The least bulb yield was attained from treatment receiving FFI 50% ETc, which was significantly different from other deficit irrigation levels and furrow methods at p<0.05 [28-30]. Yemane M, et al. reported that CFI showed significantly higher yield at 100% of irrigation level. It showed that conventional furrow irrigation system gave more yield with irrigation water amount of 100%. Among the irrigation furrow treatments, conventional furrow irrigation produced the highest bulb yield, alternate furrow irrigation system, while fixed furrow irrigation system gave the lowest bulb yield. Furthermore FFI and AFI all showed a substantial decrease in bulb yield. Bakker, et al. a study done by Al-Moshileh A, also presented similar findings with this result [31-33].

Water productivity of onion: The water productivity of furrow irrigation techniques and deficit irrigation levels were highly influence bulb yield of onion at (P<0.001). AFI method receiving 50% ETc was significantly different from other treatments except treatment receiving FFI of 50% ETc. The highest WP (7.40 kg/m^3) was obtained by AFI at 50% ETc and the lowest WP of 2.38 kg/m^3 was received at CFI of 100% ETc (control). This treatment was saved irrigation water of 572.25 mm of 75% when compared with control treatment CF of 100% ETc (Table 3). This result also indicated that deficit irrigation enhances water productivity of onion crop. Even if application of AFI 50% ETc saved irrigation water of 75%, this treatment results 22% yield penalty. AFI of 100% ETc method recorded yield reduction of 13.26%, this result is tolerable when compared with control treatment which had optimum water productivity of 4.13 kg/m^3. This result is in line with a statement given by the decrease in yield is proportionally greater with increase in water deficit. Yemane M, et al. reported that the highest value of WUE was recorded on alternate furrow irrigation technique with compared to CFI [34]. In alternate furrow irrigation technique, higher value of 7.9% of WUE was obtained as compared to that of FFI and 26% of conventional furrow irrigation technique. Mulugeta M and Kannan N, indicated that the reason of having high WUE and lower reduction of yield for AFI could be related to better distribution of the roots in both sides of the ridges it increases water and fertilizer up take by plants and the physiological response of the crop specifically in the root and leaf parts [35]. Mansouri-Far, et al. reported that irrigation water can be conserved and yields maintained (as sensitive crop to drought stress) under water limited conditions [36,37].

TRT	Treatments	Bulb diameter (cm)	Biological yield (kg/ha)**	Bulb yield (kg/ha)**	Water productivity (kg/m^3)**
T_1	AF 100%ETc	5.41	2,294^c	15,633^{abc}	4.13^{bc}
T_2	AF 75%ETc	5.41	2,535b^c	14,511^{cd}	5.14^b
T_3	AF 50%ETc	5.4	2,210^c	13,926^{cd}	7.40^a
T_4	FF 100%ETc	5.32	2,646^c	13,566^{cd}	3.60^c
T_5	FF 75 ETc%	5.54	2,314^c	14,831^{bcd}	5.20^b
T_6	FF 50%ETc	5.47	2,345^c	12,571^d	6.69^a
T_7	CF 100%ETc	5.55	4,816^a	18,022^a	2.38^d
T_8	CF 75%ETC	5.54	4,468^a	17,341^{ab}	3.04^{cd}
T_9	CF 50%ETc	5.37	3,078^b	15,568^{abc}	4.10^{cb}
Mean		5.45	2,901.00	15,107.67	4.63
CV (%)		4.66	19.6	16.12	21.66
LSD 0.05		Ns	663	2,712.90	1.17

Table 2. Analysis of variation of onion yield and yield components.

Yield response factor (K_y): Observed yield response factors (K_y) for onion bulb production ranged between 0.49 and 0.15, the lowest and highest being for CFI 75% ETc and FFI 100% ETc applications, respectively (Table 3). The higher K_y values indicate that the crop will have a greater yield loss when the crop water requirements are not meet. Generally, K_y value less than unit indicates more tolerant to water deficit and recovers partially from stress exhibiting less than proportional reductions in yield with reduced water use [38].

TRT	Treatments	Water applied (mm)	Bulb yield (kg/ha)	Water saved (%)	Yield reduction (%)	Crop response factor (K_y)
T_1	AF 100%ETc	381	15,633	50	13.26	0.33
T_2	AF 75%ETc	286	14,511	62	19.48	0.31
T_3	AF 50%ETc	190	13,926	75	22.73	0.3
T_4	FF 100%ETc	381	13,566	50	24.73	0.49
T_5	FF 75 ETc%	286	14,831	62	17.71	0.28

T_6	FF 50%ETc	190	12,571	75	30.25	0.4
T_7	CF 100%ETc	763	18,022	-	-	-
T_8	CF 75%ETC	572	17,341	25	3.78	0.15
T_9	CF 50%ETc	381	15,568	50	13.62	0.21

Table 3. Applied water, WP, water saved, yield reduction and crop response factor data.

