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Effect of Furrow Irrigation Techniques and Deficit Irrigation Levels on Yield and Water Productivity of Onion (*Allium cepa l.*) at Werer, Middle Awash Valley, Ethiopia

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Abstract: Deficit irrigation is one of the techniques used to enhance water productivity without significant yield loss in semiarid areas. A field experiment was conducted at Werer, Middle Awash Valley during the dry season of the 2017/18, 2018/19 and 2019/20 for three consecutive years to investigate the effects of deficit irrigation levels and furrow irrigation methods on onion yield and water productivity. Split plot design with three replications, in which the irrigation methods (Conventional, Fixed and Alternate Furrow) were assigned to the main plot and the three deficit levels (100% ETc, 75% ETc and 50% ETc), were in the sub-plot. Results indicate that marketable onion bulb yield and water productivity were highly affected by the interaction effect of furrow irrigation methods and irrigation levels ($p<0.05$). The highest bulb yield (17580.43 kg ha^{-}) and water productivity (11.79 kg/m^3) were obtained from conventional furrow irrigation method with100% ETc and alternate furrow irrigation with 50% ETc respectively. Considering water saved and maximum yield, Onion irrigated by AFI 100% ETC resulted in 15% yield reduction with up to 50% irrigation water saving as compared to CFI 100% ETc. The present study suggests that, under water limiting conditions, adopting alternate furrow irrigation with 100% ETc can be an alternative to increase water productivity without significant yield reduction.

Keywords: Semiarid, Deficit Irrigation Level, Alternate Furrow, Onion, Water Productivity

1. Introduction

Water scarcity has received global attention in the last decade as it challenges food security in arid and semi-arid regions [9]. In the semi-arid areas of Ethiopia, water is the most limiting factor for crop production. This water shortage has motivated some researchers and farmers to find ways to produce a crop with less irrigation water and changing from fully-irrigated to the deficit irrigated cropping system [3]. So one of the tools to overcome this phenomenon is the enhancing of water productivity, it is also called water productivity [8]. Increasing water productivity will not only increase agriculture production, but will also save the water for other purposes. Regulated deficit irrigation is one way of maximizing water productivity [10]. Different works have been done on onion moisture deficit based on decreasing the depth of irrigation water. However, much work has not been done to determine the effect of deficit irrigation strategy like partial root-zone drying in combination with decreasing depth of irrigation amount in the study area. Therefore, considering the high competition among irrigation water users and the scarcity of irrigation water in the area, this research was conducted to identify furrow irrigation methods and level of deficit irrigation that enhance water productivity without significant yield loss.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted during the cool cropping season of 2017/2018, 2018/2019 and 2019/2020 at Werer Agricultural Research located at 09°13 ′– 09°50 ′ N and 40°05 ′– 40°25 ′E with an altitude of 750 m above mean sea level. The soil in the experimental field was classified in clay textural class (Table 1). The average basic infiltration rate of the experimental site was 5 mm/hr. The local climate is semi-arid with an average annual rainfall of 589 mm, of its distribution is weak bi-modal received small rains from March to April and main rains from July to September (Figure 2). The mean monthly minimum temperature is 15°C in December, whereas the mean monthly maximum temperature is 38.4°C in June. According to long term climatic data the area is semiarid; with monthly evapotranspiration is greater than monthly rainfall (Figure 2). This indicates irrigation is the paramount importance to sustain crop production in the area.

