Management Practice to Enhance Bulb Yield and Water Productivity of Irrigated Onion under Central Highland Vertisol of Ethiopia

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Abstract

Proper utilization of water resources is crucial for the purpose of sustainable use and improved water productivity in irrigated agriculture sector of Ethiopia. Therefore, this study was conducted at Debre Zeit Agricultural Research Center to select most effective water saving techniques and improve water productivity of irrigated Onion. The experiment was done in a split plot design with three irrigation water application methods (fixed, alternate and conventional furrow method) in main plot and two mulch types (straw and plastic) and control as no mulch. From the study, it has been observed that different types of irrigation method significantly affected (p<0.01) main yield and yield components of Onion. Moreover, Onion ue to

different mulch types used and also there was no interaction effect between irrigation and mulching type. Significantly highest marketable bulb yield (39.5 t/ha) of Onion was recorded due to conventional furrow irrigation method and followed by alternate furrow irrigation method (34.3 t/ha). However, highest water use efficiency (9.7 kg/m^3) was obtained due to alternate furrow irrigation method when compared with the least water use efficiency of conventional furrow method of 5.7 kg/m^3. Hence, there was 18 to 22% increment of marketable yield and water use efficiency of onion by applying mulching over the conventional non-mulching condition and also 42% improvement of water use efficiency by using alternative furrow irrigation over the conventional furrow type. Therefore, for maximizing marketable bulb yield of onion under no water stress scenario, irrigation of onion with conventional furrow irrigation methods could be used. Whereas under limiting irrigation water resource condition, irrigation of onion could be done by alternate furrow irrigation method with plastic mulch application to minimize evaporation loss and maximize water productivity of onion for similar agro-ecology and soil type.

Keywords: Water use efficiency, furrow method, mulch type and water productivity.

Introduction

Water is one of the largest renewable natural resources but fresh water is expected to emerge as a key constraint to future agricultural growth. Globally and more population, industry and domestic requirements partly from consequences of climatic change. Major concerns on future planetary freshwater resources are the effects of climate change on changing sea temperature and levels, drought and flood events, as well as changes in water quality, and general ecosystem vulnerabilities (USGCRP, 2011). Changes in the extreme climatic events are more likely to occur at the regional level than show in national or global statistics. The unpredictability of climatic events is of key concern to farmers in all countries, particularly in Africa.

Ethiopia has a long history of traditional irrigation systems and yet. Simple river diversion still is the dominant irrigation system in Ethiopia. Awulachew *et al.* estimates of the irrigation potential of Ethiopia has estimated that 5.3 million hectares. Of the potential 3.7 million ha is from surface water (small, medium and large scale), while the remaining 1.6 million ha is from rain water harvesting technologies and ground water. In terms of utilization, only about 12% (about 857,933 ha) has been irrigated by 2015 (FDRE, 2016). So, it is prudent to make efficient use of water and bring more area under irrigate on through available water resources. This can be achieved by introducing advanced methods of irrigation and improved water management practices.

Regulated furrow (deficit) irrigation is one way of maximizing water use efficiency for higher yields per unit of irrigation water used in agriculture (Negaz *et al.,* 2012). In deficit irrigation application, the crop is exposed to a certain level of water stress either during a particular growth period or throughout the whole growing season, without significant reductions in yields (FAO, 2000). The expectation is that the yield reduction by inducing controlled water stress will be insignificant compared with the benefits gained through diverting the saved water to irrigate additional cropped area (Gijon *et al.,* 2007). In South-northern Ethiopia conditions, results on deficit irrigation level have positively influenced marketable yield of Onion bulb, with bulb yield decreasing as the water deficit level increased (Bekele and Ketema, 2007). However, previous findings showed that the amount of water applied and method of application varied across the reports by crop and study site.

