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EFFECT OF DEFICIT IRRIGATION AND FURROW IRRIGATION TECHNIQUES ON ONION WATER PRODUCTIVITY AND YIELD

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Abstract: **Deficit irrigation is important to increase the efficiency in view of limited water resources for agriculture. It is essential to find the most sensitive stage of crop and influence of deficit irrigation on crop yield. Deficit irrigation improves water productivity and irrigation management practices resulting in water saving. A field experiment was carried out at Mehoni Agricultural Research Center, Raya Valley of Ethiopia, during 2016/17 season with the objectives determine the combined effect of deficit irrigation and furrow irrigation techniques on onion yield and water productivity. five level of irrigation water amount percentage based on evapo-transpiration of the crop (ETc) (100%ETc, 85%ETc, 70% ETc, 55% ETc and 40%ETc) and three types of furrow irrigation water application techniques (alternate furrow, fixed furrow and conventional furrow) were tested in randomized completely block design (RCBD) with three replications. The combined result of deficit irrigation furrow irrigation techniques indicated that there were a significant (P<0.05) variation among treatments for plant height, bulb height, bulb diameter, bulb yield, and water productivity. Accordingly, the highest bulb yield was obtained at 100% ETc with conventional furrow method. In terms of water productivity, 40% ETc deficit irrigation level application with alternative furrow irrigation and fixed furrow irrigation gave the highest water productivity which significantly superior to all other treatments. On the other hand, the minimum water productivity was recorded from conventional furrow with 100% ETc (full irrigation).**

Keywords: **Alternate furrow, Conventional furrow, Deficit irrigation, Fixed furrow, Furrow technique, Onion, Water productivity.**

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1. INTRODUCTION

Onion (Allium cepa L.) is one of the most important vegetable and field crops grown and used throughout the world and is grown under a wide range of climates from temperate to tropical. Soil water tension significantly affects both the bulb yield and the yield components. In this respect, Sorensen et al. (2002) reported that drought stress during the final growth stage forced the onions to mature, reducing the yield.

Deficit irrigation (DI) is an optimization strategy in which irrigation is applied during drought sensitive growth stages of a crop. Outside these periods, irrigation is limited or even unnecessary if rainfall provides a minimum supply of water. Water restriction is limited to drought-tolerant phenological stages, often the vegetative stages and the late ripening period. Total irrigation application is therefore not proportional to irrigation requirements throughout the crop cycle. While this inevitably results in plant drought stress and consequently in production loss, DI maximizes irrigation water productivity, which is the main limiting factor (English M, 1990). In other words, DI aims at stabilizing yields and at obtaining maximum crop water productivity rather than maximum yields Zhang H and Oweis T, 1999).

Water is an essential resource to sustain life. It is a principal factor in agricultural production: proper development of every plant needs an optimum water supply that meets its physiological needs (Mannocchi and Mecarelli, 1994).

Ethiopia is the second most populous country in sub-Saharan Africa and third on the continent with a population of about 100 million. Agriculture is the main stay of 80% of the Ethiopian people. Agriculture also accounts for 40% of the GDP of Ethiopia (IWMI, 2010). However, most Ethiopian farmers depend on low productivity rain-fed small holder agriculture, even though rainfall is very erratic, and drought occurs very frequently. In Ethiopia, almost all food crops come from rain-fed agriculture with the irrigation sub sector accounting for only about 3% (FAO, 2005). This indicates that the water potential of the country is untouched, developing and utilizing efficiently this natural resource will rise the country to be food self sufficient within a short period of time.

Irrigation enhances crop production and household income which in turn improves the livelihood of the rural people as water and food security are closely related (FAO, 2003). Hence, irrigated agriculture is the main concern of the food security strategy of the Ethiopian Government, that is expansion of small scale irrigation and less dependent on rain-fed agriculture is taken as a means to increase food production and self-sufficiency of the rapidly increasing population of the country (GTP, 2010). Therefore, access to irrigation water is the most determinant factor affecting the food self-sufficiency at household level and national food supply. In areas where the amount and distribution of rainfall is not sufficient to sustain crop growth and development, an alternative approach set by the Ethiopian Government is to make use of the rivers, underground water and micro dams for irrigation in order to maintain crop growth so as to enhance crop production (MoA, 2010).