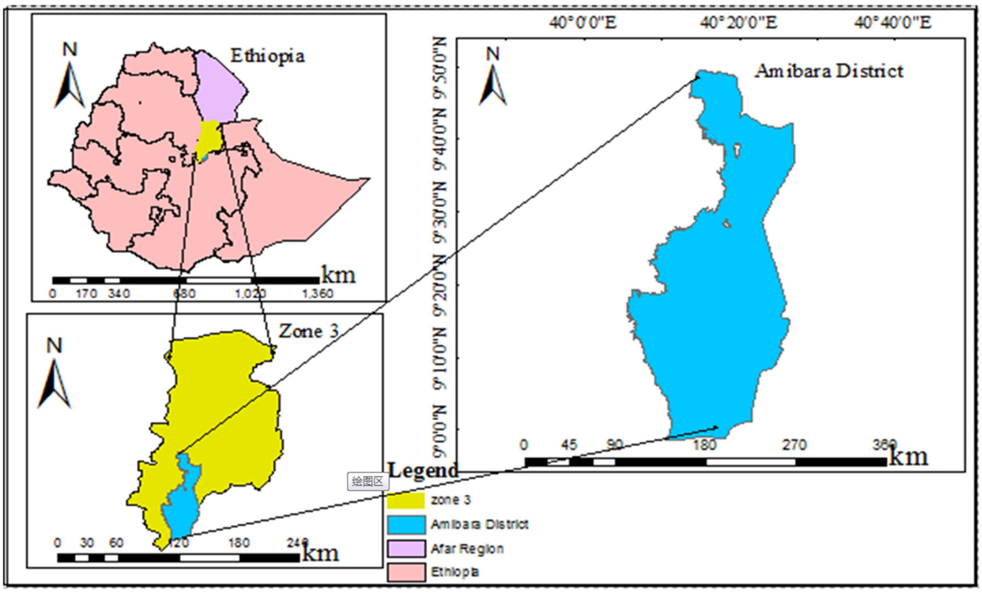

Figure 1. Map of study area.

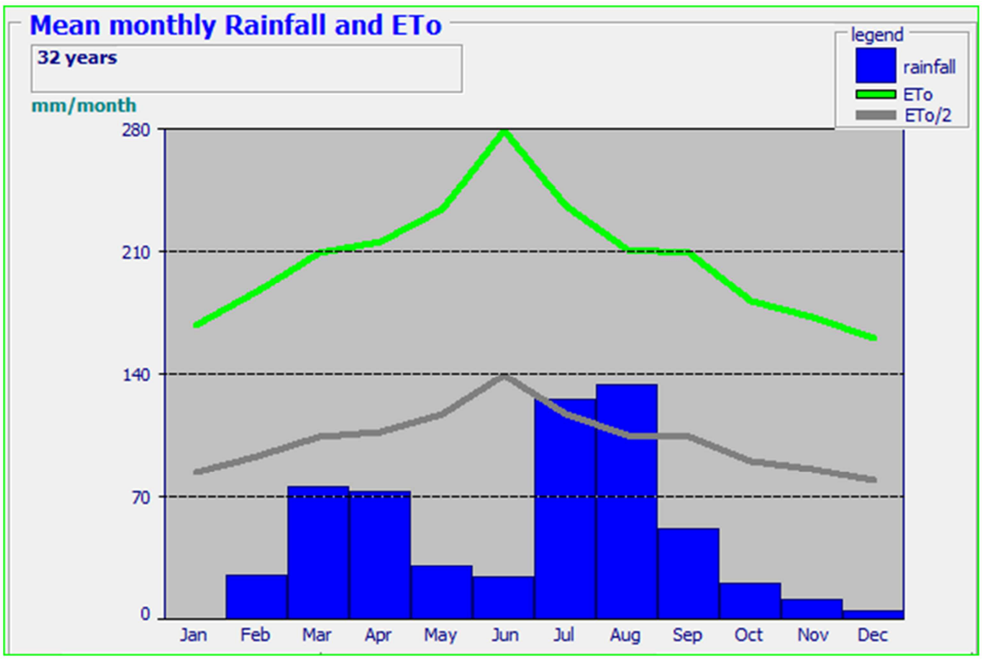

Figure 2. Mean monthly rainfall and evapotranspiration of the area from 1987-2018.

Table 1. Physical characteristics of soil at the experimental site.

Depth	Sand	Silt	Clay	Texture	BD	FC	PWP	TAW
(Cm)	(%)	(%)	(%)	-	(g/cm^3)	(Wgt. %)	(Wgt. %)	(mm/m)
0-30	10.8	32	57.2	Clay	1.29	40	24	206.4
30-60	12.8	32	55.2	Clay	1.30	39.5	23	214.5

BD=Bulk density, FC=Field capacity, PWP=permanent wilting point, TAW=Total available water

2.2. Experimental Layout and Design

The experiment was laid out in a split-plot design with three irrigation water application methods (conventional, alternate and fixed furrow) as main plots factor and three deficit levels (100% ETc, 75% ETc and 50% ETc) as subplots factor. Each sub-plots (25 m^2) having 6 furrows with 0.6m apart and 5 m long. The sub-plot size was 5 × 5 m and the spacing between blocks and plots were 3.6 m and 1.8 m respectively. The experimental treatment combinations were indicated in Table 2.