Mulch in tropics improves nutrient and water retention in the soil, encourages favorable soil microbial activity and worms, and suppresses weed growth. When properly executed, mulching can significantly improve the well-being of plants and reduce maintenance as compared to bare soil culture (Ramakrishna et al., 2006). The use of mulch reduces the natural water losses through evaporation on soil surface, thus leading to net return of crops though maximizing yield & water productivity with limited available water (Singh *et al., 2016)*, (Kumar *et al.,* 2007). Hence, reducing non-productive loss of irrigation water is best achieved through the integrated use of regulated deficit irrigation along with mulching material for maximum water use efficiency (WUE) in arid and semi-arid lands (Igbadun *et al.,* 2012). So, to improve crop production to feed the ever-increasing population under limiting water resource condition, strategies that conserve moisture in the soil and efficient irrigation techniques should be identified and practiced (Zaman *et al.,* 2001). Therefore, this study aimed to select most effective water saving techniques for Onion and evaluate the effect of different furrow irrigation and mulching type on the marketable yield of Onion bulbs.

Materials and Methods

Description of study area

The study was conducted at Debre Zeit Agricultural Research Center, located in the central highlands of Ethiopia. Its (8.760) Northern l (39.010) Eastern longitude. It has low relief difference with altitude ranging from 1610 to 1908 meters above the see level. The soil at the experimental site was heavy clay in textures with field capacity and permanent wilting point of 35% and 19%, respectively. The area receives an annual mean rainfall of around 810.3 mm with the medium annual variability and bimodal pattern. Seasonal variations and atmospheric pressure systems contribute to the creation of three distinct seasons in Ethiopia: Kiremt (June to September), Bega (October to February) and Belg (March to May). The Kiremt is the main rainy and Belg is the short lasting one while the dry season is attributed to Bega (Selshi and Zanke, 2004). Belg in the study area receives quite small rainfall to support crop production whereas Kiremt is known by long rainy season. About 76 % of the total rainfall of the area falls in Kiremt or wet season, about 15% in Belg and the rest is Bega or dry season which needs full irrigation in the area. The mean maximum temperature varies from 23.7 + to 27.70C while mean minimum temperature varies from 7.4 to 12.10C (Table-1). However; maximum and minimum reference Evapo-transpiration (ETo) was recorded as 4.9 and 3.3 mm/day in May and July respectively (Table-2).

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Month	T max (°C)	T min (°C)	Relative humidity (%)	Wind speed (m/s)	Sunshine hour (hrs)	Solar radiation (MJ/M²/day)
January	25.2	8.9	63.0	1.3	9.8	22.0
February	26.3	10.2	46.4	1.4	8.5	21.4
March	27.0	11.3	46.4	1.5	8.1	21.8
April	27.1	11.9	47.7	1.5	7.1	20.4
May	27.7	11.6	46.5	1.6	8.6	22.2
June	26.4	11.4	54.9	1.0	6.3	18.4
July	23.7	12.1	66.4	0.9	4.9	16.4
August	23.9	12.1	67.8	0.9	5.5	17.7
September	24.1	11.5	63.3	0.8	6.7	19.6
October	25.0	9.5	49.9	1.4	8.6	21.7
November	24.6	8.0	47.0	1.3	9.3	21.4
December	24.8	7.4	46.9	1.4	9.4	20.9
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Table-2: Mean Monthly rain fall, effective rainfall and ETo values of study area.

Npoui!	S og mh)nn !	Fggfdu f!S og mh)nn !	F p!)nn0e !	Tf tpo!
January	9.4	0.0	4.0	Bega
February	24.8	4.9	4.4	
March	31.5	8.9	4.7	Belg
April	44.2	16.5	4.6	
May	41.3	14.8	4.9	
June	88.9	47.1	3.9	Kiremt
July	235.1	164.1	3.3	
August	208.2	142.6	3.5	
September	83.6	42.9	3.7	
October	25.9	5.5	4.3	Bega
November	7.4	0.0	4.1	
December	1.0	0.0	4.0	
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Experimental design and procedure

The experiment was done in a split plot design with three irrigation water application methods (fixed, alternate and conventional furrow method) in main plot and two mulch types (straw and plastic) and control as no mulch. Each main plot factors (furrow irrigation methods) was assigned randomly within each replication and every sub plot factor (mulching) was randomly assigned inside each main plot. Plot size was 3.0 m x 3.0 m which consists of 5 ridges with the spacing 40cm and plant with 5cm spacing interval. Wheat straw mulch with a rate of 6 t/ha was used as mulching types in the sub plots.

