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Effect of Deficit Irrigation on Water Productivity and Yield of Onion (*Allium cepa L*) at Dire Dawa, Eastern Ethiopia

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Abstract: The problem of irrigation water scarcity is the major production constraints in the arid and semi-arid areas of Dire Dawa. The objective of this study was to evaluate the effect of deficit irrigation on water productivity and yield of onion crop. The experiment was conducted at Tony farm experimental station of Haramaya University in Dire Dawa under the furrow irrigation system. Seven irrigation treatments were replicated three times in RCBD. In the treatment combination, a full application of irrigation water (100% ETc) was used as a control treatment and Bombay red onion variety was subjected to six deficit level of treatments 90% ETc, 80% ETc, 70% ETc, 60% ETc, and 50% ETc and 40% ETc throughout the growing season. The study revealed that maximum seasonal water demand for onion (423.8 mm) was consumed by control treatment and minimum seasonal water demand was consumed by 40% ETc application level. The study revealed that full application of irrigation water (100% ETc) produces a high number of leaf per plant, plant height, leaf height, and leaf diameter than the other treatment. Maximum yield (38.09 ton/ha) was obtained by non-deficit treatment (T1) while the lowest application level of irrigation water had the lowest yield of 22.23 ton/ha. Maximum WP (12.85 kg/m^3) was obtained by T7 and minimum WP (9.36 kg/m^3) was obtained by T1 (control treatment). Statistically, no significant difference was observed between T4, T5, T6, and T7 in the case of WP. By saving 30% of irrigation water T4 (70% ETc application level) produce optimum WP (11.20kg/m^3) than T1, T2 and T3. This implies that WP decreases with increasing application level of irrigation water up to 30% deficit. The result has shown that the minimum yield response factor (ky) was produced by T4 (application of 70% ETc) by saving 30% of irrigation water. The water saved by T4 can irrigate additional land of 0.43 hector which can produce 13.97 tons of additional onion bulb yield. The benefit cost ratio obtained by 70% ETc application of irrigation level was better than other treatments. Even though the net income of control treatment was high the benefit-cost ratio obtained by this treatment was small. Generally, the finding revealed that 70% ETc application level was the best application-level than the other treatment based on water productivity, economic visibility, total yield, and percent of yield reduction and yield response factor.

Keywords: Deficit Irrigation, Furrow Irrigation, Water Productivity, Onion

1. Introduction

Water has always been the main factor limiting crop production in much of the world where rainfall is insufficient to meet crop demand. With the ever-increasing competition for finite water resources worldwide and the steadily rising demand for agricultural commodities, the call to improve the efficiency and productivity of water use for crop production to ensure future food security and address the uncertainties associated with climate change has been more urgent [10].

Agriculture is one of the main consumers of freshwater resources in the world. It is consuming more than two two-thirds of total withdrawals [14]. In the context of improving water productivity, there is a growing interest in deficit irrigation, an irrigation practice whereby water supply is reduced below maximum level and mild stress is allowed with minimal effects on yield [17]. Under conditions of scarce water supply, the application of deficit irrigation (DI) provides greater economic returns than maximizing yields per unit of water. Implementing deficit irrigation could increase the irrigated area as a result of high water productivity. [27].

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 its yield [25]. Onion has an economically important role in Ethiopia. Onion production also contributes to the commercialization of the rural economy and creates many off-farm jobs [24]. Onion production in the country is increasing from time to time.

The problem of irrigation water scarcity is the major production constraints in the Dire Dawa [16]. Due to a shortage of irrigation water, much of the potential farmland is not cultivated during the dry season and even in the rainy season, rains cannot meet the amount of water required to sustain crop production. Therefore, there is a competition between farmers for the limited irrigation water in the study area. To satisfy many farmers in the area, water productivity should be increased. Deficit irrigation is known to increase water productivity with insignificant or minimum yield reduction.

Even though there is scarcity of irrigation water, farmers of the study area are using the traditional irrigation system by loosing much water. If carefully applied, deficit irrigation is found to be alternative method of water saving in irrigated agriculture. Reduced water application can be done in several ways. These techniques were found to be effective in water and labor-saving. The activity was done with the main objective of evaluating the effect of deficit irrigation on water productivity and yield of onion. The specific objectives of this study where to evaluate and compare water saving and productivity potential of varying water application depths at a different level of deficit irrigation, to evaluate the effect of deficit irrigation on yield and yield components of onion crop and to evaluate the effect of deficit irrigation on the economical value of irrigation water at the different application level.

2. Materials and Methods

2.1. Description of Study Area

The experiment was conducted at Tony farm experimental station of Haramaya University in Dire Dawageographically located between 9°27' to 9°49'N latitude and 41°38'to 41°40'E longitude and at 1160m above sea level. Dire Dawa is found at 515 km East of Addis Ababa. It is situated in the semi-arid tropical zone of Eastern Ethiopia. The area experiences a bimodal type of rainfall and the mean annual rainfall is 604 mm. The mean annual maximum and minimum temperatures vary from 29°C to 35.4°C and 14.5°C to 22.6°C, respectively. The Soil textural class of the study area is classified as clay loam soil.

