Effect of Regulated Deficit Irrigation and Mulch Levels on Quality and Economic Importance of Onion (*Allium Cepa* L.) at Werer, Middle Awash Valley, Ethiopia

ABSTRACT

In Ethiopia, the Onion is one of the most significant vegetables produced by smallholder farmers mainly as a source of cash income and for seasoning the local stew. The rift valley area is a semi- arid with limited water resources and cumulative demand for water combined with high evapotranspiration rates limits the production and productivity of the Onion crop. Hence, alternatives need to be explored for effective and efficient use of the existing water resources. Thus, a field experiment was conducted at Werer Agricultural Research center to evaluate the response of onion (Allium cepa L) Quality and Economic Importance under deficit irrigation and straw mulching levels. The experiment was laid out in a randomized complete block design in factorial technique of three levels of irrigation (100, 80 and 60% of ETc) and four levels of straw mulch (0, 3, 6 and 9 ton wheat straw per ha) in three replications. The output of the Cropwat model showed that the highest seasonal water requirement of onion was 422.5 mm at 100% ETc while; the lowest was 253.5 mm at 60% ETc. The analysis of variance revealed that statistically, there was a significant ($p<0.05$) difference in leaf diameter, neck and bulb diameter, and marketable bulb yield by interaction effect of deficit irrigation and straw mulch levels; and Total soluble solid and bulb dry matter content were highly significant ($p<0.01$) influenced by the main effects of deficit irrigation and straw mulch levels. The highest marketable bulb yield (33.47 t/ha) was obtained from an experimental plot treated with a combined application of 100% of ETc and 6 t/ha straw mulch, while the lowest (21.10 t/ha) was obtained from plots treated with 60% ETc irrigation level and no mulch treatment. Partial budget analysis revealed that the most economically attractive combination for small-scale farmers with lower cost of production and higher net benefits was from the application of 80% ETc and 6 t/ha straw mulch. Therefore, in terms of marketable bulb yield and water profitable productivity, irrigating with 80% ETc with 6 t/ha straw mulch would be recommended for production of onion in the study area.

Keywords: Deficit irrigation, Evapotranspiration, Partial budget analysis, Straw mulch, Onion Marketable yield, TSS

1. INTRODUCTION

In Ethiopia, the Onion is one of the most significant vegetables produced by smallholder farmers mainly as a source of cash income and for seasoning the local stew 'wot' (Lemma and Shemelis, 2003). According to survey work showed on small-scale irrigation operators of 500 agro-pastoral households in Amibara and Fentale districts of the Awash basin, onion cultivar Bombay Red yielded an average of 19.3 tons per ha at an increasing rate of returns to production where the household generated income in profitability rate (Nigussie *et al.*, 2015). Nowadays, the problem facing irrigated agriculture is how to increase crop yield while utilizing a finite amount of water. Adopting techniques that enhance water management, particularly at the field scale, is one

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strategy to address this problem. In order to do this, the combined practices of mulching and controlled deficit irrigation seem highly promising. Irrigating crops with less water than necessary is known as regulated deficit irrigation. This can be accomplished by decreasing the amount of water applied per irrigation at certain crop growth stages that are known to be less sensitive to moisture stress, or by withholding or skipping irrigation events. This method saves water, labor costs, and sometimes even energy, even though it frequently results in lower agricultural yields. Evidence from studies has demonstrated a correlation between deficit irrigation practices and higher crop water productivity, particularly when the moisture stress brought on by the shortfall is not as severe (e.g. Sammis et al., 2000; Kirda, 2002; Igbadun et al., 2006).

According to Kadayifci et al. (2005), deficit irrigation can give higher economic returns than maximizing yields per unit of area when there is a limited supply of water. Without a doubt, the use of deficit irrigation to increase water output is becoming more and more popular. Mulching, on the other hand, is covering the cropped soil surface with either organic or inorganic materials. Mulching can lower evaporation, retain soil moisture, alter soil temperature, and enhance aeration. Typical organic mulching materials are grasses and crop leftovers; typical inorganic mulching materials are synthetic materials, such as polyethylene sheets in various thicknesses and colors. Studies have demonstrated that a significant portion of the overall evapotranspiration is attributed to soil surface evaporation. According to research findings, a cropped field's total evapotranspiration is mostly attributed to soil surface evaporation (Ahmad et al., 2007). Evaporation is the primary source of moisture loss from the plant root zone until the crop reaches complete vegetative cover. Although it might have helped shape the microclimate in which the crop grew, water lost through evaporation is not employed to the crop's advantage in yield production. More water is easily accessible in the soil when the rate of evaporation is decreased by mulching the soil surface. Because of this, the crop is able to retain the turgidity of its leaves, which improves the efficiency of radiation consumption and the creation of biomass output. It also balances its transpiration rate with the atmospheric water demand (Anisuzzaman et al., 2009).

The rift valley area is a semi- arid with limited water resources and cumulative demand for water combined with high evapotranspiration rates limits the production and productivity of the crop. Hence, alternatives need to be explored for effective and efficient use of the existing water resources (Enchalew *et al.*, 2016). There is a growing interest in irrigating with different deficit level of irrigation to improve water productivity. Mulching is another agronomic practice for conserving soil moisture and reducing the rate of evaporation. Combination of regulated deficit irrigation and mulching is expected to improve crop yield. Zhang *et al*. (2014) found that mulching with straw reduced soil evaporation loss, improve water infiltration and conserved soil moisture. In addition, straw mulching saved 30% of irrigation water and increased water use efficiency (Zhang *et al*., 2014). This can be achieved by introducing improved cultural and water management practices. Straw mulch not only conserves soil moisture, but also increases soil temperature, reduce weed problems and simulate higher crop yields by more efficient utilization of soil moisture (Biswas *et al.*, 2017). Deficit irrigation and straw mulch are known to individually save scarce water but, there has not been a study made to use surface irrigation in conjunction with surface covering for different climate and crop under moisture stress in

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Ethiopia. Therefore, in view of the existing low productivity and water shortage, this study needed to be carried out.

