Integrated Effect of Mulching Materials and Furrow Irrigation Methods on Onion (*Allium cepa l.*) Yield and Water use Effeciency at Werer, Middle Awash Valley, Ethiopia

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Abstract

In semi arid environment, salinity, less moisture in the soil and very fast water evaporation from the upper portion of the soil is a key barrier for crop production this highlights the need to optimize furrow irrigation and the use of available water by reducing evaporation losses is a key for growing crop with minimum input of water. The experiment was conducted at Werer Agricultural Research Center during the dry season of the 2016/2017 - 2018/2019 for three consecutive years to investigate the effects of mulching materials and furrow irrigation methods on onion yield and water productivity under semiarid conditions. Split plot design with three replications, in which the irrigation methods (Conventional, Fixed and Alternate Furrow) were assigned to main plot and the three mulching materials (no mulch, wheat straw and white plastic mulch), were to the sub-plot. Results indicate that marketable onion bulb yield and water use efficiency were affected by the main effect of furrow irrigation methods and mulching materials ($p \leq 0.05$).But interaction of irrigation methods and mulch had no significant effect on marketable onion bulb yield and water use efficiency. The conventional furrow irrigation (10081.52kg ha^{-1}) and wheat straw mulch (12121.63 kg ha^{-1}) resulted in the maximum marketable bulb yield. The alternate furrow irrigation (2.32 kg/m^3) and the wheat straw mulch (2.51 kg/m^3) resulted in the maximum water use efficiency. This study suggests that under limiting irrigation water, alternate furrow irrigation along with wheat straw mulch minimize evaporation loss; maximize water productivity and sustain onion production.

Keywords: Semi arid, Evapotranspiration, Furrow irrigation, Mulch, Water productivity, bulb yield

Introduction

Water is the main limiting factor for production of many crops in the arid and semiarid regions. Climate change due to increased evapotranspiration and excessive water abstraction without properly assessing the available water resources contributes to water scarcity in the awash basin (Adeba *et al.*, 2015).

The application of mulch is known to be effective in reducing soil evaporation and saving water Zhang *et al*. (2014). Organic mulches such as straw, hay, grass or leaf matter can reduce the moisture loss from the soil by preventing evaporation from sunshine, prevent weed growth, provide home for earthworms, increase soil organic matter content, enhance biological activity, improve soil structure and increase plant nutrients after decomposition (Ramakrishna *et al*., 2006, Depar *et al*., 2016). Plastic film mulch is widely used as a low-cost measure to improve water retention in the soil, increase soil temperature and reduces soil evaporation (Liu *et al*., 2010). On the other hand, fixed and alternative furrow irrigation techniques have been used by researchers, the two irrigation techniques reported to lead to increased WUE and reduce evapotranspiration as compared to the conventional furrow irrigation method, (Chai *et al*., 2016, Zinabu, 2019,). In view of the above facts, the present study was undertaken to evaluate the effect of mulching materials and appropriate furrow irrigation method that enhance yield and water use efficiency of onion.

Mulching proves to be beneficiary though increment in soil moisture, reduction in soil erosion, maintenance of soil temperature etc. It helps in improvise in soil structure, soil fertility and soil biological regime. Though also mulching is having many advantages it shows some limitations as it may harbour some pests and diseases. Mulching proves to be beneficiary though increment in soil moisture, reduction in soil erosion, maintenance of soil temperature etc. It helps in improvise in soil structure, soil fertility and soil biological regime. Though also mulching is having many advantages it shows some limitations as it may harbour some pests and disease.

Materials and Methods

Description of the study area

The experiment was conducted at Werer Agricultural Research Center from 2017/18 to 2019/220 for three consecutive years. The geographical location of the site was with an altitude of 750 m asl. The site receives a mean annual rainfall of 589 mm with an average minimum and maximum temperature of 15 and 38.4°C, respectively. The soil in the experimental field has been classified as clay soil.

Experimental design

Treatments were arranged in a split-plot design with three replications in which the three irrigation water application methods (conventional, alternate and fixed furrow) as main plots factor and two mulch types (straw and plastic) and control (no mulch) as subplots factor. Each sub-plots (25 m^2) having 6 furrows with 0.6m apart and 5 m long. There were 3.6 and 1.8 m distance as a border line between the main-plots and sub-plots, respectively. The treatment combinations were indicated in Table 1.