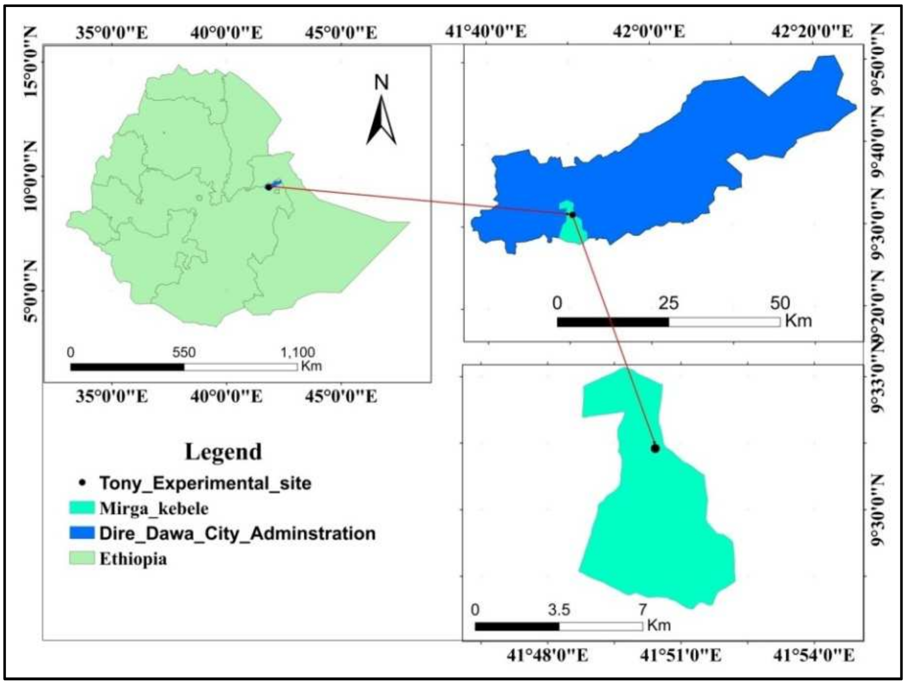

Figure 1. *Location Map of the Study Site.*

From long term (1988-2018) the two seasons are 'Meher', which occurs in months of July, August, and September, and 'Belg' that occur in March, April, and May. April and August receive the highest of the annual rainfall while December, January, and September receive the less temporal distribution of rainfall (Figure 2).

Since there was strong variability in long term climate data collected, the rainfall of the study area was first changed to dependable rainfall (80% probability of exceedance). A simple method of computing dependable rainfall was done by grouping the rainfall data by 10 mm interval and then selecting the high-frequency rainfall [2]. Since not all dependable rainfall is effective, determination of effective rainfall was computed bythe equation:

Peff = 0.6 * P - 10 for precipitation less or equal to 70mm (1)

Peff = 0.8 * P - 24 for precipitation greater than 70 mm (2)

Where
Peff – Effective Precipitation (mm)
P- Precipitation (mm)

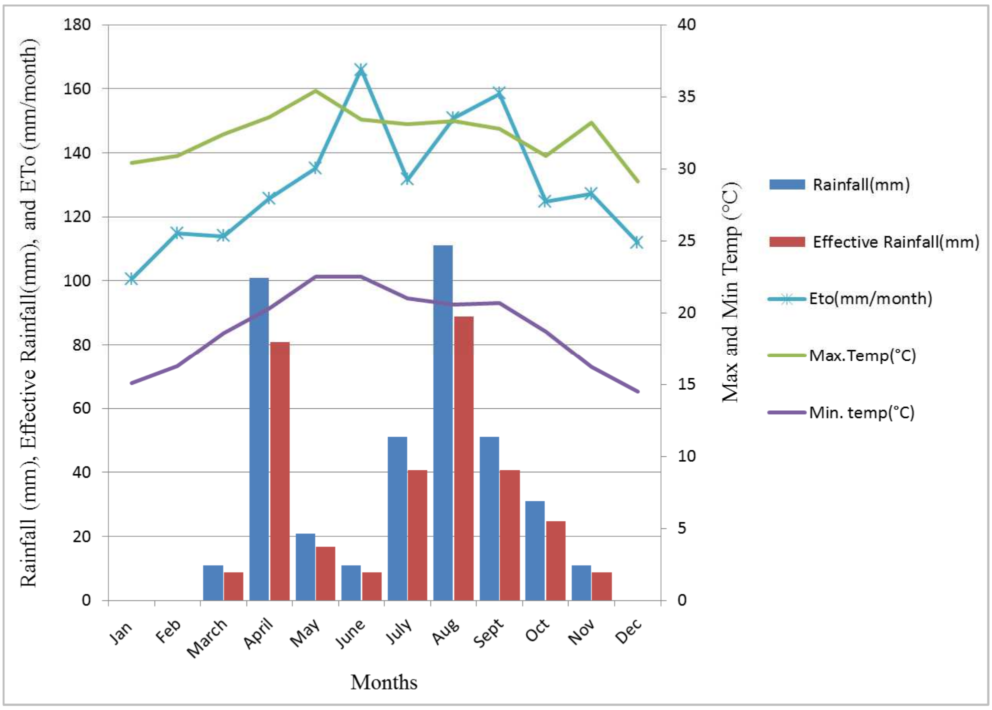

Figure 2. *Rainfall, Effective Rainfall, ETo, and Temperature of the study area.*