Objectives

- To investigate the effect of deficit irrigation and straw mulch levels on quality and economic importance of Onion.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Werer Agricultural Research Center (WARC) experimental site during 2018/19 off-season (September to March). Werer is located in Gabiresu Zone of Afar Regional State and found at 280 km from Addis Ababa in the eastern direction (Figure 1). The center is located at 9^0 16’8” N and 40^0 9’41” E, and an altitude of 740 m.a.s.l.

The soil of experimental site is mainly Fluvisols followed by Vertisols occupying about 30% of the total area (Wondimagegne and Abere, 2012). The Fluvisols are coarser in texture than Vertisols and their textural classes range between clay and silt loams. The soils are brown in color and turn to dark brown when moist. Generally, the wide-spread occurrence of salinity and sodicity problem in irrigated area of Amibara District farms is mainly due to weathering of Na, Ca, Mg and K rich igneous rocks and poor irrigation water management (Ashenafi *et al*., 2016). According to Werer Agricultural Research Center long term climatic data (1988 - 2017), the relative humidity ranges between 37 and 55%. The mean monthly rainfall distribution indicates that, July and August are the main rainy season followed by March and April (short rainy season) (Figure 2)

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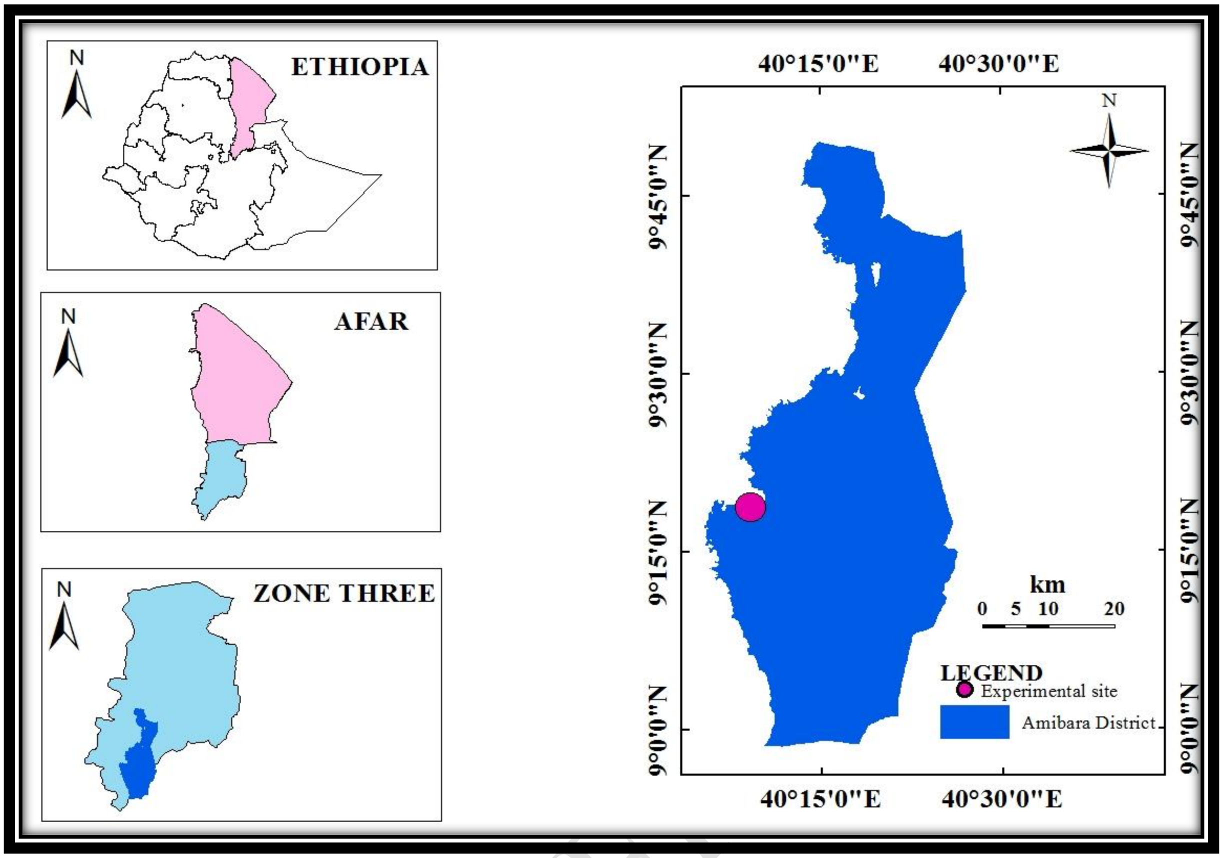