The amount of irrigation water applied was calculated using CROP WAT 8.0 software by using necessary input data (crop, soil and long term climatic data). Irrigation water was applied up to field capacity by monitoring soil moisture content using gravimetric method in the conventional furrow plot. The calculated irrigation depth based on the water holding capacity of the soil in the management allowable depletion level was measured using three-inch Parshall flume before diverted to each sub plots.

Data collection and analysis

The selected variety of **Onion (Var. Nafis)** was planted in November for the consecutive three years in Debre Zeit Agricultural Research Center of main station. During the implementation period, all agronomic & yield parameters and data of irrigation water was collected following the data sheet including date of 50% emergency, days of 95% maturity, stand count at harvesting, fresh biomass yield, marketable yield, bulb diameter and weight was measured after the sample was sun dried for three days. Water use efficiency was calculated using the following formula.

Equation-1: ***Water Use Efficiency of Irrigated Onion.***

Where; Water use efficiency (kg/m^3), Marketable bulb yield (kg/ha) and Net irrigation water applied (m^3/ha).

The collected data were analyzed using statistical analysis system (SAS) software procedure of general linear model for the variance analysis. Mean comparisons

least significant difference (LSD) at 5% probability level.

Results and Discussion

Marketable Yield of Onion Bulb

The combined analysis of marketable yield data showed that different types of furrow irrigation and application of mulch in agricultural water management was significantly ($p<0.01$) influenced.

Effect of Furrow Type on Onion Yield

Result analysis showed that different types of furrow method had a significant difference ($p<0.01$) on onion yield as indicated in table-3 below. The maximum Onion yield (39.5 t/ha) were observed at conventional furrow irrigation water application method (Table-3). The maximum marketable Onion yield obtained at conventional furrow irrigation was statistically superior to both alternate and fixed furrow irrigation. However, minimum marketable yield (28.9 t/ha) were obtained at fixed furrow irrigation method. Therefore, the highest marketable yield of onion obtained at conventional furrow irrigation method lead to an improvement of 27 % while alternative furrow was 16% than the fixed furrow irrigation method.

Table-3: Combined analysis of marketable Onion bulb yield (t/ha).

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/C/ Treatments with similar letter in the column & also in rows are not significantly different; CV: coefficient of variation; LSD: least significant difference; CFI: conventional furrow irrigation; AFI: alternate furrow irrigation; FFI: fixed furrow irrigation.

Effect of Mulching on Onion Yield

Field experiment of combined analysis result also revealed that different types of mulch on onion yield had highly significant ($p<0.01$) influence as indicated in Table-3. Therefore, maximum marketable yield of onion bulb (37.1 t/ha) were observed at straw mulching condition but the maximum bulb yield obtained at straw mulching condition was statistically similar with that of plastic mulch. Moreover, the minimum (29.5 t/ha) marketable yield obtained at no mulching condition was statistically significant different with both straw and plastic mulching. So, the highest marketable yield of onion bulb obtained at straw followed by plastic mulching showed an improvement of 20% and 18% respectively over the conventional non-mulching condition.

Even though irrigation water depth is reduced due to different irrigation water management methods like alternate and fixed furrow, the applied depth could be conserved due to reduction of evaporation from soil surface by mulching. The conserved moisture content of soil in the root zone could enhance crop transpiration and nutrient uptake and transportation in the plant body. Similarly, **Xu *et al.* (2015)** reported that plastic mulching improves the accumulation of dry matter, leading to a significantly greater final biomass and an improvement of grain yield of maize by 15-26% both in the dry years. Moreover, **Yaseen *et al.* (2014)** revealed that maximum increase in biomass (29.56%) and grain yield (35.5%) were recorded on mulch and higher irrigation depth treatments. **Panigrahi *et al.* (2011)** also revealed that application of black plastic mulching improves yield of okra plant by 21.4 to 36.9% at different allowable soil moisture depletion level and alternate furrow irrigation method.