2.2. Experimental Design and Treatment

The experiment was laid out in RCBD consisting of seven treatments with three replications. The treatments contain different amounts of irrigation water application levels which are listed in Table 1 below. The experimental field was divided into 21 plots and the size of each plot was 3m * 4m dimension to accommodate five furrows with a spacing of 0.6 m and has 4m length. Onion is known by two-row plant so transplanting was done row to row spacing 40cm; space between ridge 20cm and plant spacing was 10cm. The buffer zone of plot and replication was 2m from the water supplying canal and 2 m between plots to eliminate the influence of lateral water movement. For each plot, division box structures were constructed to dissipate the energy of water diverted to the plots. The Experimental treatment combinations are given in Table 1 below.

Table 1. *Description of Treatments.*

Treatment	Treatment Combination
T1	Optimum Irrigation of 100%ETc (Control)
T2	Irrigation Water Application Level of 90%ETc
T3	Irrigation Water Application Level of 80%ETc
T4	Irrigation Water Application Level of 70%ETc
T5	Irrigation Water Application Level of 60%ETc
T6	Irrigation Water Application Level of 50%ETc
T7	Irrigation Water Application Level of 40%ETc

The amount of irrigation water was applied by the furrow irrigation method and measured using Parshall Flume. Out of the experimental field, Parshall Flume was set at 10 m away from the experimental plot in the main canal. It was set inside a straight and uniform section of the canal. UREA and DAP were the two fertilizers applied equally for each treatment with a rate of 100 kg/ha and 200 kg/ha, respectively [24]. There were pests and diseases in the areas of the experiment. To protect the experiment both bacticide and pesticide chemicals (Proof, menchozem, and Ridomil Gold) were used according to their rate of application. To achieve the aim of trial onion diseases and pests were controlled.

Before the start of treatments, soil samples were taken from three spots at random from the diagonal of the experimental field. The samples were taken from four depths (0-15cm, 15-30cm, 30-45cm, and 45-60cm). The soil properties analyzed include bulk density, water retention at field capacity (FC), permanent wilting point (PWP), soil texture, soil PH, organic carbon, and electrical conductivity of the soil. The sample of this irrigation water was taken using a sampling bottle and a proper sampling kit at the pump. The collected irrigation water sample was analyzed for PH and electrical conductivity of water (ECw) in the laboratory.

2.3. Determination of Crop Water Requirement of Onion

Long term climatic data (1988 -2018) records such as rainfall, maximum and minimum temperature, wind speed, relative humidity, and sunshine hours were collected from Dire Dawa meteorological station for determination of Onion water requirements. Reference evapotranspiration (ETo) of onion was computed using CROPWAT model version 8.0 [11] from Dire Dawa meteorological station.

Evapotranspiration of the crop was determined by multiplying the crop coefficient (Kc) of the crop by the reference evapotranspiration (ETo). The crop coefficient values for respective growth stages were 0.7, 1.05, and 0.95 for the initial, mid and end-stage, respectively [2]. Based on the Kc values of the crop and length of each growth stages, crop coefficient was interpolated for development and late season. The length of growth stages of onion crop during the experiment was 20, 30, 40, and 25 days for initial, development, mid-season, and late season, respectively. The graph of interpolated Kc value for development and late-season stage of onion was developed as in Figure 3 below.

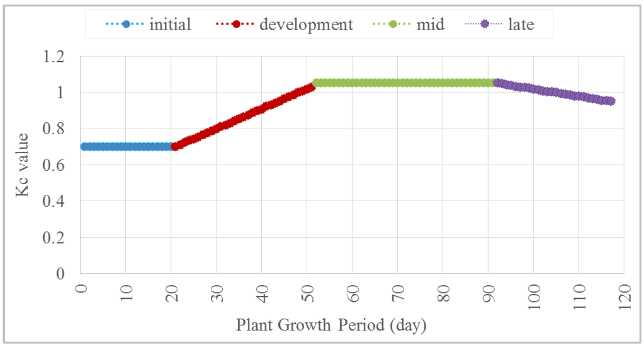

Figure 3. *Crop Coefficient for Different Growth Stage of Onion.*

The net depth of irrigation supplied at any time is obtained from a simplified water balance equation as:

$$In = ETc - Pe \tag{3}$$

Where; In-Net Irrigation Depth (mm), ETc- The Crop Water Requirement (mm) and Pe -The Effective Rainfall (mm).