Table 1. Experimental treatment combinations

Treatments	
Main plots	**Subplots**
Alternate Furrow Irrigation	Wheat Straw Mulch (dry)
	Plastic Mulch (white)
	No Mulch
Fixed Furrow Irrigation	Wheat Straw Mulch (dry)
	Plastic Mulch (white)
	No Mulch
Conventional Furrow Irrigation	Wheat Straw Mulch (dry)
	Plastic Mulch (white)
	No Mulch (control)

Transplanting of Seedlings and Management

The transplanting was done after 45 days in row at plant spacing of 10 cm between plant and 30 cm between rows. Wheat straw mulch with a rate of 6 ton ha^{-1} and white plastic mulch 30 microns thickness was used as mulching material and applied uniformly to the experimental plots at the time of transplanting. Soil moisture level was monitored by using gravimetric soil moisture content determination method and the amount of water applied to the experimental plot was measured by using three inch parshall flume. All agronomic practices were done according to the recommendation made for the area.

Irrigation water use efficiency

Irrigation water use efficiency was estimated as a ratio of grain yield to the total water applied (GIR) through the growing season and it was calculated using the following equation (Zwartand Bastiaanssen, 2004).

$$\text{IWUE} = \frac{YLD}{GIR} \quad (1)$$

Where IWUE is Irrigation water use efficiency (kg/m^3), YLD is onion bulb yield (kg/ha) and GIR is the gross irrigation requirement (m^3/ha).

Data collected

The collected data includes long term climatic data (rainfall, maximum and minimum temperature, wind speed, relative humidity, and sunshine hours); physical properties of soil; date of planting, emergence, transplanting, flowering, and maturity; date of irrigation; soil moisture content before and after irrigation;

amount of irrigation applied in each irrigation event; marketable and unmarketable bulb yield.

Statistical Analysis

The data were subjected to analysis of variance (ANOVA) using SAS version 9.3. Treatment means were compared using the least significant difference (LSD) at 5% level of probability.

Result and Discussion

Effects of furrow irrigation methods on onion marketable bulb yield

The overall mean values of bulb yield of onion showed that statistically there was significant difference 0.05) in mean marketable bulb yield of onion among different furrow irrigation water application methods (Table 2). Significantly higher mean marketable bulb yield of (10081.52 kg ha^{-1}) onion was obtained from onion grown under conventional furrow irrigation method and the lower (6843.30 kg ha^{-1}) was recorded from onion grown under fixed furrow irrigation method.

Table 2. Main effects of furrow irrigation method on onion marketable bulb yield.

Treatments		Marketable bulb yield (kg ha^{-1})			
		2016/2017	2017/2018	2018/2019	Combined mean
Irrigation Methods	CFI	11056.59	9106.44	10081.52	10081.52[a]
	AFI	8647.67	8245.48	8446.57	8446.57[b]
	FFI	7390.19	6296.41	6843.30	6843.30[c]
	Year*Method*Mulch	NS			
	CV (%)	10.4			
	LSD (0.05)	906.504			

NS= Non-significant, CFI= Conventional furrow irrigation, AFI= Alternate furrow irrigation, FFI= Fixed furrow irrigation, CV= Coefficient of variation; LSD=Least significant difference.

The substantial grain yield increase in the conventional furrow irrigation method might be due to full application of irrigation water could be attributed to the increment in vegetative growth, which associated with increment bulb yield. The result of the current study is in agreement with the result of Rop *et al.* (2016) who reported that yield decreased with increasing water stress significantly. Likewise, Narayanan and Seid (2011) obtained maximum yield from conventional furrow irrigation (irrigation water application of 100% crop water requirement) than the alternate and fixed furrow irrigation methods.

Effects of mulching materials on onion marketable bulb yield

There was significant difference (P 0.05) in marketable onion bulb yield among the mulching materials (Table 3). Significantly higher mean marketable bulb yield of (12121.63 kg ha^{-1}) onion was recorded from wheat straw mulch and lower mean marketable bulb yield (4289.54 kg ha^{-1}) was obtained from plastic mulch. Field observations during the studies indicated that onion under wheat straw mulch was more stable and actively vegetative growth may have lead into bulb formation than plastic and no mulch. Khaledian *et al*. (2011) indicated that crop yield could also be increased because of the improvements in soil physical properties and fertility under straw mulching. These results are also fully supported by Ramalan *et al.* (2010) who reported that marketable onion bulb yield was significantly higher under straw mulch as compared to plastic and no mulch**.** Likewise Perez *et al*. (2004) and Samuel *et al*. (2018) reported that the highest yield was obtained from wheat straw mulch and the lowest from plastic mulch.