Figure 1. Map of the study area

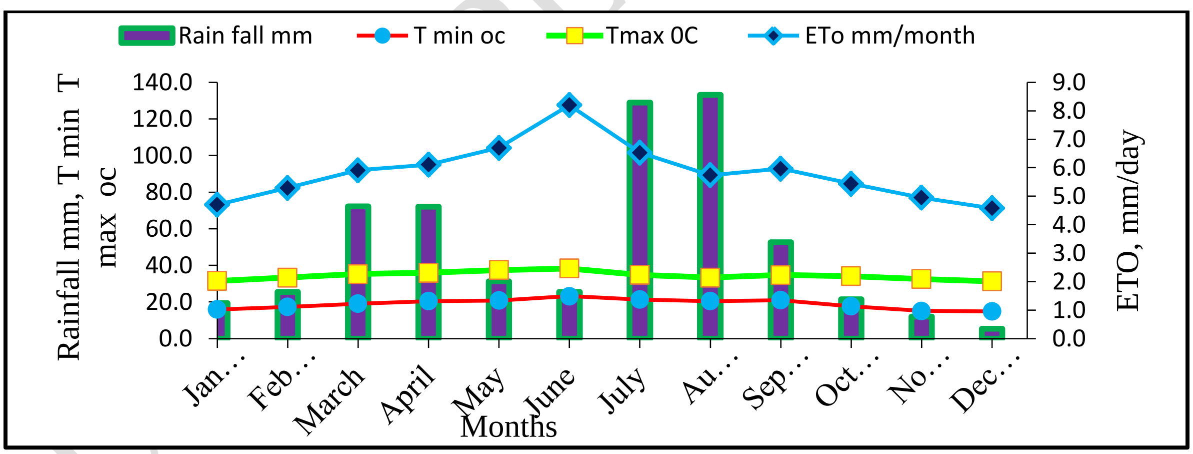

Figure 2. Mean monthly rainfall (mm), minimum and maximum temperature (^{o}c), and ETo (mm/day) of the study area.

2.2. **Data Collection, Computations and Analyses**

2.2.1. Soil sampling and analysis

Moisture content at field capacity (FC) and permanent wilting point (PWP) were determined at Oromia Water Works Enterprise Soil laboratory.

Soil texture was determined by the Boycouos hydrometer method for analyzing soil particle size distribution (Bouyoucos, 1962) and the textural class was assigned using USDA textural triangle.

Bulk density: To determine bulk density, undisturbed soil sample of known volume was taken using core-sampler from four representative places in the trial plot at three different depths (0-20 cm, 20-40 cm and 40-60 cm) (Hillel, 2004).

$$\mathrm{Bd} = \frac{\mathrm{Ms}}{\mathrm{Vt}} \qquad (3.1)$$

Where, Bd = bulk density (g/cm^3), Ms = dry weight of the soil (g) and Vt = total volume of the soil (cm^3).

Infiltration Rate Determination: Infiltration characteristic of the soil was resolute with double ring infiltrometer as outlined by Walker (2003) was observed to install and recording the parameters.

Then, Kostiakov Equation – A simple form of the Infiltration equation which is in general use was developed by Kostiakov (1932) and is expressed as:

$$\mathrm{Y} = \mathrm{at}^{b} \qquad 3.4$$

where: Y- cumulative infiltration, t- time from start of infiltration, ‘a’ and ‘b’ are soil constants to be determined experimentally.

2.2.2. Determination of crop water Requirement

Reference Evapotranspiration (ETo): Long term (1988-2017) daily weather data was used to calculate ETo. Climatic parameters that were used are maximum temperature (Tmax), minimum temperature (Tmin), relative humidity (H), wind speed (at two meter) and sunshine hour (hrs). The ETo was estimated by the CROPWAT software (FAO, version 8.0) using the FAO Penman-Monteith approach (Allen *et al*., 1998).

Crop coefficient was collected from FAO Irrigation and Drainage Paper 56 for onion (Allen *et al*., 1998). The crop coefficient values for respective growth stages are 0.7, 1.05 and 0.75 for initial, mid and end stage, respectively. Based on the KC values of the crop and length of each growth stages, daily crop coefficient was interpolated for development and late season. Length of growth stages of 15, 30, 40 and 25 days for initial, development, mid-season and late season, respectively, were considered (Allen *et al*., 1998).

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$$ETC = ETo*Kc \quad (3.6)$$

where, ETc is crop evapotranspiration in mm per day, Kc is crop factor in fraction and ETo is reference crop evapotranspiration in mm per day.

The Net irrigation requirement was calculated using the following equation.

$$NIR = ETC - Pe \quad (3.7)$$

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

Determination of effective rainfall was computed based on equation 3.3 and 3.3 of 'dependable rainfall' (FAO/AGLW formula) using daily rainfall data.

$$Pe = 0.8 * P - 24 \text{ for month } \geq 70mm \quad (3.8)$$
$$Pe = 0.6 * P - 10 \text{ for month} \leq 70mm \quad (3.9)$$

Where, Pe is the effective rainfall (mm/day) and P is total rainfall (mm/day).

The gross irrigation requirement was obtained from the following equation:

$$GIR = \frac{NIR}{Ea} * 100 \quad (3.10)$$

where; GIR = Gross irrigation requirement (mm), NIR = Net irrigation requirement (mm), Ea = Application efficiency (%).

The time required to deliver the desired depth of water into each furrow was calculated using equation 3.6 given by Michael (2008). The time required to deliver the desired depth of water into each plot was calculated using the equation:

$$T = \frac{A*d}{6q} \quad (3.11)$$

where; d = gross irrigation depth of water to be applied (cm), A = Area of the experimental plot (m^2), T= application time (min) and q = flow rate of discharge (l/s).

2.3 Treatment and Experimental Design

The experiment was laid out as randomized complete block design (RCBD) in three replications. The mulching treatment was applied after establishment. The experimental field plot layout was made by dividing the field in to 36 plots (Table 1) and each experimental plot had plot size of 5.4 m by 5 m to contain eight furrows of 5 m length with spacing of 60 cm between ridges and the middle six furrows were considered as net plot from which the data collection was under taken. The spacing between plots and replications was 1.6 m and 3.6 m, respectively to eliminate influence of lateral sub-surface water movement. The spacing between plants and between rows was 10 cm and 30 cm, respectively.