Field irrigation application efficiency (E_a) is the ratio of water directly available in the crop root zone to water received at the field inlet. It is affected by the rate of supply, infiltration rate of the soil, the storage capacity of the root zone, and land leveling. Furrow irrigation could reach a field application efficiency of 70% when it is properly designed, constructed, and managed. The average ranges vary from 50 to 70%. However, a more common value is 60% [9]. For this particular experiment, irrigation efficiency was taken as 60%, which is common for surface irrigation methods in furrow irrigation. Based on the net irrigation depth and irrigation application efficiency, the gross irrigation water requirement was calculated based on equation 3.7.

$$Ig = \frac{In}{Ea} \tag{4}$$

Where; I_g-Gross Irrigation Depth (mm), I_n-Net Irrigation Depth (mm) and E_a-Furrow Application Efficiency (%).

The time required to deliver the desired depth of water into each furrow was calculated using equation 5 given by [21].

$$T = \frac{Ig*W*L}{6Q} \tag{5}$$

Where; Ig = gross depth of water applied (cm), T = Application Time (min), W= Space of Furrow of the Plot (m), L= Length Furrow of the Plot (m) and Q= Flow Rate (l/s).

Irrigation scheduling was done based on control treatment (100% ETc). The control treatment (optimum irrigation) was irrigated based on the allowable moisture depletion level in the effective root depth that aims to refill the soil moisture to field capacity. Since onion is sensitive to water deficit, allowable moisture depletion was 25% of the TAW (ρ=25%) [7]. The six treatments received a lower amount of irrigation water than the control treatment based on their level of deficit percentage.

Water productivity is defined as crop yield per unit volume of water supply to the crops, Molden [22], and is estimated by dividing crop yield by total applied water. In this study crop, water productivity was estimated as the ratio of onion bulb yield to the total irrigation depth applied to Onion during the season. It is expressed as:

$$WP = \frac{Y}{W} \tag{6}$$

Where, Y is onion bulb yield (kg/ha) and W is irrigation depth applied during the season (m^3/ha).

The amount of water saved (SW) per hectare of land from irrigation deficit was computed by subtracting deficit water application levels from the irrigation treatment that used the highest irrigation water level, i.e. 100% ETc. The extra irrigable land area (A) in hectare which was served by the saved irrigation water was determined by dividing the total saved water per hectare of land (SW) in m^3 by the irrigation water use for a hectare of land (IWU) in m^3/ha as:

$$A = \frac{SW}{IWU} \tag{7}$$

To evaluate the effect of deficit irrigation treatments on onion yield, samples were collected from the central ridge to avoid border effects. Data on the growth parameter of onion was recorded from five randomly selected plants in three middle rows of each experimental plot and the same plant was used for subsequent measurement. Data on total yield and marketable onion yield was collected from three central rows by leaving the border effect on both sides from each experimental plot. Then the yield results were converted to a hectare basis using the following formula.

The partial budget analysis was used for economic water productivity analysis by considering the general relationship between the crop water use and crop yield per hectare of land at the different deficit irrigation application levels. Total revenue, the total variable cost, total fixed cost, total cost, net income and Benefit-cost ratio, of each treatment, were analyzed by partial budget analysis based on CIMMYT procedure [4]. The data used for economic analysis were fixed cost and variable cost. Fixed costs include seed cost, fertilizer cost, farm implement cost, and chemical cost. Variable cost includes the cost of irrigation water for each treatment and labor cost for each treatment.

For the calculation of total revenue, the average marketable yield of each treatment was taken and then adjusted by multiplying 10% following the procedure of CIMMYT. The assessment was undertaken to take the price of onion at the local market. Based on the assessment done 1kg of onion was 8ETB at a time at field level. For calculation of labor cost, the price of human labor was 50ETB in the field. For calculation of irrigation water cost for each treatment, the price of water was taken as 3 ETB/1000m^3 [19]. Net income (NI) in ETB/ha, generated from onion crop, was computed by subtracting the total cost (TC) in ETB/ha from the total return (TR) in ETB/ha obtained from onion sale [18]. TC is the sum of FC and VC.

Benefit cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended.

2.4. Statistical Analysis of Data

All collected data were subjected statistical analysis system (SAS) version 9.0 statistical package using all of its procedures [26] for the variance analysis.

3. Result and Discussion

3.1. Analysis of Soil and Water Property of Experimental Site

The result of soil physical property analysis shown that the average composition of clay, silt, and sand percentages was 32.25, 24.75, and 43, respectively (Table 2). Thus, according to the USDA soil textural classification, the particle size distribution of the experimental site revealed that the soil textural class is clay loam. The result shown that bulk density of experimental site was found between the range of 1.02 g/cm^3-1.21 g/cm^3. Analysis of FC, PWP, and TAW are shown that there was a variation between different soil depths (Table 2).