***Table 2.** Experimental treatment combinations.*

Treatments	
Main plots	**Subplots**
	100% ETc
Alternate Furrow Irrigation	75% ETc
	50% ETc
	100% ETc
Fixed Furrow Irrigation	75% ETc
	50% ETc
	100% ETc
Conventional Furrow Irrigation	75% ETc
	50% ETc

2.3. Crop Agronomy

Onion seed of "Adama Red" variety was used for this experiment as this variety is the most commonly grown in study areas. The onion seedlings were raised in the nursery and transplanted six weeks after planting. The transplanting was done in row at plant spacing of 10 cm between plant and 30 cm between rows. All agronomic practices were done according to the recommendation made for the area.

2.4. Determination of Crop Water Requirement

The amount of irrigation water applied was calculated using CROPWAT 8.0 software by using necessary input data of crop, soil and long term climatic data. The soil moisture status of each plot was monitored gravimetrically and the calculated irrigation depth was applied when 25% of plant-available water was depleted. The calculated gross irrigation amount of water was applied to the furrow using calibrated parshall flume with 3 inch dimension.

2.5. Water Productivity

Crop water productivity was estimated as a ratio of grain yield to the total water applied (GIR) through the growing season and it was calculated using the following equation:

$$\mathrm{CWP} = \frac{\mathrm{Y}}{\mathrm{GIR}}$$

Where CWP is crop water productivity (kg/m^3), Y is the onion marketable bulb yield (kg/ha) and GIR is the gross irrigation requirement (m^3/ha).

2.6. Agronomic Data Collection

The field data such as bulb length, bulb diameter, unmarketable, and marketable bulb yield were taken from each plot. Bulb length and diameter was taken by randomly selected 5 plants from each plot by excluding the border rows. At the end of the season the amount of bulb yield produced was harvested from each plot, weighted and converted into hectare base. The harvested yield was categorized into marketable and unmarketable based on its size and degree of damage.

2.7. Statistical Analysis

The collected data were analyzed using SAS version 9.3. Treatment means were compared using the least significant difference (LSD) at the 5% level of probability level.

***Table 3.** Crop water requirement and irrigation water applied (mm) to each treatment.*

Treatments	Number of irrigation	CWR (mm)	E. Rainfall (mm)	NIR (mm)	GIR (mm)
CFI 100% ETc	16	395.4	0.0	395.4	659
CFI 75% ETc	16	296.4	0.0	296.4	494
CFI 50% ETc	16	197.4	0.0	197.4	329
AFI/FFI 100% ETc	16	197.4	0.0	197.4	329
AFI/FFI 75% ETc	16	148.2	0.0	148.2	247
AFI/FFI 50% ETc	16	99.0	0.0	99.0	165

CFI=Conventional furrow irrigation; AFI=Alternate furrow irrigation; FFI=fixed furrow irrigation; and ETc=Crop evapotranspiration, CWR=Crop water requirement, E. Rainfall=Effective rainfall, NIR=Net irrigation water requirement, GIR=Gross *irrigation water requirement*

3. Result and Discussion

3.1. Amount of Water Applied

The total seasonal amounts of irrigation water applied were varied according to treatments (Table 3). In total, 16 irrigation events were adopted during the crop growing period. The total seasonal amount of net irrigation depth applied according to treatments is presented in Table 3.

3.2. Bulb Length

Bulb length of onion was significantly affected ($P<0.05$) by different furrow irrigation water application techniques and irrigation levels (Table 4). Significantly taller onion bulb length (4.47cm) was recorded from conventional furrow irrigation technique whereas the shorter mean value of bulb length (4.15cm) was recorded from fixed furrow irrigation technique. Irrigation level on the other hand, significantly ($p<0.05$) affected the bulb size of onion (Table 4). Significantly taller onion bulb length of (4.40 cm) was measured from onion received full application (100%ETc) while the minimum (4.23cm) was obtained from onion treated with 50% ETc deficit level. The significant increase in bulb length under conventional furrow irrigation with full (100% ETc) water application could be due to higher irrigation depth applied attributed to adequate moisture in the root zone, resulting in better uptake of nutrients and finally increased plant growth and development. The result of this study was in agreement with [1] who reported that the maximum bulb length and diameter of onions was recorded from onion grown under conventional furrow irrigation method and full (100% ETc) water application.