Furrow irrigation water application system is the most popular surface irrigation, as it requires a smaller initial investment compared to other types of irrigation water application systems. This type of irrigation method is the most widely used in Ethiopia in almost all large and small irrigation schemes FAO (2002). It usually causes excessive deep percolation at the upper part of the furrow, insufficient irrigation at the lower part and considerable runoff, resulting in low application efficiencies and distribution uniformities. Therefore, proper furrow irrigation practices have to be devised to minimize water application and irrigation costs and to save water at the same time maintaining higher crop yields.

In the semi-arid areas of Ethiopia, water is the most limiting factor for crop production. In these areas where the amount and distribution of rainfall is not sufficient to sustain crop growth and development, an alternative approach is to make use of the rivers and underground water for irrigation. Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water Oweis et al. (1998). Therefore, in an effort to improving water productivity, there is an increasing interest in therefore, the objective of the study was to determine the combined effect of deficit irrigation and three furrow irrigation techniques on onion yield and water productivity.

2. MATERIALS AND METHODS

2.1. Description of the experimental site

A field experiment was carried out under Mehoni Agricultural Research Center during the season of 2016/17. It is situated at an altitude of 1578 meter above sea level (m.a.s.l). The area is characterized by bimodal rainfall pattern with a short rainy season (belg) and (kirmet), a long term average rainfall of 300 -500mm, and its average minimum and maximum annual temperature is 18 ^{0}C and 32 ^{0}C, respectively. Geographically the experimental site is located between 12° 51'50" North Latitude and 39° 68'08" East Longitude. The soil textural class of the experimental area is clay with pH of 7.1-8.1 (MehARC, 2015).

2.2. Climatic Characteristics

The average climatic data (Maximum and minimum temperature, relative humidity, wind speed, and sun shine hours) on monthly basis of the study area were collected from the near meteorological station. The potential evapotranspiration ETo was estimated using CROPWAT software version 8.

Table 1: Physical characteristics of soil at the experimental site

Soil texture	Bulk density (g/cm^3)	Field capacity (%)	Permanent wilting point (%)	Total water holding capacity (mm)
Clay	1.1	45.47	28.47	170.02

2.3. Experimental Layout and Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates. The treatments consisted of fourteen deficit levels with furrow irrigation techniques, viz., AFI with 85% ETc (15% deficit), AFI with 70% ETc (30% deficitt), AFI with 55% ETc (45% deficit), AFI with 40 % ETc (60% deficit), CFI with 85% ETc (15% deficit), CFI with 70% ETc (30% deficit), CFI with 55% ETc (45% deficit, CFI with 40 % ETc (60% deficit) and FFI with 85% ETc (15% deficit), FFI with 70% ETc (30% deficit), FFI with 55% ETc (45% deficit), FFI with 40 % ETc (60% deficit) and a control treatment of 100% ETc (no deficit) with three furrow irrigation techniques (Table 1).

Control irrigation implies the amount of irrigation water applied in accordance with the computed crop water requirement with the aid of CROPWAT program. The treatments were replicated three times resulting in a total of 45 plots.

Table 2: Treatment used in the experiment

Treatment	Combinations
T1	Convectional furrow irrigated at 100% ETc
T2	Convectional furrow irrigated at 85% ETc
T3	Convectional furrow irrigated at 70% ETc
T4	Convectional furrow irrigated at 55% ETc
T5	Convectional furrow irrigated at 40% ETc
T6	Alternative furrow irrigated at 100% ETc
T7	Alternative furrow irrigated at 85% ETc
T8	Alternative furrow irrigated at 70% ETc
T9	Alternative furrow irrigated at 55% ETc
T10	Alternative furrow irrigated at 40% ETc
T11	Fixed furrow irrigated at 100% ETc
T12	Fixed furrow irrigated at 85% ETc
T13	Fixed furrow irrigated at 70% ETc
T14	Fixed furrow irrigated at 55% ETc
T15	Fixed furrow irrigated at 40% ETc

2.4. Statistical analysis

The collected data were analyzed using SAS 9.1 statistical software Mean separation was carried out using least significance difference (LSD) test at 5% probability level.

Analyses of variances for the data recorded were conducted using SAS 9.1 statistical software carried out using least significance difference (LSD) test at 5% probability level used for mean separation and the analysis of variance indicated the presence of significant treatment differences.

3. RESULTS AND DISCUSSION

3. 1. Crop water and Irrigation Demand

The reference evapotraspiration (ETo) value of the site ranged between 3.9 mm/day in January to 4.8 mm/day in March, with an average of 4.3 mm/day for the whole growth period. Based on this output, the seasonal irrigation requirement was found to be 362.45 mm (Table 3). This amount was needed for full irrigation level treatments.