Table 2. *Analysis of soil physical property of the experimental site.*

Depth (cm)	Particle size distribution (%)			Soil textural classes	Bulk density (g/cm^3)	FC (%)	PWP (%)	TAW (mm)
	Sand	clay	silt					
0-15	46	28	26	Sandy clay loam	1.21	30.40	19.05	20.60
15-30	44	31	25	Clay loam	1.02	30.00	15.00	22.95
30-45	42	34	24	Clay loam	1.12	33.30	14.28	31.95
45-60	40	36	24	Clay loam	1.16	38.51	15.78	39.55
Total available water in an effective root zone of 60cm								115.05

Note: FC- Field Capacity, PWP –Permanent Wilting Point, TAW- Total Available Water

The soil infiltration rate of the experimental site was conducted using the double-ringinfiltrometer. The test was done at three locations on a diagonal basis. The average basic infiltration rate of the experimental site was 7.2 mm/hr.

The result of irrigation water quality analysis shown that the average PH value was 7.20 and the electrical conductivity of irrigation water was 0.37 ds/m. According to [13] electrical conductivity of irrigation water (ECw) classification of < 0.7 ds/m (no salinity effect), 0.7– 3 ds/m (slight to moderate salinity effect), > 3 ds/m (severe salinity effect). Based on FAO classification the irrigation water quality of the study area was classified as no salinity effect. According to [3], the irrigation water is classified in terms of pH <7 low, 7-8 slight to moderate, and >8 severe. Based on this classification, the pH value of irrigation water in the study area shown that slight to moderate.

From the result of soil chemical property analysis, the soil had an average electrical conductivity of 0.29dS/m. From the obtained result the soil is safe in terms of salinity and no need of considering leaching requirements in the determination of irrigation needed. The result also revealed that the average soil PH study area was 7.13 which are suitable for the growth of onion because the result implies that moderate in both acidity and alkalinity. According to [12] soil reaction (PH) classification, soils are classified as strongly alkaline (> 8.5), moderately alkaline (7.1-8.5), neutral (7,) slightly acidic (6.6 - 6.9), moderately acid (5.6 - 6.5), strongly acid (4.6 - 5.5) and very strong acid (< 4.5). Accordingly, the soil of the study area is classified as moderately alkaline.

Table 3. *Irrigation water and soil chemical property of the experimental site.*

Soil depth (cm)	Soil chemical property				Irrigation water chemical property	
	PH	EC (dS/m)	OM (%)	OC (%)	PH	EC (dS/m)
0-15	6.70	0.30	4.30	2.50		
15-30	7.41	0.29	4.15	2.41		
30-45	7.30	0.31	3.61	2.10	7.20	0.37
45-60	7.10	0.27	3.20	1.86		
Average	7.13	0.29	3.81	2.22		

* EC-electrical conductivity, OM-organic matter and OC- organic carbon.

3.2. Crop Water Requirement of Onion

Seasonal water demand for onion was determined start from seasonal water application depth from transplanting to harvest and vary between treatments according to their deficit level percentage. The Seasonal crop water requirement of onion determined for the control treatment (100% ETc) was 423.80 mm (Table 4). There was an occurrence of rainfall during the study which was deducted from total crop water demand. The total rainfall recorded during the experiment was 21 mm which was recorded in March and April 2019. The total effective rainfall was 16.8 mm from two months. The obtained effective rainfall was reduced from the net irrigation requirement of onion.

The maximum amount of net irrigation (407 mm) was consumed by control treatment (Application level of 100% ETc). The minimum amount of net irrigation (162.80 mm) was consumed by T7 (Application level of 40% ETc). The intermediate treatments obtain net irrigation water between 407 mm to 162.80 mm according to their deficit level percentage (Table 4).

The maximum amount of gross irrigation (678.33 mm) was consumed by control treatment (Application level of 100% ETc) and the lowest amount of gross irrigation (271.33mm) was consumed by application level of 40% ETc. For intermediate treatments T2, T3, T4, T5, and T6 the calculated gross irrigation application was 610.50mm, 542.67 mm, 474.83 mm, 407.00 mm, and 339.16 mm. The obtained seasonal water demand for onion in this study is in agreement with the report of [15, 6] in which they report that maximum gross irrigation (664.30 mm) and 672.16 mm for onion production was consumed by 100% ETc (control treatment) respectively.

Table 4. *Seasonal Irrigation Water Applied for Each Treatment.*

Treatments	Total ETc (mm)	Total net irrigation (mm)	Total gross irrigation (mm)
T1 (100%ETc)	423.80	407.00	678.33
T2 (90%ETc)	381.42	366.30	610.50
T3 (80%ETc)	339.04	325.60	542.67
T4 (70%ETc)	296.66	284.90	474.83
T5 (60%ETc)	254.28	244.20	407.00
T6 (50%ETc)	211.90	203.50	339.16
T7 (40%ETc)	169.52	162.80	271.33

* ETc- Crop-Evapotranspiration.