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Table 1. Description of treatments

Treatment No.	Treatment label	Description
T - 1.	$DI_{100}M_{0t}$	100% of ETc, No mulch
T - 2.	$DI_{100}M_{3t}$	100% of ETc, 3 t/ha straw mulch
T - 3.	$DI_{100}M_{6t}$	100% of ETc, 6 t/ha straw mulch
T - 4.	$DI_{100}M_{9t}$	100% of ETc, 9 t/ha straw mulch
T - 5.	$DI_{80}M_{0}$	80% of ETc, No mulch
T - 6.	$DI_{80}M_{3t}$	80% of ETc, 3 t/ha straw mulch
T - 7.	$DI_{80}M_{6t}$	80% of ETc, 6 t/ha straw mulch
T - 8.	$DI_{80}M_{9t}$	80% of ETc, 9 t/ha straw mulch
T - 9.	$DI_{60}M_{0}$	60% of ETc, No mulch
T - 10.	$DI_{60}M_{3t}$	60% of ETc, 3 t/ha straw mulch
T - 11.	$DI_{60}M_{6t}$	60% of ETc, 6 t/ha straw mulch
T - 12.	$DI_{60}M_{9t}$	60% of ETc, 9 t/ha straw mulch

T = treatments, ETc = Crop evapotranspiration, DI = deficit irrigation, M = straw mulch levels.

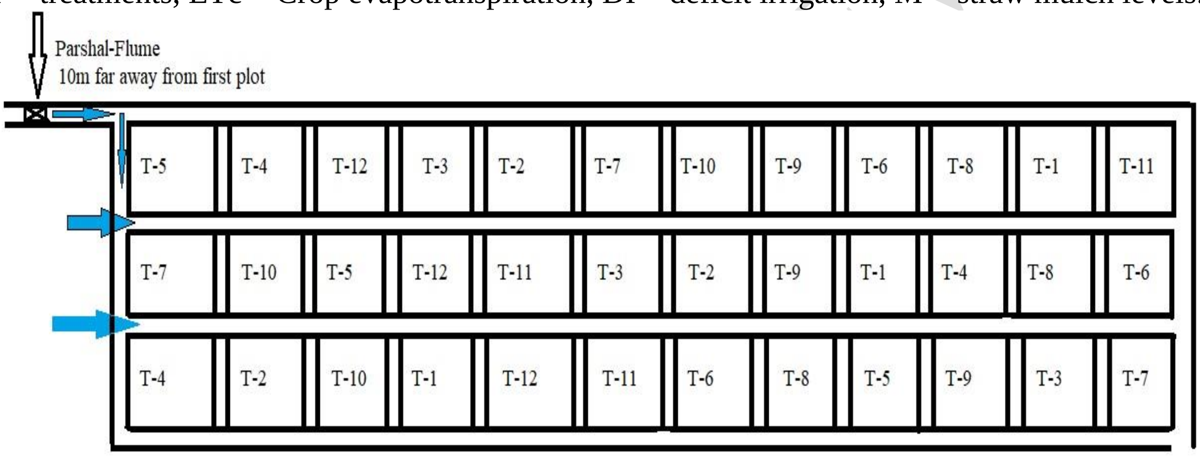

Figure 3. Field layout of the experiment

2.4 Growth and Yield Parameters Data Collection

Leaf diameter (cm): The mid-diameter of the longest leaves of ten randomly selected plants was measured at physiological maturity using caliper and the average mean diameter were calculated.

Bulb dry matter (g): Six bulbs were randomly taken from each plot and chopped into small 1-2 cm cubes, mixed thoroughly, and two sub-samples each weighing 200g was weighed. The exact weight of each sub-sample was determined and recorded as fresh weight. Each subsample was placed in a paper bag and put in an oven until constant dry matter was attained. Each sub-sample was then immediately weighed and recorded as dry matter yield.

Total soluble solid (^{0}Brix): The TSS was determined at harvesting time from ten randomly selected bulbs using the procedures described by Waskar *et al*. (1999). The TSS was determined by a hand refracto-meter (ATAGO TC-1E) with a range of 0 to 32 ^{0}Brix and resolutions of 0.20 Brix by placing 1 to 2 drops of clear juice on the prism, washed with distilled water.

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Bulb length (cm): The lengths of ten randomly selected bulbs per plot were measured from the bottom to the top using caliper and the mean value was computed.

Bulb diameter (cm): The mean size of the bulb at harvest was computed by measuring the diameters at the middle of ten randomly selected bulbs in each plot using caliper (Lemma and Shimeles, 2003).

Marketable bulb yield (t/ha): Bulbs which are free of mechanical, disease and insect pest damages, uniform in color and medium to large in size (20 - 160 g) was considered as marketable yield. The weight of such bulbs obtained from the net plot area of each plot was measured in kilogram using scaled balance and expressed as ton per hectare (Lemma and Shimeles, 2003).

2.5. Data Analysis

The collected data were statistically analyzed appropriate for RCBD using statistical analysis system (SAS) version 9.0 statistical package using procedure of general linear model (SAS, 2002) for the variance analysis. Mean comparisons were executed using least significant difference (LSD), when treatments show significant difference to compare difference among treatments mean.