Accordingly, the 85, 70, 55, and 40% of irrigation level with the furrow irrigation techniques of CFI were applied 308.1, 253.7, 199.4 and 145mm, with AFI 210.8, 183.7, 156.6, 129.4 and 102.2mm, and with FFI 210.8, 183.7, 156.6, 129.4 and 102.2mm, respectively. This amount of seasonal ETc for AFI and FFI the effective rainfall with 29.65 mm added that obtained the three furrows which does not irrigate at that time due to the rainfall. Crop water requirement (ETc) values were low at the beginning of the growing season, increased gradually to attain a maximum during March and April and subsequently decreased (Table 8). This result indicates that, the maximum amount of water was applied around bulb formation of the onion. This was also confirmed by Boyhan *et al*. (2001), that peak use of water generally occurs during the latter stages of bulb enlargement especially during periods of warm weather.

Table 3: Crop and irrigation water requirement onion in the study area

Date	ETo mm/period	Crop Kc	ETc mm/period	Total Rain mm/period	Effective rain mm/period	IRn mm/period	IRg mm/period
13-Jau	23.4	0.5	11.7			11.7	16.71
19- Jau	22.62	0.5	11.31			11.31	16.16
25-Jau	24.3	0.5	12.15			12.15	17.36
31-Jau	23.7	0.5	11.85			11.85	16.93
6-Feb	25.62	0.56	14.3472			14.3472	20.50
13-Feb	27.93	0.67	18.7131	12	3.9	14.8131	21.16
20-Feb	29.96	0.78	23.3688	36.5	18.8	4.5688	6.53
27-Feb	30.38	0.92	27.9496	17.3	7	20.9496	29.93
6-Mar	30.17	1.05	31.6785			31.6785	45.26
13-Mar	34.16	1.05	35.868			35.868	51.24
20-Mar	32.34	1.05	33.957			33.957	48.51
27.Mar	31.01	1.05	32.5605	32	16	16.5605	23.66
Apr-3	33.11	1.05	34.7655			34.7655	49.67
Apr-10	32.27	1.02	32.9154			32.9154	47.02
Apri-17	31.08	0.94	29.2152	28	13.6	15.6152	22.31
Total	432.05		362.45	125.8	59.3	303.05	432.93

3.2. Effect of parameters to onion in response of deficit Irrigation

Statistical analysis has shown a highly significant (P<0.01) difference for days to maturity, plant number, bulb height, marketable bulb yield and water productivity under different treatments. However, no significant deference was observed for average bulb weight.

3.2.1. Days to maturity

Different deficit levels with furrow irrigation techniques has a significant influence (p<0.05) on days to maturity.

Significantly longer 106.7 and 105 days to maturity were recorded at 100% and 85% of irrigation level with convectional furrow irrigation techniques respectively (Table 4).

On the other hand, significantly lower 96.3 days to maturity were recorded in plots where fixed furrow irrigation combined with 40% irrigation depth was used.

This result is in agreement with that of Brewster (1994) who reported that treatments that lacked supplemental irrigation water advanced bulb maturity of onion. Similarly, the findings of Solomon (2004) and Ahmed et al. (2008) also showed significant decrease in the number of days to flowering of haricot and faba beans under water stress. This could be due to the fact that plants under stress tend to complete their life cycle, which enables them escape from the unfavourable conditions by ending lifecycle few days earlier than those under normal or high soil moisture conditions, thereby ensuring perpetuation of the species (Al-Suhaibani, 2009).

3.2.2. Plant height

Plant height of onion was highly significantly (P ≤ 0.01) affected by the combined effects of furrow irrigation techniques and deficit irrigation.

Significantly higher plant height of 48.6 cm and 46.5 was recorded for 100%ETc (full irrigation) of irrigation depth of water applied with convectional furrow irrigation technique and 100% of alternative furrow irrigation techniques respectively. While CFI with 85% ETc, CFI with 70% ETc and AFI with 85% ETc irrigation water levels got 45.5 cm, 43.7 cm, and 42.7 cm plant heights respectively. AFI with 40%ETc and FFI with 40% ETc of irrigation depth of water applied recorded the lowest plant height of 40.8 cm and 38.9 cm respectively.

Plant height is a good indicator for determining the water stress. This finding is in agreement with the finding of Aklilu (2009) and Takele (2009) who reported that the plant height of pepper decreased with decreased irrigation levels and also increase with the irrigation level. Wien (1997) indicated that plant height had a linear correlation with the availability of soil moisture. The present result was also in agreement with the work of Al-Moshileh (2007) who reported that with increasing soil water supply, plant growth parameters (plant height) were significantly increased.