3.3. Effects of Deficit Irrigation on Growth Parameters of Onion

3.3.1. Leaf Number Per Plant

The result from the analysis of variance shown that there was significant difference between treatments in case of the number of leaf per plant (Table 5). Statistically, there was no significant difference between T1, T2, and T3. This implies that leaf number was not highly affected by irrigation deficit up to 80% ETc application level. The result obtained in line with [8] who reports that vegetative growth of onion decrease as the application level of irrigation water decrease. Similarly, the report of [15, 28] also shown that number of leaves decreased with decreasing soil moisture level and a high amount of leaf number was obtained by application level of 100% ETc.

Table 5. *Effect of deficit irrigation on the growth parameter of onion.*

Treatments	Leaf Numberper plant	Plant Height (cm)	Leaf Height (cm)	Leaf Diameter (cm)
T1	12.667a	56.67 a	53.00a	1.810a
T2	11.667ab	55.33ab	48.00a	1.583ab
T3	11.000ab	52.33b	46.67ab	1.257b
T4	10.000b	47.67c	44.00ab	1.113bc
T5	7.333c	40.33d	36.33bc	0.687cd
T6	7.333c	40.33d	36.33bc	0.640cd
T7	6.667c	35.00e	32.33c	0.587d
CV%	7.5	2.3	7.9	14.0
L.S.D.	1.27	1.91	5.97	0.27

Note: Different letters in a column imply significantly different and those followed by the same letter are not significantly different according to LSD at $P<0.05$ level of significance.

3.3.2. Plant and Leaf Height

The result shown that the highest plant height of onion 56.67cm was recorded from the control treatment (T1). The minimum plant height 35cm was recorded from treatment T7 and which was significantly different from all other treatments. The highest leaf height 53 cm was recorded from control treatment T1. The minimum leaf height of 32.33 cm was recorded from treatment T7. The results are in agreement with [20] who report that the higher water supply resulted in the higher vegetative parameters (plant and leaf height). This finding also in line with the results of [1] who reported that plant height of onion decreased with decreased irrigation levels and also increase with the irrigation water level.

3.3.3. Leaf Diameter

There was significant difference ($p<0.05$) between different application levels of irrigation water on onion leaf diameter. Thus treatment that irrigated by full irrigation water had the widest leaf diameter (1.810 cm) than the others deficit level. The smallest leaf diameter (0.587cm) was obtained by T7 which gets the smallest amount of irrigation water. Statistically, there was no significant difference between T1 and T2 and also no significant difference was observed between T2, T3, and T4. The result has shown that decreasing the amount of irrigation required decreases the leaf diameter of onion.

3.4. Effect of Deficit Irrigation on Yield and Yield Component of Onion

The result on the Effect of Deficit Irrigation on Yield and Yield Component of Onion were presented in Table 6 below.

Table 6. *Effect of Deficit Irrigation on Yield and Yield Components of Onion.*

Treatments	Total bulb yield (t/ha)	Avg. bulb weight (g)	Onion bulb diameter (cm)	Marketable onion yield (t/ha)
T1	38.09a	136.8aa	6.923a	37.03a
T2	36.66a	132.0aa	6.773a	33.39b
T3	34.33ab	123.6bb	6.290b	32.03b
T4	32.49ab	117.0bb	6.100b	31.66b
T5	29.08bc	104.7cc	5.567c	27.02c
T6	25.21cd	90.8dd	4.720d	24.31d
T7	22.23d	80.0ee	4.060e	21.13e
CV%	10.4	4.0	4.6	4.6
L.S.D.	5.756	8.02	0.47	2.424

3.4.1. Total Bulb Yield

Maximum yield (38.09 t/ha) was obtained by non-deficit treatment (T1) while the lowest application level of irrigation water had the lowest yield of 22.23 t/ha. The other treatments T2, T3, T4, T5 and T6 produce yields of 36.66 t/ha, 34.33 t/ha, 32.49 t/ha, 29.08 t/ha, and 25.21t/ha respectively. Up to 70% ETc application of irrigation water statistically similar yield was obtained (Table 6). But from 60% ETc up to 40% ETc application of irrigation water total bulb yield was reduced and affected by decreased application level of irrigation water. The result is also in agreement with the finding of [5] who report that yield decreased with increasing water stress signifying the more stress the crop is subjected to, the slower it is for it to recover leading to progressively lower yield.

3.4.2. Average Weight of Onion Yield

The analysis on average onion bulb shown that significant difference was observed between treatments due to different deficit irrigation levels (Table 6). These findings indicate that individual onion bulb weight was affected by the deficit application level. Up to 30% deficit of irrigation water optimum bulb weight was obtained which produces optimum total onion yield. But from 40% up to 60% deficit of irrigation water, the average weight of onion bulb was reduced. Statistically, no significant difference was observed between T4 and T3.