Water Use Efficiency (WUE)

Water use efficiency was significantly ($p<0.01$) influenced due to different types of irrigation water management methods (Table-4).

Effect of Furrow type on water use efficiency

Results indicated that the water use efficiency of marketable Onion bulb was significantly influenced by application of irrigation water though furrow type. The highest was recorded under alternate furrow irrigation as compared with conventional and fixed furrow method. Maximum water use efficiency (9.86 kg/m^3) observed at alternate furrow which was statistically superior to both conventional and fixed furrow whereas minimum water use efficiency (5.7 kg/m^3) was recorded at conventional furrow irrigation (Table-3). Therefore, the highest water use efficiency of onion obtained at alternative furrow irrigation showed an improvement of 42% and fixed furrow type 31% over the conventional non-mulching condition.

Table-4: Combined analysis of WUE (kg/m^3) of Onion.

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D	5.01	6.04	6.06	5.70^d	/5 !
B	8.45	10.91	10.20	9.86	
	7.07	9.15	8.71	8.31^c	
Nf o	6.84^c	8.70	8.32		
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/C/ Treatments with similar letter in the column & also in rows are not significantly different; CV: coefficient of variation; LSD: least significant difference; CFI: conventional furrow irrigation; AFI: alternate furrow irrigation; FFI: fixed furrow irrigation.

Effect of mulch type on water use efficiency

Application of different types of mulch in field experiment had significantly ($p<0.01$) influenced marketable yield of Onion bulb and water use efficiency. The combined analysis revealed that, water use efficiency was maximized at straw mulch followed by plastic mulching than no mulch condition. The maximum water use efficiency (8.7 & 8.32 kg/m^3) obtained at straw & plastic mulching was statistically no difference with each other but both are superior to no mulch conditions. Hence, the minimum water use efficiency (6.84 kg/m^3) was observed at no mulch condition. Hence, there was 21.4 % and 21.6% increment of water use efficiency of onion by applying straw and plastic mulching respectively over the conventional non-mulching condition.

Generally, different mulching types lead to maximize water use efficiency. **Xu *et al.* (2015*)*** reported that water use efficiency of maize under plastic mulching (3.27 kg/m^3) was increased by 16% compared to the control treatment without mulching, although the overall evapotranspiration was similar between the two treatments. With reduced soil evaporation, the conserved moisture due to plastic mulching might be allotted to transpiration which improve nutrient uptake and transportation to plant body. Based on different studies in different location, **Montazar and Kosari (2007)** reported that water use efficiency of different crops including onion could be enhance though mulching to conserve moisture in the soil for proper utilization by the plant. The conserved moisture content of soil in the root zone due to mulching could enhance crop transpiration and nutrient uptake and transportation in the plant body with limited available water.

Conclusion and Recommendations

Based on the findings of this experiment, application of mulch played a greater role in minimizing evaporation, due to that available water to plants root varied appreciably. Generally, there was 18 to 22% increment of marketable yield and water use efficiency of onion by applying mulching over the conventional non-mulching condition and also 42% improvement of water use efficiency by using alternative furrow irrigation over the conventional furrow type. Moreover, the highest onion bulb yield obtained at conventional furrow irrigation method lead to an improvement of 27 % while alternative furrow was 16% than the fixed furrow irrigation method.

Therefore, for increasing marketable bulb yield of onion under no water stress scenario, irrigation of onion with conventional furrow irrigation methods could be used. However, under limiting irrigation water resource condition, irrigation of onion could be done with alternate furrow irrigation method with straw mulch application to minimize evaporation loss and maximize water use efficiency of onion for similar agro-ecology and soil type.

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