3.2.3. Leaf length

Significant differences ($P < 0.05$) on leaf length were also observed by the combined effect of deficit irrigation and furrow techniques. The higher leaf length were recorded by 100% ETc of irrigation level with convectional furrow irrigation, followed by CFI with 85% ETc and CFI with 70% ETc with the value of 36.4 and 36 cm respectively (Table 4).

Significantly shortest leaf length of 30.1 cm and 31cm were recorded in plots where fixed furrow irrigation techniques with 40% ETc and 55% ETc used. In general, leaf length increased with increasing irrigation depth, as the plant does not experience moisture stress at any growth and development.

This result is supported by observations of Kumar et al. (2007) and Bagali (2012) who reported longer leaves at 100% crop water requirement compared to treatments of deficit irrigation. Water deficit leads to retarded plant growth as it results in closure of stomata and interfere with photosynthesis ability and nutrient uptake of plants and consequently, reducing cell division and growth and thus resulting in stunting of leaves. During water deficit, stomata close to conserve water, limiting carbon dioxide availability and decrease in photosynthesis. This means that carbon assimilation is reduced and therefore the rate of leaf growth is reduced. It has been demonstrated that the decrease in available water under moisture stress first affects leaf expansion and then stomata conductance and gas exchange (Sadras and Milory, 1996). Similarly, Smith (2011) quoted that the rate of transpiration, photosynthesis and growth are lowered by even mild water stresses.

3.2.4. Number of leaf per plant

Higher number of leaf per plant was recorded of 10.4 was recorded at 100% ETc (full irrigation) with convectional furrow irrigation followed by CFI with 85% ETc and AFI with 100 ETc with the value of 9.95 and 8.9 respectively. There were no significances difference between AFI with 70% ETc, AFI 55% ETc, FFI with 100% ETc and FFI with 85% ETc of irrigation level. The lower number of leaf per plant was observed at FFI with 40% and FFI with 55% ETc irrigation level with the value of 6.9 and 7.9 leaves per plant respectively.

This result seems closely related to that of Biswas et al. (2003), who 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 (Curah and Proctor, 1990). The obtained result was also in agreement with the findings of Wien (1997) who found that leaf number had a linear correlation with the availability of soil moisture.

3.2.5. Bulb height

The ANOVA result showed highly significant ($P \leq 0.01$) difference due to the combined effect of furrow techniques technique and deficit irrigation (Table4 4).

The higher bulb height of 55.4mm, 55.33 mm, 53.7 mm, was recorded by CFI when it was applied with 100%, AFI with 100% ETc, and CFI with 85% ETc irrigation level respectively. The CFI at full irrigation (100%) was given 7.74 mm greater than it produced in plots which received 85% and 13.47 mm greater which received 40% irrigation level of FFI. On the other hand, Alternative Furrow Irrigation produced bulb height of 53.37 mm in plots which received of

100% of irrigation water applied, 10.98 mm and 11.37 mm greater than it produced in treatments which received AFI of 40%, and FFI 40% of irrigation water applied respectively (Table 4). The short bulb heights of onion were recorded from AFI and FFI with 40% ETc of deficit irrigation level.

The result indicated that the 40% irrigation depth might have reduced transpiration and photosynthesis and assimilate available for growth of the crop, which thus caused to produce small bulbs. This result is in line with that of Olalla et al. (2004) who observed smaller sized bulbs in mild water-stressed onion plants. Similarly, Neeraja et al. (1999) reported that higher level of irrigation 1.2 IW: CPE resulted in maximum bulb length.

Table 4: Main effects of deficit irrigation and furrow irrigation techniques on Maturity day, Plant height (cm), Leaf length (cm), Number of leaf and Bulb height (mm) of onion