3.4.3. Bulb Diameter of Onion

The result on onion bulb diameter shown that there was significantly different ($p<0.05$) between treatments due to deficit irrigation level. Onion bulb diameter was determined as an indicator of the size and it was found to be significantly influenced by deficit irrigation level. Statistically, there was no significant difference between T1 and T2. Also, no significant difference was observed between T3 and T4 in case of bulb diameter.

3.4.4. Marketable Onion Yield

The result of marketable yield of onion revealed that there was significant difference ($p<0.05$) between treatments due to the application level of irrigation water. The maximum amount of marketable yield (37.03t/ha) was obtained by control treatment (100%ETc of application level). Minimum marketable onion yield (21.13t/ha) was produced by the smallest application of irrigation water (40%ETc application). The intermediate treatments produce marketable onion yield between 37.03 t/ha and 21.13t/ha (Table 6).

3.5. Effect of Deficit Irrigation on Water Productivity

The result on WP shown that there was significant difference ($p<0.05$) between different deficit irrigation levels. Maximum WP (12.85 kg/m^3) was obtained by minimum application of irrigation water (40% ETc) while the lowest value 9.36 kg/m^3 of WP was obtained from T1 (100% ETc). Statistically, water productivity of T4 (70% ETc application level) had no significant difference with the treatment which produce maximum water productivity (40%ETc application) (Table 7). By saving 30% of irrigation water, the application of 70%ETc produces optimum yield which produces optimum water productivity. The finding is in agreement with [23] who state that increased water saving and water productivity through irrigation at 70% ETc deficit irrigation level under conventional furrow irrigation system can solve the problem of water shortage. The intermediate treatment produces the WP between 12.85 kg/m^3 and 9.36 kg/m^3 (Table 7). The result is in agreement with the finding of [5] who report that water productivity for onion yield was affected significantly by deficit irrigation treatments up to 80% ETc application and increase from 70% ETc application to the most deficit irrigation level treatment.

Table 7. *Effect of Deficit Irrigation on Water Productivity.*

Treatments	Onion Yield (kg/ha)	Water productivity (kg/m^3)
T1	38086a	9.36c
T2	36657a	9.96bc
T3	34326ab	10.43bc
T4	32490ab	11.20abc
T5	29077bc	11.58ab
T6	25213cd	11.89ab
T7	22228d	12.85a
CV%	10.4	9.6
L.S.D.	5756.1	1.885

The result showed that the amount of irrigation water saved which can irrigate another additional area was increase as decreasing application level (Table 8).

Table 8. *Effect of Deficit Irrigation on Water Saving and Yield Reduction.*

T	WU (m^3/ha)	TY t/ha)	WS (%)	WS (m^3/ha)	YD (%)	AIBSW	Yieldto be gain (t/ha)
T1	6783.30	38.086	0	0	0	0	0
T2	6105.00	36.657	10	678.3	3.75	0.11	4.03
T3	5426.70	34.326	20	1356.6	9.87	0.25	8.58
T4	4748.30	32.49	30	2035	14.69	0.43	13.97
T5	4070.00	29.077	40	2713.3	23.65	0.66	19.20
T6	3391.60	25.213	50	3391.7	33.79	1.00	25.213
T7	2713.30	22.228	60	4070	41.64	1.50	33.34

Note: T-treatment, WU-water use, TY-total yield, WS-water saved, YD-yield decrease, AIBSW-area to be irrigated by saved water.

Even though there was relative yield reduction, there was the additional yield gain due to irrigating additional areas by saved water from deficit irrigation level (Table 8). Additional yield which can be irrigated by saved irrigation water from T2, T3, T4, T5, T6 and T7 were 4.03, 8.58, 13.97, 19.20, 25.213 and 33.34 /ha respectively (Figure 4).

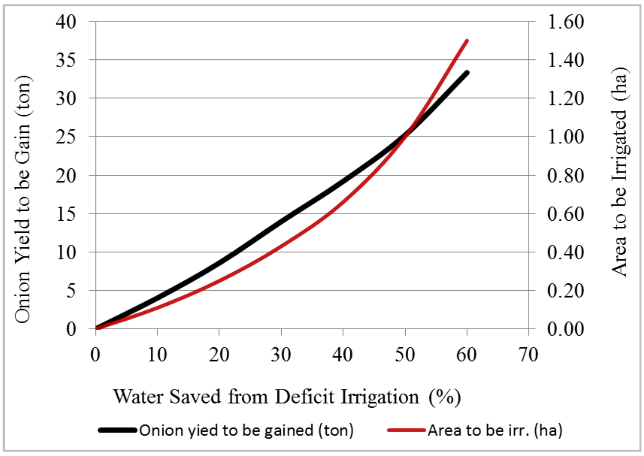

Figure 4. *Effect of deficit irrigation on water saving and an additional area that to be irrigated.*

The result showed that the water saved by T4 (application of 70% ETc) can irrigate additional land of 0.40 ha which can produce 13.11 ton of additional onion bulb yield (Table 8) with the minimum yield reduction factor (ky) (Table 9) by saving 30% of irrigation water.