Conclusion

Water scarcity is an increasingly important issue in many parts of the world. Climate change, a rapid population growth and increasing consumption of water per capita aggravated this problem. Therefore efficient use of water is a key factor for irrigation water management globally, with wide spread efforts being made to increase water productivity and reduce the environmental impacts of irrigation. Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield.

This study was, therefore, conducted with the aim of evaluating two different ways of deficit irrigation application on bulb yield and water productivity of onion yield, thereby to select best water saving strategy without adverse effect on yield of onion crop.

The over years analysis of data result showed that AFI was best water saving irrigation method that can be suited for onion production without a significant bulb yield loss with a maximum water productivity. Implementation of AFI 100% ETc will lead to 50% more water being available to irrigate more land without a significant effect on bulb yield of onion with greater values of water use efficiency.

Therefore, the experimental finding shows that application of alternate furrow irrigation is best water saving technology as compared to conventional furrow irrigation system. This study revealed that alternate furrow deficit irrigation with 100% ETc is recommended in the study area for optimum onion yield production and water productivity.

Acknowledgments

The authors are grateful to Ethiopian Institute of Agricultural Research, for providing funds to conduct the experiment. The authors are also very grateful to Kulumsa Agricultural Research Center for the provision of logistics during the conduct of the experiment. We are also greatly indebted to all of staff members of natural resources management research process for the provision of technical support, suggestion and guidance thorough the execution of the experiment.

References

1. Al-Harbi AR. Effect of irrigation regimes on growth and yield of onion (*Allium cepa L.*). *J King Satui Univ* 15. 2002.
2. Ali MH, Hoque MR, Hassan AA and Khair A, et al. Effect of deficit irrigations on yield, water productivity, and economic return of wheat. *Agric Water Manag* 92 (2007): 151–161.
3. Al-Moshileh A. Effects of planting date and irrigation water level on onion *(Allium cepa L.)* production under central and Saudi Arabian conditions. *J Basic Appl Sci* 8 (2007): 14-28.
4. Anbese A, Seyoum T and Hordofa T. Effect of irrigation methods and irrigation levels on yield and water productivity of onion at Awash Melkasa, Ethiopia. *Octa J Environ Res* 8 (2020): 004–016.
5. Bakker DM, Raine SR and Robertson MJ. A preliminary investigation of alternate furrow irrigation for sugar cane production. Australian Society of Sugar Cane Technologists, Queensland, Brisbone. 1997.
6. Biswas SK, Sarker PK, Islam AM and Bhuiyan MA, et al. Effect of irrigation on onion production. *Pak J Biol Sci* 6 (2003): 1725-1728.
7. Currah L and Proctor FJ. Onion in Tropical Regions. Natural Resources institute. Chatham Maritime, Kent, UK. 1990. 232.
8. Doornebos J and Kassam AH. Yield response to water. FAO Irrigation and Drainage, Rome, Italy. 1979. 33.
9. Enchalew B, Gebre SL, Rabo M and Hindaye B, et al. Effect of Deficit Irrigation on Water Productivity of Onion (*Allium cepal.) under Drip Irrigation. Irrigat Drainage Sys Eng* 5 (2016): 172.
10. Food and Agricultural Organization (FAO). State of food and agriculture: Climate change. Agriculture and Food Security. 6-9 October 2022, Bosnia and Herzegovina. Balkans. 2016.
11. Faramarzi M, Yang H, Schulin R and Abbaspour KC, et al. Modeling wheat yield and crop water productivity in Iran: implications of agricultural water management for wheat production. *Agric Water Manage* 97 (2010): 1861–1875.
12. Fereres E and Soriano MA. Deficit irrigation for reducing agriculture water use. *J Exp Bot* 58 (2007): 147-159.
13. Gebregwergis F, Weldetsadik K and Alemayhu Y. Effect of irrigation depth and nitrogen levels on growth and bulb yield of onion (*Allium cepa L.)* at alage, Central Rift valley of Ethiopia. *Int J Res Irrig Eng Water Managet* 5 (2016): 152-162.
14. Huffaker R and Hamilton J. Conflict. Irrigation of Agricultural Crops (2nd edition). Agronomy Monograph, ASA-CSSA-SSSA publishing. Wisconsin, USA. 2007.
15. Igbadun HE, Ramalan AA and Oiganji E. Effects of regulated deficit irrigation and mulch on yield, water use and crop water productivity of onion in Samaru, Nigeria. *Agric Water Manage* 109 (2012): 162–169.
16. Jones HG. Irrigation scheduling; advantages and pitfalls of plant based methods. *J Exp Bot* 55 (2004): 2427-2436.
17. Kadayifci A, Tuylu Gİ, Ucar Y, Cakmak B, et al. Crop water use of onion (*Allium cepa L.) in Turkey. Agric Water Manage* 72 (2005): 59-68.
18. Kang SZ, Liang WH and Zhang J. Water use efficiency of controlled root division alternate irrigation on maize plants. *Agric Water Manage* 38 (1998): 69-76.
19. Kang SZ and Zhang JH. Controlled alternate partial root-zone irrigation: its physiological consequences and impact on water use efficiency. *J Exp Bot* 55 (2004): 2437-2446.
20. Kang SZ, Liang YP and Zhang J. Alternate furrow irrigation for maize production in an arid area. *Agric Water Manage* 45 (2006): 267-274.
21. Kumar S, Imtiyaz M, Kumar A and Singh R, et al. Response of onion (*Allium cepa L.)* to different levels of irrigation water. *Agric Water Manage* 88 (2007): 161-166.
22. Lascano RJ and Sojka RE. Irrigation of agricultural crops (2nd edition). Agronomy Monograph no. 30. ASA-CSSA-SSSA publishing, Wisconsin, USA. 2007. 664.