Treatment	MD	PH (cm)	LL	NL	BH (mm)
Convectional furrow irrigated at 100% ETc	106.7^{a}	48.6a	39.5^{a}	10.4^{a}	55.4^{a}
Convectional furrow irrigated at 85% ETc	105^{a}	45.5^{abc}	36.4^{ab}	9.95^{ab}	53.7^{b}
Convectional furrow irrigated at 70% ETc	103^{b}	43.9^{bcde}	36^{ab}	9.2^{abc}	53.01^{b}
Convectional furrow irrigated at 55% ETc	102.33^{bc}	$41.6d^{efg}$	33.75^{bc}	8.87^{abcd}	48.7^{d}
Convectional furrow irrigated at 40% ETc	100^{de}	40.3^{fg}	31.8^{bc}	8.2^{bcd}	46.6^{de}
Alternative furrow irrigated at 100% ETc	102^{b}	46.5^{a}	36^{ab}	8.9^{abc}	55.3^{b}
Alternative furrow irrigated at 85% ETc	101^{cd}	42.7^{cdef}	35.7^{ab}	8.4^{abcd}	47.7^{de}
Alternative furrow irrigated at 70% ETc	98.3^{ef}	41.3^{efg}	32.7^{bc}	8.2^{bcd}	45.1^{ef}
Alternative furrow irrigated at 55% ETc	$98f^{g}$	40.7^{efg}	32.7^{bc}	8.16^{bcd}	43.4^{g}
Alternative furrow irrigated at 40% ETc	97^{ef}	40.01^{fg}	31.5^{bc}	8.16^{bcd}	42^{i}
Fixed furrow irrigated at 100% ETc	101.3^{bcd}	44.8^{bcd}	34.5abc	8.5^{abcd}	50.3^{c}
Fixed furrow irrigated at 85% ETc	$97.6f^{g}$	42.3^{cdef}	32.4^{bc}	8.2^{bcd}	$47.6d^{e}$
Fixed furrow irrigated at 70% ETc	97.3^{fg}	42.4^{efg}	32.37^{bc}	8.4^{bcd}	45.6^{ef}
Fixed furrow irrigated at 55% ETc	$97.3f^{g}$	40.6^{fg}	31^{bc}	7.9^{cd}	42.4^{hi}
Fixed furrow irrigated at 40% ETc	96.3^{g}	38.9^{g}	30.1^{c}	6.9^{d}	41.7^{i}
$LSD_{(0.05)}$	1.77	3.3	5.07	1.9	1.17
CV (%)	3.5	4.6	8.9	1.3	3.7

Means with the same letter (s) are not significantly different at $P \leq 0.05$; NS= not significantly different from each other at $P < 0.05$; LSD= least significant difference; CV = Coefficient of variation.

3.2.6. Bulb diameter

The analysis of variance for the furrow irrigation techniques and deficit irrigation has shown significant difference on bulb diameter.

As shown in Table 5, the largest bulb diameter was recorded (62.1 mm) when 100% ETc (full irrigation) amount of irrigation water applied with convectional furrow irrigation and followed by 85% and 70% of CFI. There were no significant differences between 100% ETc of AFI, 85% ETc of CFI and 70% ETc of CFI. On the other hand, the smallest bulb diameter (44.5 mm) was recorded from irrigation level treated fixed furrow irrigation with 40% ETc of deficit irrigation depth.

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 Kumara et al. (2007) who observed that irrigation at 1.20 Ep produced higher mean bulb size, which decreased with the decrease in amount of irrigation. In the same way, Abdulaziz (2003) and Biswas et al. (2003) indicated that bulb diameter of onions were increased at higher levels of irrigation. Similarly, Olalla et al. (2004) reported that plots which received the greatest volumes of water yielded harvests with higher percentages of large-size bulbs whereas water shortages led to higher percentages of small-size bulbs. This indicates that transpiration, photosynthesis and growth rates were lowered by water stress as stressed plant produces smaller sized bulbs.

3.2.7. Marketable bulb yield

The statistical analysis revealed that there was significant difference of onion bulb yield among the different deficit irrigation treatments ($p < 0.05$).

The highest marketable bulb yield of 26.8 tone/ha was obtained at the 0% deficit irrigation level (100% ETc) with convectional furrow irrigation technique and followed by 100% ETc of alternative furrow irrigation and 85% ETc of convectional furrow irrigation with the value of 23.71 tone/ha and 23.64 tone /ha respectively. The lowest mean bulb yield of onion was recorded from fixed furrow irrigation with 40% ETc of deficit irrigation (14.32 tone/ha). The yield reductions were increased as deficit irrigation levels increased from 100% ETc to 40% ETc of deficit irrigation. In this study the bulb yield response to fixed furrow irrigation and alternate furrow irrigation was higher at 100% than at 85% of irrigation water applied. Yet, 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%, and AFI with 100% ETc gave optimum yield..

Furthermore AFI and FFI all showed a substantial decrease in bulb yield (7.51% and 15.5%, respectively). Sepaskhah and Ghasemi (2008), reported that small amount of applied water reduced yield in every other furrow irrigation (AFI and FFI) as compared to CFI due to water stress, when the same irrigation frequency was applied which supported the result of this research.