2.6. Partial Budget Analysis

The variable costs of this experiment among treatments were cost of irrigation water, straw mulch and costs of labor for irrigating. Irrigation water users in the middle Awash Valley are charged for their water consumption on volume basis with a charging rate of 3 ETB/1000 m^3 (Gebremeskel and Mekonnen, 2014). The cost of wheat straw mulch was 2 ETB per kg. The cost for daily labor during the experimental season was 60.00 Birr per day. The farm gate price of onion during the harvesting season was 7.0 Birr per kg. The net income (NI) was calculated by subtracting total variable cost (TVC) from TR (Kuboja and Temu, 2013) and is computed as:

$$\mathrm{NI} = \mathrm{TR} - \mathrm{TVC} \qquad (3.14)$$

Where: NI -Net income, TR -Total income from sales, TVC -Total variable cost spent during production.

The marginal return rate measures the increase of the net income, which is generated by each additional unit of expenses and is computed as equation 3.13.

$$\mathrm{MRR} = \frac{\Delta \mathrm{NI}}{\Delta \mathrm{VC}} \qquad (3.15)$$

Where: MRR-Marginal rate of return (%), ∆NI – change in net income, ∆VC – change in variable cost.

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3. RESULTS AND DISCUSSION

3.1. Preliminary Field Investigation Results

Selected phyico-chemical properties of the soil of the experimental site such as Texture, bulk density, field capacity, permanent wilting point, pH, EC and organic matter content were analyzed and summarized (Table 2 and 3).

Table 2. Physical properties of soils of the experimental site

Soil physical property		Soil depth		
		0-20 cm	20-40 cm	40-60 cm
Texture (Particle size distribution)	Sand (%)	13	12	11
	Silt (%)	38	38	38
	Clay (%)	49	50	51
Textural class		Clay	Clay	Clay
Field Capacity (%) (Weight basis)		40	39.5	39
Permanent Wilting Point (%) (Weight basis)		24	23	22
Bulk density (g/cm^3)		1.29	1.30	1.31
Total Available Water (mm/m)		206.4	214.5	222.7

Table 3. Analysis of chemical properties of soil and Irrigation water

Soil depth (cm)	Soil chemical properties					
	pH	EC (dS/m)	TOC (%)	TN (%)		
0-20	8.51	1.71	1.11	0.05		
20-40	8.31	1.35	0.90	0.04		
40-60	7.96	0.92	0.70	0.05		
Average	8.26	1.33	0.90	0.046		
		Irrigation Water chemical properties				
			[Ca]+ [Mg] (meq/l)		[Na] (meq/l)	SAR
	8.2	0.95	5.90		5.70	3.32

TN = Total Nitrogen, TOC = Total organic carbon.

Infiltration characteristics of the experimental site

This data was used to generate the cumulative infiltration and the infiltration rate curves as shown in Figure 4. The infiltration rate which is the speed at which water enters into the soil is measured by the depth (in mm) of the water layer that can enter the soil in one hour. The basic infiltration rate in this experiment was found to be 5.2 mm/hr. which was in the upper range of clayey soil (1-5 mm/hr.) (Hillel, 2004). This means that a water layer of 5.2 mm on the soil surface will take one hour to infiltrate.

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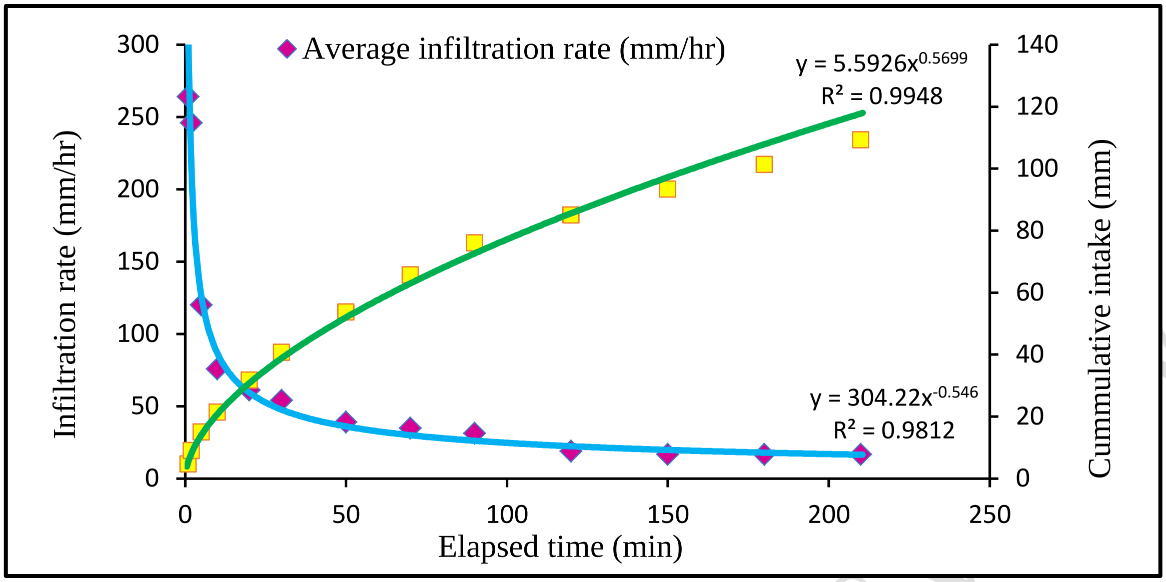

Figure 4. Cumulative intake and infiltration rate curves for the soil of experimental site.

3.2. Crop Water Requirement of Onion

Seasonal crop water requirement of onion was determined based on the seasonal water application depth from transplanting to harvest and varied based on treatments. The highest net irrigation water application was 422.5 mm obtained from the control treatment (100% ETc) and the minimum was 253.5 mm from the highly stressed treatment (60% ETc). The highest gross irrigation seasonal water requirement that was calculated by applying 60% field application efficiency was obtained from 100% ETc as 704.12 mm and the lowest was 422.5 mm from 60% ETc. The result of onion seasonal water demands of 422.1 mm that was obtained from optimal irrigation agrees with MOA (2011) and Gobena *et al*. (2017).