3.3. Bulb Diameter

The bulb diameter of the onion was significantly affected ($P<0.05$) by irrigation method and level (Table 4). Among the different irrigation methods, the maximum bulb size was recorded from onion grown under conventional furrow irrigation method (5.32 cm). The minimum bulb diameter of (4.74 cm) was obtained from a fixed furrow irrigation method. However the minimum result obtained from fixed furrow irrigation was statistically similar to alternate furrow. The findings of the present study are similar to the findings of [6] those who obtained that maximum bulb diameter of the onion from the conventional furrow irrigation application. Irrigation levels on the other hand, significantly ($P<0.05$) affected the bulb size of an onion (Table 4). Among irrigation levels, full irrigation (100% ETc) application recorded higher bulb diameter (5.24 cm). The minimum bulb diameter of (4.73 cm) was obtained from treatment which receives 50% ETc irrigation level. The result indicated that the 50% ETc irrigation application might have reduced transpiration and photosynthesis, which decreased the amount of available nutrient and water assimilated for growth and development leads to produce small size bulbs. This result is in agreement with that of a study conducted by [2] who reported that high amount of soil moisture application leads to large photosynthesis area, results to large bulb diameter.

Table 4. *Effect of furrow irrigation methods and irrigation levels on onion bulb length and bulb diameter.*

Treatments		Bulb length (cm)	Bulb diameter (cm)
Irrigation methods	CFI	4.47^{a}	5.32^{a}
	AFI	4.31^{b}	5.00^{b}
	FFI	4.15^{c}	4.74^{b}
	LSD (0.05)	0.04	0.31
Irrigation level	100% ETc	4.40^{a}	5.24^{a}
	75% ETc	4.30^{b}	5.10^{b}
	50% ETc	4.23^{c}	4.73^{c}
	LSD (0.05)	0.07	0.13
	CV (%)	1.6	2.6
	Irrigation method * Irrigation level	NS	NS

Means within a column followed by the same letter are not significantly different at 5% level of significance. NS=Non-significant, CFI=Conventional furrow irrigation, AFI=Alternate furrow irrigation, FFI=Fixed furrow irrigation, CV=Coefficient of Variation, LSD=Least significant difference.

Also, the obtained data by [5, 6] indicated that the bulb diameter of onions increased at higher levels of irrigation.

3.4. Marketable Bulb Yield

The interaction of irrigation method and irrigation level has shown a significant ($P<0.05$) effect on the marketable bulb (Table 5). Significantly higher marketable bulb yield of (17580 kg/ha) was obtained from conventional furrow with full (100% ETc) irrigation level and the lowest marketable bulb yield of (11053kg/ha) was obtained from onion grown under fixed furrow irrigation with 50% ETc deficit irrigation level. The significant onion marketable bulb yield increase in the conventional furrow irrigation method with 100% ETc irrigation level might be due to the fact that a larger amount of irrigation water application attributed to adequate moisture in the root zone, resulting in better uptake of nutrients, increment in vegetative growth and development, which associated with increment bulb yield. The results of the present study are similar to the findings of [6, 1], who also found the highest marketable bulb yield from onion grown under conventional furrow with full irrigation application (100% ETc) in onion crop.

Table 5. *Marketable bulb yield of onion as affected by the interaction of furrow irrigation methods and irrigation levels.*

Treatment	Marketable bulb yield (kg/ha)		
Furrow Irrigation Methods	Irrigation level		
	100% ETc	75% ETc	50% ETc
CFI	17580.43^{a}	16498.57^{b}	12533.25^{de}
AFI	14875.60^{c}	13099.00^{d}	11651.76^{fg}
FFI	11982.85^{ef}	11627.05^{fg}	11053.36^{g}
LSD (0.05)	796.88		
CV (%)	3.5		

Means within columns and rows followed by the same letter are not significantly different at the 5% level of significance. NS=Non-significant, CFI=Conventional furrow irrigation, AFI=Alternate furrow irrigation, FFI=Fixed furrow irrigation, CV=Coefficient of Variation, LSD=Least significant difference.

Table 6. *Onion water productivity as affected by the interaction of furrow irrigation methods and irrigation levels.*

Treatment	Water productivity (Kg/m^{3})		
Furrow Irrigation Methods	Irrigation Levels		
	100% ETc	75% ETc	50% ETc
CFI	4.45^{g}	5.57^{f}	6.34^{e}
AFI	7.53^{d}	8.84^{c}	11.79^{a}
FFI	6.06^{e}	7.85^{d}	11.19^{b}
LSD (0.05)	0.41		
CV (%)	3.2		

Means within columns and rows followed by the same letter are not significantly different at the 5% level of significance. NS=Non-significant, CFI=Conventional furrow irrigation, AFI=Alternate furrow irrigation, FFI=Fixed furrow irrigation, CV=Coefficient of Variation, LSD=Least significant difference.