The present result agreed with the general principle that the response of crop to full irrigation is generally higher under irrigated conditions than none irrigated one. The increment in marketable bulb yield due to application of irrigation water could be attributed to the increment in vegetative growth and increased production, which is associated with increment in leaf area index, bulb diameter and average bulb weight (Neeraja et al., 1999).

Similarly, Shoke et al. (1998) and Shoke et al. (2000) indicated that the bulb and dry matter production of onion is highly dependent on appropriate water supply. Similar results were also reported by Kloss et al. (2012) who showed that dealing with improvement of water productivity is closely related to the irrigation practice of regulated deficit irrigation and has a direct effect on yield i.e., if the amount of water applied decreases intentionally the crop yield will drop.

3.2.8. Unmarketable bulb yield

Significantly higher unmarketable onion bulb yield was recorded when fixed furrow irrigation technique with 40% ETc water applied (2.08 tone/ha) and followed by Alternative furrow irrigation techniques, while the lowest unmarketable bulb yield of 1.54 tone/ha and 1.67 tone/ha were observed when AFI with 100% ETc and CFI with 100% ETc irrigation depth applied respectively (Table 5).

The result revealed that, yield of very small bulbs increased with deficit irrigation. Stressed onion plants may bulb too early, produce small-sized bulbs and bulb splits and, thus, produce high amount of unmarketable yield (Kebede, 2003).This could be due to low rate of transpiration caused by stomata closer under moisture stress condition which brought about reduced photosynthesis and poor bulb growth and developments.

Corresponding to this, Martin et al. (2004), Olalla et al. (2004) and Zayton (2007) reported that plots which received the lowest volumes of water during the development and ripening stages produced higher percentage of small size bulbs. From present result, increasing water deficit had a positive relationship with the production of high yield of under size bulbs.

3.2.9. Total bulb yield

The total bulb yield which is the sum of unmarketable and marketable bulb yield was showed a significance effect *($P<0.05$)* by the treatments.

Higher total onion bulb yield was recorded when convectional furrow irrigation system with 100% ETc irrigation depth (full irrigation) applied that gave 28.48 tone/ha and followed by CFI with 85% ETc and AFI with 100% ETc of deficit irrigation.

On the other hand, the lowest total bulb yield of 16.4 tone/ha was recorded when fixed furrow irrigation system was applied with 40% ETc of deficit irrigation (Table 5).

The increment in onion total bulb yield might be attributed to large size of onion bulb due to application of high level of irrigation. This is because that it encourages cell elongation, above ground vegetative growth and imparts dark green colour of leaves,

which is important for more assimilate production and partition that favours onion bulb growth (Brady, 1985). The increased total bulb yield by applying full (no deficit) irrigation could have better performance on vegetative growth like plant height, number of leaves and leaf length which increase photosynthetic capacity of the plant, which in turn can improve bulb weight and contribute to increment in total bulb yield.

As the irrigation level increased from 40% ETc to 100% ETc, the total bulb yield increased. This result was also in agreement with the findings of Ferreira et al, (2002).

3.3. Effects of Irrigation Level and Furrow Irrigation Techniques on Water productivity

Deficit irrigation with furrow irrigation techniques had highly significant influence on water use efficiency of onion ($P \leq 0.01$)

3.3.1. Water productivity

The analysis of variance shows that irrigation furrow techniques with deficit irrigation influenced water productivity. WP values ranged from 9.1 kg m^{-3} for fixed furrow irrigation with 40% ETc deficit irrigation level to 4.43 kg m^{-3} for convectional furrow irrigation with 100% ETc (full irrigation). The highest WP was recorded from alternate and fixed furrow irrigation with 40% ETc of deficit irrigation with the value of 9.1 and 8.6 kg $m.^{-3}$ (Table 5). The lowest water productivity of onion was recorded from the 100% ETc of convectional furrow irrigation. Alternative furrow irrigation technique with 100% ETc deficit irrigation was 28% superior to convectional furrow irrigation with 100% ETc (full irrigation).

The results of this research are in agreement with Gençoglan and Yazar (1999), who reported that WUE values decreased with increasing irrigation level. In line with this result, Samson and Tilahun (2007) reported that deficit irrigations increased the water use efficiency of onion. Similarly, Shock et al., (1998), Fabeiro et al. (2003), Kebede (2003), Kirnak et al. (2005) and Sarkar et al. (2008) reported that irrigation water use efficiency was higher at lower levels of available soil moisture.