3.3. Effect of Deficit Irrigation and Straw Mulch Levels on Leaf diameter

Analysis of variance revealed that deficit irrigation and straw mulching levels had a highly significant ($P < 0.01$) influence on onion leaf diameter. The interaction effect of the two factors had also significant ($P < 0.05$) influence on leaf diameter of onion. The experimental plots treated with 100% ETc and 9 t/ha straw mulching produced leaves with the widest diameter (3.33 cm), but there was no significant difference from plots treated with 100% ETc and 6 t/ha (Trt 3), 80% ETc and 6 t/ha (Trt 7), and 60 ETc and 9 t/ha (Trt 12). However, plots treated with 60% ETc and no straw mulch produced leaves having narrowest diameter (1.77 cm), and had non-significant difference with 100 and 80% ETc irrigation application with no straw mulch.

Thus, the leaf diameter of onion experimental plots treated with 100% ETc and 9 t/ha straw mulching increased by 53.15% as compared to the leaf diameter of onion plots treated with 60% ETc and no straw mulching (Table 4). The increase in leaf diameter with increase irrigation water could be mainly due to better availability of soil moisture that has enhancing effects on the vegetative growth of plants by increasing cell division and elongation.

Table 4. Effects of Deficit irrigation and straw mulching levels on Leaf diameter of onion

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Treatments	Leaf diameter of onion (cm)			
Deficit Irrigation	Straw mulching levels (t/ha)			
	0	3	6	9
100% ETc	2.24[efg]	2.53[cde]	3.10[ab]	3.33[a]
80% ETc	1.97[fg]	2.66[bcde]	2.95[abc]	2.83[bcd]
60% ETc	1.77[g]	2.43[def]	2.71[bcde]	2.90[abcd]
LSD (0.05)	0.50			
CV (%)	11.16			

Means followed by the same letter are not significantly different at 5% level of significance.

3.3.1. Effect of Deficit Irrigation and Straw Mulch Levels on Neck and bulb diameter

Statistical analysis revealed that deficit irrigation and straw mulching levels had highly significant ($P < 0.01$) influence on bulb neck diameter. The interaction effect of the two factors also had a significant ($p<0.05$) effect on neck diameter of onion. The widest (2.48 cm) neck diameter of onion was recorded from the application of 100% of ETc and 9 t/ha straw mulching and had non-significant difference with 100% ETc and 6t/ha straw mulch. The narrowest (1.25 cm) neck diameter, on the other hand, was obtained from combined application of 60% of ETc and no mulch treatment and had non-significant difference with 80% ETc with no straw mulch, and 60% with 3t/ha straw mulch (Table 5).

The analysis of variance has shown a highly significant ($P<0.01$) difference in bulb diameter among different deficit irrigation and straw mulching levels. The interaction of deficit irrigation and straw mulching level had significant ($P < 0.05$) effect on the onion bulb diameter (Table 6). The application of 100% of ETc in combination with 6 t/ha straw mulch gave the highest onion bulb diameter of (6.38 cm) and had non-significant difference with the application of 80% ETc and 6 t/ha straw mulch. This might be due to an adequate amount of soil moisture application leads to larger photosynthesis area, resulting in large bulb diameter.

This result agreed with a study done by Demirtas and Serhat (2009) who indicated that the bulb diameter has increased trend with increasing level of irrigation application. Mubarak and Hamdan, (2018) from trend analysis indicated that the bulb diameter was related linearly with the irrigation levels (as percentage of ETc), with R^2 value of 0.998 and 0.994 at the 1% level, under mulch and no-mulch condition, respectively. Irrespective of the system of soil cover used, the highest diameter was recorded at the 100% of ETc and the lowest value was recorded at the 60% of ETc, with a significant decrease of about 40%.

Table 5. Effects of deficit irrigation and straw mulching levels on neck diameter, bulb diameter and bulb length of onion

Deficit Irrigation	Neck diameter (cm)				Bulb diameter (cm)			
	Straw mulching levels (t/ha)							
	0	3	6	9	0	3	6	9
100% ETc	1.68[cde]	1.80[bc]	2.36[a]	2.48[a]	5.07[g]	5.52[def]	6.38[a]	5.73[cd]
80% ETc	1.48[ef]	1.70[cde]	1.97[b]	1.88[cb]	4.66[h]	5.32[efg]	6.20[ab]	5.94[bc]

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60% ETc	1.25^{f}	1.50^{def}	$1.74b^{cd}$	1.82cb	4.16^{i}	5.00^{gh}	5.17^{fg}	5.70^{cde}
LSD (5%)	0.26				0.40			
CV (%)	8.61				4.33			

Means followed by the same letter are not significantly different at 5% level of significance.

3.3.2. Bulb length

Statistical analysis made on yield components indicated that the interaction effect of deficit irrigation and straw mulching levels had a significant ($p< 0.05$) influence on bulb length of onion. The longest (4.28 cm) onion bulb length was obtained from experimental plots treated with 80% ETc and 9 t/ha straw mulching and it had non-significant difference with the combination of 100% ETc with 3, 6, 9 t/ha straw mulching, 80% ETc and 6, 9t/ha, and 60% ETc with 3 and 9t/ha. The shortest (2.98 cm) were obtained from plots treated with 60% ETc and no mulch treatment, had no significant difference with 80% ETc and no mulch (Table 7). This is an indication that larger onion sizes can be produced when the applied water is optimum and the moisture stress affect the size of the onion negatively.