3.5. Water Productivity

The interaction of irrigation method and irrigation level has shown significant ($P<0.05$) effect on the water productivity (Table 6). Significantly higher water productivity of (11.79kg/m^3) was obtained from alternate furrow with irrigation level of 50% ETc and the lowest water productivity of (4.45kg/m^3) was obtained from onion grown under conventional furrow with 100% ETc. Water productivity was significantly higher under deficit irrigation as compared to full (CFI 100% ETc) because less volume of irrigation water was used under deficit irrigation). In another similar study [1] reported that maximum water productivity from AFI 50% ETc. These findings are also supported by [4], who reported maximum water productivity from the lower level of deficit irrigation with alternate furrow.

3.6. Water Applied–Yield Relationship

The seasonal relationships between irrigation water applied and marketable bulb yield of onion was presented in Figure 3. The correlation coefficient (R2=0.84) in figure 3 showed that a linear relationship was found between the amount of water applied and marketable bulb yield of onion. This clearly indicates that the increase in onion bulb yield was proportional to the increment of water applied. As expected, the lowest marketable bulb yields of onion corresponded to the lowest amounts of water applied indicates onion yield is adversely affected by water deficit. This relation is closely in line with [7, 10], who they reported that there is a linear relationship between the decrease in relative water consumption and the decrease in relative yield.

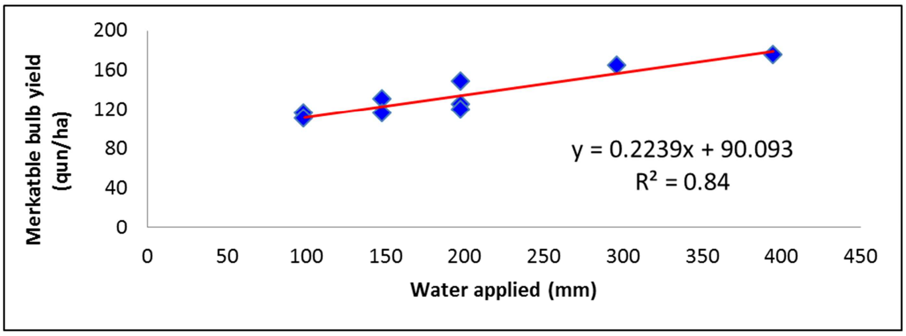

Figure 3. *Linear relationship between onion marketable yield and water applied.*

3.7. Relative Yield Reduction and Water Saved

Percentage of yield reduction and water saved from irrigation methods and application levels of onion production estimated for each treatment. As indicated in Figure 4, the result showed that CFI 100% ETc recorded maximum yield because this treatment received full crop water requirement, hence no yield reduction observed. The minimum yield reduction was obtained from CFI 75%ETC in the same way it saves 25% water from the required amount of growth, irrigation for one hectare in CFI 100% ETc. However AFI 100% ETc saved 50% of water with only 15% yield reduction as compared to the control (CFI 100% ETc). This clearly shows that the 15% of yield reduction resulted from AFI 100% ETc could be compensated by additional land to be irrigated by 50% of water saved under water stress condition.