Table 5: Main effects of deficit irrigation and furrow irrigation techniques on Bulb diameter (mm), Marketable bulb yield (tone/ha), (kg/ha), UN marketable bulb yield (tone/ha), Total biomass yield (tone/ha) and Water productivity (m^3/ha) of onion

Treatment	BD (mm)	MBY (tone/ha)	UMBY (tone/ha)	TBY (tone/ha)	WP (m^3/ha)
Convectional furrow irrigated at 100% ETc	62.2^{a}	26.8^{a}	1.67^{cd}	28.48^{a}	4.43^{h}
Convectional furrow irrigated at 85% ETc	56.7^{ab}	23.64^{b}	1.69^{cd}	25.4^{b}	4.61^{h}
Convectional furrow irrigated at 70% ETc	53.6^{abc}	20.36^{cd}	1.65^{cd}	22.05^{cd}	4.81^{h}
Convectional furrow irrigated at 55% ETc	53^{abc}	19.16^{de}	1.72^{bcd}	20.89^{de}	5.7^{ef}
Convectional furrow irrigated at 40% ETc	49.6^{bc}	17.73^{fg}	1.93^{abc}	17.67^{fg}	6.5^{cd}
Alternative furrow irrigated at 100% ETc	56.8^{ab}	23.71^{b}	1.54^{d}	25.2^{b}	5.67^{ef}
Alternative furrow irrigated at 85% ETc	55.1^{ab}	21.93^{bc}	1.69^{cd}	23.76^{bc}	6.2^{de}
Alternative furrow irrigated at 70% ETc	54.2^{ab}	20.03^{cd}	1.91^{abc}	21.94^{cd}	6.9^{bc}
Alternative furrow irrigated at 55% ETc	51.8^{bc}	17.08^{ef}	1.94^{abc}	19.06^{ef}	6.9^{bc}
Alternative furrow irrigated at 40% ETc	47.8^{bc}	15.13^{fg}	1.97^{ab}	17.08^{gf}	9.1^{a}
Fixed furrow irrigated at 100% ETc	52.3^{bc}	20.86^{cd}	1.77^{bcd}	22.63^{cd}	5^{gh}
Fixed furrow irrigated at 85% ETc	50^{bc}	19.39^{d}	1.89^{abc}	21.28^{de}	5.4^{fg}
Fixed furrow irrigated at 70% ETc	49.1^{bc}	18.72^{de}	1.92^{abc}	20.65^{de}	6.4^{cd}
Fixed furrow irrigated at 55% ETc	48.3^{bc}	15.99^{fg}	1.97^{ab}	17.97^{fg}	6.97^{bc}
Fixed furrow irrigated at 40% ETc	44.5^{c}	14.32^{g}	2.08^{a}	16.4^{g}	8.6^{a}
$LSD_{(0.05)}$	9.34	2.21	0.274	2.42	0.61
CV (%)	10.6	6.7	8.8	6.7	5.6

- ***Means with the same letter (s) are not significantly different at $P \leq 0.05$; LSD= least significant difference; CV = Coefficient of variation.***

3.3.2. Comparison of onion bulb yield with water productivity

As shown in figure below, if insufficient water is applied during the crop cycle the crop was not fully develop resulting in low yield and high water productivity. And crop yield and water productivity can be increased if a considerable amount of water is added. Also, as the type of furrow irrigation and deficit irrigation depth differ, the yield and water production also varies. Conventional furrow irrigation with 100% ETc (full irrigation) was gave highest yield and low water production following alternate furrow irrigation of 100% ETc with equivalent yield of CFI and higher water productivity and fixed furrow irrigation with lower yield and high water productivity. As seen from figure below, the yield and water applied in three furrow irrigation treatments is leaner that means as the amount of water increased the yield increases. Alternate furrow irrigation gives optimum yield and water production.