The result indicated that the lower 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 6. Effects of deficit irrigation and straw mulching levels on bulb length and average bulb weight of onion

Deficit Irrigation	Bulb length (cm)			
	Straw mulching levels (t/ha)			
	0	3	6	9
100% ETc	3.54^{d}	4.06^{ab}	4.20^{ab}	4.03^{ab}
80% ETc	3.20^{e}	3.77^{cd}	4.08^{ab}	4.28^{a}
60% ETc	2.98^{e}	4.03^{ab}	4.00^{cb}	4.26^{a}
LSD (5%)	0.25			
CV (%)	3.85			

Means followed by the same letter are not significantly different at 5% level of significance.

3.3.3. Total soluble solids

The effect of deficit irrigation and straw mulching levels had a significant ($P < 0.05$) influence on the total soluble solids (TSS) of the onion. However, the interaction of deficit irrigation and straw mulching levels application didn't show any significant difference on the total soluble solids of the onion. The highest total soluble solids (13.15 ^{o}brix) were recorded from experimental plots treated with 100% ETc irrigation level and the smallest TSS (11.61 ^{o}brix) was recorded from experimental plots irrigated by 60% ETc, and had no significant ($p<0.05$) difference with 80% ETc deficit irrigation. This might be adequate irrigation application is better

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for onion bulb development and quality, which may be attributed to better utilization of nutrients under controlled irrigation water application. A similar result was also reported by Fatideh and Asil (2012) who indicated that the total soluble solids (TSS) of onion increased with the increase in irrigation from 0.50 to 1.10 of potential evaporation. This result was also in conformity with Patel and Rajput (2013), who found that TSS of onion varies with the variation in irrigation levels at different growth stages.

The highest TSS (13.0 ^{o}brix) was recorded from application of 6 t/ha straw mulching and had no significant difference with all mulch levels, except with no mulch. The lowest TSS value was recorded from no mulch treatment and had no significant difference with 3t/straw mulch (Table 8). Mulching increased TSS content in general and the better TSS by mulching might be due to more assimilation of nutrients and better soil moisture as observed by Olfati *et al*. (2008) in carrot.

3.3.4. Bulb dry matter content

The analysis of variance showed that bulb dry matter content of onion was significantly ($P < 0.01$) affected by the main effects of straw mulching levels and deficit irrigation. However, the interaction effect of these two factors had non-significant influence on bulb dry matter yield. The highest onion bulb dry matter content (15.37g) due to irrigation treatments was obtained from experimental plot treated with the application of 100% ETc and this had non-significant difference with 80% ETc deficit irrigation and the lowest bulb dry matter content (13.82 g) recorded from irrigation application of 60% ETc. This could possibly be due limitation in assimilate production and accumulation in bulbs under stress conditions.

On the contrary, Olalla *et al*. (2004) reported that the dry matter yield was not affected by the volume of water intake (with volumes ranging from 603.1 to 772.0 mm) in drip irrigation system. The dry matter yield was predicted to significantly increase with the decrease in the level of water deficit increases. This is in close conformity with findings of Kadayifci *et al.* (2005), Nagaz *et al.* (2012), and Patel and Rajput (2013). For example, Nagaz *et al.* (2012) found that applying 40% of water deficit (i.e., irrigating with 60% of ETc) caused considerable decreases in dry matter, bulb weight, and bulbs per hectare compared to those under either 100% ETc or regulated deficit irrigation at 80% ETc.

On the other hand, the highest onion bulb dry matter (15.66g) due to straw mulching level was recorded from the experimental plots treated with 6 t/ha straw mulch and had no significant difference between mulch levels except no mulch treatments (Table 8). The lowest value (13.35g) was obtained from the experimental plots treated with no mulch treatments.

Table 7. Effect of deficit irrigation and straw mulching levels on total soluble solids and bulb dry matter of onion

Treatment	Parameters	
Deficit Irrigation	Total Soluble Solids (^{o} brix)	Bulb dry matter (g)
100% ETc	13.15^a	15.37^a
80% ETc	12.17^b	15.05^a
60% ETc	11.61^b	13.82^b

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Treatment	Parameters	
Deficit Irrigation	Total Soluble Solids (^{o} brix)	Bulb dry matter (g)
LSD (5%)	0.86	0.76
Straw Mulching Levels (t/ha)		
0	11.37^{b}	13.35^{b}
3	12.26^{ab}	14.94^{a}
6	12.98^{a}	15.66^{a}
9	12.62^{a}	15.02^{a}
LSD (5%)	1.00	0.87
CV (%)	3.02	6.05

Means followed by the same letter are not significantly different at 5% level of significance.

3.3.5. Marketable bulb yield

Analysis of variance exhibited that the interaction effect of deficit irrigation by straw mulching levels exhibited a highly significant (P<0.01) influence on the marketable yield. The highest marketable yield of onion (33.47 t/ha) was obtained from combined application of 100% ETc irrigation and 6 t/ha straw mulch and not statistically different with 80% ETc and 6t/ha straw mulch. The lowest marketable yield (21.10 t/ha) was obtained from treatment received 60% ETc and no mulch. As the level straw mulch increases from 3, 6 and 9t/ha irrespective increasing irrigation levels, for instance at 80% ETc, marketable bulb yield increases by 11%, 26% and 14%, over non-mulch treatment, respectively. Higher marketable bulbs of onion at higher irrigation levels might be due to the increase in the formation of growth measurements causing faster synthesis and transportation of photosynthates from source to descends. Similarly, the finding of Singh and Singh (2018) indicated that onion bulb yield (t/ha) increase significantly with increase in irrigation regimes and using residue mulching.