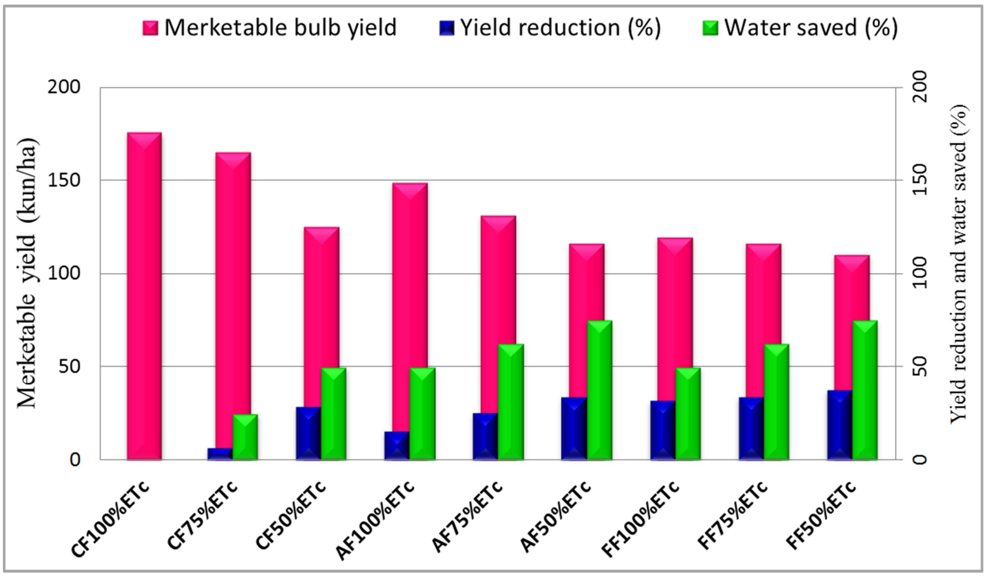

Figure 4. *Percentage of yield reduction and water saved with respect to full irrigation (CFI 100%ETc).*

4. Conclusion

The alternate furrow irrigation with full water application (AFI 100%ETc) can increase agricultural production by expand irrigable land with existing amount of water in water scarce area. Results obtained from this study showed that the interaction effect of irrigation methods and deficit irrigation levels was shown significantly different on marketable bulb yield and water productivity. The convention furrow irrigation with full water application (CFI 100% ETc) was recorded higher marketable yield. However in terms of water productivity, 50% of water saved from alternate furrow irrigation with full application (AFI 100% ETc) with only 15% yield reduction as compared to the control (CFI 100% ETc). This showed that yield reduction in AFI 100% ETc can be compensated by additional area to be irrigated by the water saved. Therefore irrigating onion by using AFI 100% ETc may result in optimum yield and increase water productivity under limited irrigation water condition of semi-arid climate of middle awash valley and others similar agro ecologies.

Conflict of Interest

The authors declare that they have no competing interests.

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References

[1] Akele Z. 2019. Evaluation of Alternate, Fixed and Conventional Furrow Irrigation Systems with Different Water Application Level on Onion Yield in Dubti, Afar, Ethiopia. Evaluation. 9 (5).

[2] Al- Moshileh, A. 2007. Effects of planting date and irrigation water level on onion (Allium cepa L.) production under central Saudi Arabian conditions. J. Basic Appl. Sci. 8: 14-28.

[3] Awulachew S. B., Ayana M. 2011. Performance of irrigation: An assessment at different scales in Ethiopia. *Experimental Agriculture*. *47* (S1), 57.

[4] Bhagyawant, R. G. Gorantiwar, S. D. Dahiwalkar, S. D. Bhalekar, M. N. and Khedkar, D. D. 2015. Yield Response Factor for Onion (Allium Cepa L) Crop under Deficit Irrigation in Semiarid Tropics of Maharashtra. Curr. Agri. Res. Jour., Vol. 3(2), 128-136 (2015).

[5] Enchalew, B., Gebre, S. L., Rabo, M., Hindaye, B., Kedir, M., Musa, Y., & Shafi, A. (2016). Effect of deficit irrigation on water productivity of onion (Allium cepal.) under drip irrigation. *Irrigat Drainage Sys Eng*, *5* (172): 2.

[6] Mebrahtu Y., Woldemichael A., Habtu S. 2018. Response of onion (Allium cepa l.) to deficit irrigation under different furrow irrigation water management techniques in Raya Valley, Northern Ethiopia. *African Journal of Plant Science*. *12* (5), 105-113.

[7] Mehari, H., 2019. *Effect of deficit irrigation levels and furrow irrigation techniques on yield and water productivity of maize (Zea mays L.) in Raya Azebo district, northern Ethiopia* (Doctoral dissertation, MSc thesis, Haramaya University, Haramaya, Ethiopia).

[8] Nazeer M., Ali H. 2012. Modeling the response of onion crop to deficit irrigation. *Journal of Agricultural Technology*. *8* (1), 393-402.

[9] Nouri H., Stokvis B., Galindo A., Blatchford M., Hoekstra A. Y. 2019. Water scarcity alleviation through water footprint reduction in agriculture: the effect of soil mulching and drip irrigation. *Science of the total environment*. *653*, 241-252.

[10] Temesgen T., Ayana M., Bedadi B. 2018. Evaluating the effects of deficit irrigation on yield and water productivity of furrow irrigated Onion (Allium cepa L.) in Ambo, Western Ethiopia. *Irrigat Drainage Sys Eng*. *7* (203): 2.