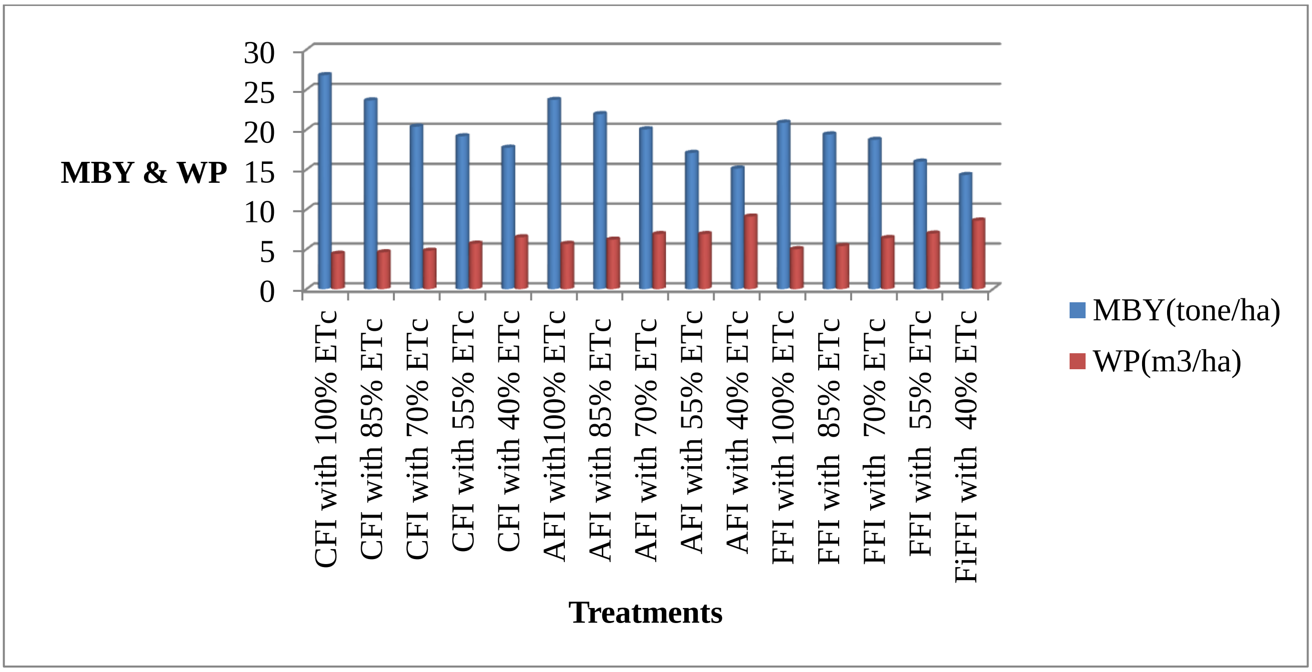

Figure 1: Onion ETc as a function of irrigation techniques and level

As shown in the table below, as the amount of water applied increased over conventional irrigation the yield also increased, but high water productivity of water were gained in Fixed and Alternate furrow irrigation and alternative furrow irrigation techniques. Clearly, water productivity depends on total applied water.

Table 6: Applied water, water use efficiency, water saved and percent yield reduction under the furrow techniques and deficit irrigation

Treatment	Bulb Yield (tone/ha)	AW (mm)	WP (kg/mm^3)	Water Saved (mm)	Yield Reduction (%)
Convectional furrow irrigated at 100% ETc	26.8	362.4	4.43	0	0
Convectional furrow irrigated at 85% ETc	23.64	308	4.61	54.4	11.8
Convectional furrow irrigated at 70% ETc	20.36	253.7	4.81	108	27.2
Convectional furrow irrigated at 55% ETc	19.16	199.4	5.7	163	37.5
Convectional furrow irrigated at 40% ETc	17.73	144.9	6.5	217.5	47.3
Alternative furrow irrigated at 100% ETc	23.71	250	5.67	112.4	17.4
Alternative furrow irrigated at 85% ETc	21.93	212.5	6.2	149.9	20.5
Alternative furrow irrigated at 70% ETc	20.03	175	6.9	187.4	30.9
Alternative furrow irrigated at 55% ETc	17.08	137.5	6.9	224.9	48.5
Alternative furrow irrigated at 40% ETc	15.13	100	9.1	262.4	68.3
Fixed furrow irrigated at 100% ETc	20.86	250	5	112.4	39.3
Fixed furrow irrigated at 85% ETc	19.39	212.5	5.4	149.9	35.5
Fixed furrow irrigated at 70% ETc	18.72	175	6.4	187.4	41.7
Fixed furrow irrigated at 55% ETc	15.99	137.5	6.97	224.9	57.7
Fixed furrow irrigated at 40% ETc	14.32	100	8.6	262.4	78

4. CONCLUSIONS

In conclusion, in the study areas water is a limiting factor, it is possible to get equivalent bulb yield of onion when applied alternative furrow irrigation technique with 100% ETc of irrigation depth. Alternative furrow irrigation can save a substantial amount of water and labour without highly reduction of onion yield in the study area. This also demonstrates that crop water use efficiency will be increased by using AFI which may result in substantial benefits, under limited water condition, labour saving and improved flexibility in farm irrigation management are also expected to be achieved using AFI. This result should be of significant value in this area to irrigate additional land.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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