The study revealed that yield response factor (ky) increases with decreasing irrigation water application level. Since the obtained Ky<1, the crop is more tolerant to water deficit, and recovers partially from a deficit, exhibiting less than proportional reductions in yield with reduced water use.

When Ky> 1, the crop response is very sensitive to water deficit with proportional larger yield reductions; Ky< 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; Ky = 1, the yield reduction is directly proportional to reduced water use [7].

Table 9. *Yield Response Factor of Onion.*

Treatments	ETc (mm)	Onion yield (kg/ha)	$1-\frac{Ya}{Ym}$	$1-\frac{ETa}{ETm}$	Ky
T1	423.8	38086	0	0	0
T2	381.42	36657	0.037	0.1	0.37
T3	339.04	34326	0.098	0.2	0.48
T4	296.66	32490	0.1469	0.3	0.49
T5	254.28	29077	0.236	0.4	0.59
T6	211.90	25213	0.3379	0.5	0.68
T7	169.52	22228	0.4163	0.6	0.69

Note: ETc-crop evapotranspiration (mm), Ky- yield response factor, Eta-actual Evapotranspiration (mm), ETm- maximum evapotranspiration (mm), Ya-actual yield (kg/ha) and Ym-maximum yield (kg/ha).

3.6. Effect of Deficit Irrigation on Economic Water Productivity

Data concerning economic comparison was presented in Table 10. The detailed evaluation of the economic analysis of irrigation treatments had shown that there was an increasing trend of net income (NI) for an increase in the water application level. This was because the unit price of irrigation water of 3 birr/1000m^3, the rate of farms in the area pay for irrigation water was very low. As a result, the direct impact of water saving in generating NI was very low for a hectare of land per season which means the very small value from a hectare. Maximum total cost (42439.7 ETB) was obtained by control treatment whereas the minimum variable cost (24175.9 ETB) was obtained by T7.

Benefit-cost ratio (BCR) of each treatment was computed as the ratio of NI earned to the TC expended. Accordingly, maximum BCR (6.28) was obtained by T4 means that treatment which receives an application level of 70% ETc. However, the lower BCR was recorded by T1 and T2. This implies that even though the maximum yield was obtained by those treatments they were economically not more attractive. From this economic analysis T4 (70% ETc application level of irrigation water) was the most economically attractive treatment with high BCR and optimum net benefit.

Table 10. *Partial Budget Analysis for Deficit Irrigation.*

T	I. water (m^3/ha)	UMY (Kg/ha)	AMY (Kg/ha)	TR (ETB/ha)	TVC (ETB/ha)	TFC (ETB/ha)	TC (ETB/ha)	NI (ETB/ha)	BCR
T1	6783.3	37026	33323.4	266587.2	30439.7	12000	42439.7	236147.5	5.56
T2	6105.0	33390	30051.0	240408.0	27395.8	12000	39395.8	213012.3	5.41
T3	5426.7	32026	28823.4	230587.2	24351.8	12000	36351.8	206235.4	5.67
T4	4748.3	31998	28798.2	230385.6	21306.8	12000	33306.8	209078.8	6.28
T5	4070.0	27017	24315.3	194522.4	16727.6	12000	28727.6	177794.8	6.19
T6	3391.6	24313	21881.7	175053.6	15219.9	12000	27219.9	159833.7	5.87
T7	2713.3	21128	19015.2	152121.6	12175.9	12000	24175.9	139945.7	5.79

Note: T- Treatment, UMY-unadjusted marketable yield, AMY- adjusted marketable yield, TR-total revenue, TVC-total variable cost, TFC-total fixed cost, TC-total cost, NI-net income, BCR-benefit-cost ratio.

4. Conclusion and Recommendation

The finding showed that water productivity increase as water application level decrease and vice versa. This implies that water productivity reduced as more water was consumed even though the maximum yield was obtained. Statistically, water productivity of T4 (70%ETc application level) had no significance different from the treatment which produces maximum water productivity (40% ETc application level). By saving 30% of irrigation water, the application of 70% ETc was producingoptimum yield with optimum water productivity than other treatments. Economic analysis of the study shown that BCR of treatments was affected by different application levels of irrigation water. Even though the net income of control treatment (100% ETc application level) was high, the BCR obtained by this treatment was small.

Based on water productivity, economic visibility, total yield, percent of yield reduction, and yield response factor, 70% ETc application level of irrigation water was recommended as the best application-level than the other treatments. Since the water productivity value obtained by 100% ETcapplication level was very small, a full application of irrigation water should not be used for the production of onion in water-scarce area. The deficit irrigation strategy should be adopted by farmers and other users to save scarce water resource in water-limited area.

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