Table 3. Main effects of mulching materials on marketable onion bulb yield.

Treatments		Marketable bulb yield (kg ha^{-1})			
		2016-2017	2017-2018	2018-2019	Combined mean
Mulch	Straw	14669.00	9574.26	12121.63	12121.63^{a}
	No mulch	10374.19	7546.26	8960.22	8960.22^{b}
	Plastic	2051.26	6527.81	4289.54	4289.54^{c}
	Year*Method*Mulch	NS			
	CV (%)	15.2			
	LSD(0.05)	707.37			

NS = Non-significant, CV = Coefficient of Variation; LSD= Least signifcant difference.

Effects of furrow irrigation methods on onion unmarketable bulb yield

There was significant difference (P 0.05) in unmarketable onion bulb yield among the furrow irrigation methods (Table 4). Significantly higher mean unmarketable bulb yield of (1081kg ha^{-1}) onion was recorded from onion grown under fixed furrow irrigation method and lower mean unmarketable bulb yield (719 kg ha^{-1}) was obtained from onion grown under conventional furrow irrigation method. This could be due to low rate of transpiration caused by stomata closer under moisture stress condition which brought about reduced photosynthesis and poor bulb growth and developments. Stressed onion plants may bulb too early, produce small-sized bulbs and bulb splits and, thus, produce high amount of unmarketable yield Kebede (2003). Corresponding to this, De Santa Olalla *et al*. (1994), De Santa Olalla *et al*. (2004) and Zayton (2007) reported that plots which received the lowest volumes of water during the crop growing season produced higher percentage of small size bulbs

Table 4. Main effects of furrow irrigation methods on unmarketable onion bulb yield.

Treatments		Unmarketable bulb yield (kg ha^{-1})			
		2016-2017	2017-2018	2018-2019	Combined mean
Irrigation Methods	CFI	857	581	719	719^{c}
	AFI	1003	769	886	886^{b}

Crop water use efficiency was significantly highest under alternate furrow irrigation with straw mulch as compared to other treatments because less volume of irrigation water used under alternate furrow irrigation together with save water, regulate soil temperature and improve soil organic matter of straw mulch produce more onion bulb yield with less water results highest water use efficiency. This result is in agreement with the finding of Yemane *et al*. (2018) who obtained highest water use efficiency from alternate furrow irrigation system. On other hand Mandefro and Quraishi (2015) reported maximum water use efficiency from wheat straw mulch. Similar finding were also reported on potato yield that higher water use efficiency was obtained at alternate furrow irrigation water application technique under straw mulch (Samuel *et al*., 2018).

Table 6. Interaction effects of furrow irrigation methods and mulching materials on water use efficiency of onion.

Treatments	Water use efficiency (Kg/m^3)
Alternate furrow with straw mulch	3.27[a]
Fixed furrow with straw mulch	2.84[b]
Alternate furrow with no mulch	2.40[c]
Fixed furrow with no mulch	1.97[d]
Conventional furrow with straw mulch	1.94[d]
Conventional furrow with no mulch	1.51[e]
Alternate furrow with plastic mulch	1.29[e]
Fixed furrow with plastic mulch	0.84[f]
Conventional furrow with plastic mulch	1.70[f]
CV (%)	7.6
LSD (0.05)	0.51

Means within a column followed by the same letter are not significantly different at 5% level of significance. NS = Non-significant, CV = Coefficient of variation, LSD = Least significant difference.

Conclusion

The results of this experiment showed that among the furrow irrigation methods studied, conventional furrow irrigation method was obtained maximum marketable yield than other two. However comparing the results from water use efficiency point of view, maximum water use efficiency was recorded from onion grown under alternate furrow irrigation method with straw mulch. This clearly showed that yield reduction as a result of alternate furrow irrigation method can be compensated by 50% of water saved by alternate furrow irrigation method as compared to conventional furrow irrigation water application method. On other hand mulching materials also varied in their effectiveness on onion bulb yield production. Among the mulches used, wheat straw mulch gave higher bulb yield of onion. In conclusion, this study suggests that under limiting irrigation water, adopting alternate furrow irrigation with wheat straw mulch can minimize evaporation loss, maximize water use efficiency and sustain the onion production at werer and other similar agro ecology.

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