Among deficit irrigation and straw mulch levels, treating the experimental plots with 80% ETc. The trend to imply marketable yield shows that was significantly higher as the soil moisture stress decreases. This could be due to the difference in depth of irrigation water applied. The increment of marketable yield as the amount of irrigation levels increased is similar with the previous work of Habtie (2007) which indicated that yield reduction was associated with increase in soil moisture tension which when allowed continuing resulted in loss of turgidity, cessation of growth and yield reduction. Daniel *et al.* (2018) also obtained highest marketable yield of onion bulbs applying water depth corresponding to 100% ETc, compared with 75% ETc, performing irrigation management with Class A pan and without using mulch. In conformity to the current results, Igbadun *et al*. (2012) reported that the bulb yield of onion was highly decreased through regulated deficit irrigation. Similar results were also reported by Kloss *et al.* (2012) who showed that improvement of water productivity is closely related to the irrigation practice of regulated deficit irrigation and has a direct effect on marketable bulb yield that is, if the amount of water applied decreases intentionally the crop yield will decrease. Moreover, the increment in marketable bulb yield due to application of straw and irrigation water could be credited to the increment in vegetative growth and increased production of assimilate, which is linked with increment in leaf area index, bulb diameter and average bulb weight.

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Table 8. Effects of deficit irrigation and straw mulching levels on marketable bulb yield of onion

Deficit Irrigation	Marketable bulb yield (t/ha)			
	Straw mulching levels (t/ha)			
	0	3	6	9
100% ETc	25.80^{cd}	26.77^{c}	33.47^{a}	29.64^{b}
80% ETc	23.36^{e}	26.37^{cd}	31.57^{ab}	27.19^{c}
60% ETc	21.10^{f}	23.23^{e}	24.53^{de}	25.90^{cd}
LSD (5%)	1.94			
CV (%)	4.32			

Means followed by the same letter are not significantly different at 5% level of significance.

3.4. Partial Budget Analysis

The highest benefit cost ratio (5.1) was obtained from T-9 (60% ETc with no mulch) and minimum BC ratio (2.4) obtained from T-12 (60% ETc and 9t/ha straw mulching). Maximum yield may be obtained with the fulfillment of the entire crop water requirements. However, practicing irrigation with deficit irrigation level can save irrigation water which increases the irrigated area, frequency of cultivation or release more water for downstream. The economic importance of water used can be worked out for specific situation before expanded to the large scale for adoption. However, the use of deficit irrigation (DI) and straw mulching for better growth and higher yield could be economically attractive to reduce the drought stressed conditions in water limiting areas. The results in line with Ali *et al*. (2007) who reported water saved by DI can be used to irrigate more land on the same farm or in the water user's community, which, given the high opportunity cost of water, and may largely compensate for the economic loss due to yield reduction.

The dominance (D) analysis for the different amount of water and straw mulching levels are shown in Table 9. The dominance analysis was done based on total variable cost and net benefit; thus, if variable cost increases and net benefit decreases, the treatments are said to be dominated (CIMMYT, 1988). The minimum acceptable marginal rate of return (MARR %) should be between 50% and 100% CIMMYT (1988). Hence, the most economically attractive combination for small scale farmers with lower total variable cost and higher net benefits were in response to the application of 80% ETc and 6 t/ha straw mulching (T-7). However, for resource full producers (investors), application of 100% ETc and 6 t/ha straw mulch (T-3) was also with higher cost and highest net benefit is recommended as a second option.

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Table 9. Partial budget, MRR and BCR analysis for deficit irrigation and straw mulching levels trial on marketable yield of onion

Treatments	Gross irrigation (m^3/ha)	UMY (kg/ha)	AMY (kg/ha)	Gross Income (birr/ha)	TVC (birr)	NB (birr/ha)	MRR (%)	BCR
9	4225.0	21100.1	18990.09	132930.63	21800.13	111130.50	-	5.1
5	5633.3	23358.9	21023.01	147161.07	26300.17	120860.90	216.2	4.6
1	7041.7	25803.3	23222.97	162560.79	27500.22	135060.57	1183.3	4.9
10	4225.0	23225.6	20903.04	146321.28	29800.13	116521.15	D	3.9
6	5633.3	26373.3	23735.97	166151.79	34300.17	131851.62	340.7	3.8
2	7041.7	26770.7	24093.63	168655.41	35500.22	133155.19	108.6	3.8
11	4225.0	24533.3	22079.97	154559.79	37800.13	116759.66	D	3.1
7	5633.3	31570	28413.00	198891.00	42300.17	156590.83	885.1	3.7
3	7041.7	33466.7	30120.03	210840.21	43500.22	167339.99	895.7	3.8
12	4225.0	25896.7	23307.03	163149.21	45800.13	117349.08	D	2.6
8	5633.3	27186.7	24468.03	171276.21	50300.17	120976.04	80.6	2.4
4	7041.7	29635.7	26672.13	186704.91	51500.22	135204.69	1185.7	2.6

T = Treatments, UMY = Unadjusted marketable yield, AMY= Adjusted marketable yield, TVC = Total variable cost, NB = net benefit, BCR = benefit cost ratio, MRR = marginal rate of return, D = dominated.

4. CONCLUSIONS

Based on the above findings, the following conclusion can be made for further consideration and improvement of onion production and water productivity in the study area in particular and water stressed area in general.

- ✓ Adopting the 80% ETc with 6 t/ha wheat straw mulch application is suggested because of its higher marketable bulb yield, economical attractive and higher water productivity; it is the best alternative for better onion production in the study area.
- ✓ However, as the experiment is conducted in one location for one season using one cultivar, conducting similar researches over locations and seasons involving new cultivars would be relevant to get conclusive result for best recommendation.

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