23. Mansouri-Far C, Sanavy SA and Saberali SF. Maize yield response to deficit irrigation during low-sensitive growth stages and nitrogen rate under semi-arid conditions. *Agric Water Manage* 97 (2010): 12-22.
24. Mermoud A, Tamini TD and Yacouba H. "Impacts of different irrigation schedules on the water balance components of an onion crop in a semi-arid zone," *Agric Water Manag* 77 (2005): 282–293.
25. Mulugeta M and Kannan N. Effect of Deficit Irrigation on Maize under Conventional, Fixed, and Alternate Furrow Irrigation Systems at Melkassa, Ethiopia. *Int J Eng Res Technol* 4 (2015): 119-126.
26. Nikolaou G, Neocleous D, Christou A and Kitta E, et al. Implementing sustainable irrigation in water-scarceregions under the impact of climate change. *Agronomy* 10 (2020):1120.
27. Patane C and Cosentino SL. Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. *Agric Water Manage* 97 (2010): 131-138.
28. Patel Nab and Rajput TBS. Effect of deficit irrigation on crop growth, yield and quality of onion in subsurface drip irrigation. *Int J Plant Prod* 7 (2013): 417–435.
29. Rosegrant MW, Cai X and Cline SA. World water and food to 2025: Dealing with scarcity. International Food Policy Research Institute, Washington DC, USA. 2002. 322.
30. Sarkar S, Goswami SB, Mallick S and Nanda MK, et al. Different indices to characterize water use pattern of micro-sprinkler irrigated onion (*Allium cepa L.)*. *J Agric Water Manage* 95 (2008): 625-632.
31. Scheierling SM and Treguer DO. Water productivity in agriculture: looking for water in the agricultural productivity and efficiency literature. *Water Econ Policy* 2 (2016):1650007.
32. Shock CC, Feibert EBG and Saunders LD. Irrigation criteria for drip-irrigated onions. *HortScience* 35 (2000):63-66.
33. Sleper DA, Fales SL and Collins ME. Irrigation of agricultural crops (2ndedition). Agronomy Monograph no. 30. ASA-CSSA-SSSA publishing, America. 2007. 664.
34. Tsegaye B, Bizuayehu T, Woldemichael A and Mohammed A, et al. Yield and yield components of onion (*Allium cepa L.)* as affected by irrigation scheduling and nitrogen fertilization at Hawassa area districts in Southern Ethiopia. *Int J Agric Sci Food Technol* 2 (2016): 15–20.
35. Yemane, Mebrahtu, Abraham Woldemichael and Solomon Habtu. Response of onion (*Allium cepa l.)* to deficit irrigation under different furrow irrigation water management techniques in Raya Valley, Northern Ethiopia. *Afr J Plant Sci* 12 (2018): 105-113.
36. Wien H. Physiology of vegetable crops. In: J.L. Brewster (Ed.). Onions and Garlic, Cambridge University Press, New York. 1997. 581-612.
37. Zhang Y, Kendy E, Qiang Y and Changming L, et al. Effect of soil water deficit on evapotranspiration, crop yield, and water use efficiency in the North China Plain. *Agric Water Manag* 64 (2004): 107-122.

How to cite this article: Lindi, Samuel, Bakasho Iticha and Mehiret Hone. "Response of Onion to Furrow Irrigation Methods under Different Deficit Irrigation Levels at Ziway Dugda District, Arsi Zone, Ethiopia." *Irrigat Drainage Sys Eng* 11 (2022): 330