Vol. 11(4), pp. 62-69, April 2019
DOI: 10.5897/JHF2019.0583
Article Number: A21682960869
ISSN 2006-9782

http://www.academicjournals.org/JHF

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Journal of Horticulture and Forestry

Full Length Research Paper

Effect of drip lateral spacing and mulching on yield, irrigation water use efficiency and net return of onion (*Allium cepa L.*) at Ambo, Western Shoa, Ethiopia

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Received 4 March, 2019; Accepted 11 April 2019

Field experiment was conducted at Ambo during the 2017/2018 to investigate effects of drip lateral spacing and mulching on yield, water use efficiency and net return of onion. Eight treatments with three replications were randomized in complete block design to conduct the experiment. Two levels of drip lateral spacing and four levels of mulch were used to evaluate their effects. The result showed that both onion yield and water use efficiency were affected by main effects of drip lateral spacing and mulching but not affected by their interaction effect. The maximum bulb yield 34990 and 35117 kg ha^{-1} of onion were recorded from onion grown under drip lateral in every row and white plastic mulching, respectively. Water use efficiency of 1.14 and 1.15 kg L^{-1} were recorded from onion grown under drip lateral spacing in every row and white plastic mulching, respectively. Even though white plastic mulch scores significantly higher yield and water use efficiency, highest net returns of 246,410 and 284,616 ETB ha^{-1} were obtained from drip laterals in every rows and no mulch, respectively. This suggests that drip laterals in every rows and no mulching is economically feasible for drip irrigated onion production at Ambo.

Key words: Drip irrigation, drip lateral spacing, mulching, bulb yield, water use efficiency, net return, Ambo woreda.

INTRODUCTION

Irrigation water, limited information and cost of production are the most limiting factor for irrigated vegetable production in areas where rainfall is unevenly distributed temporary and spatially. Vegetable crops are consumed in either raw or cooked form. The edible portion may be a root, a tuber or storage stem, a bulb, leafstalk, leaf, an immature flower, a seed, the immature fruit and mature fruit. They play an important role in contributing to the household food security. At present, following tomato, onion (*Allium cepa L.*) is one of the most popular vegetables in the world (FAO, 1999). Ethiopia has a great potential to produce onion every year for both local consumption and export with an average yield of 13.3 tones/ha which is below world average production (CSA,

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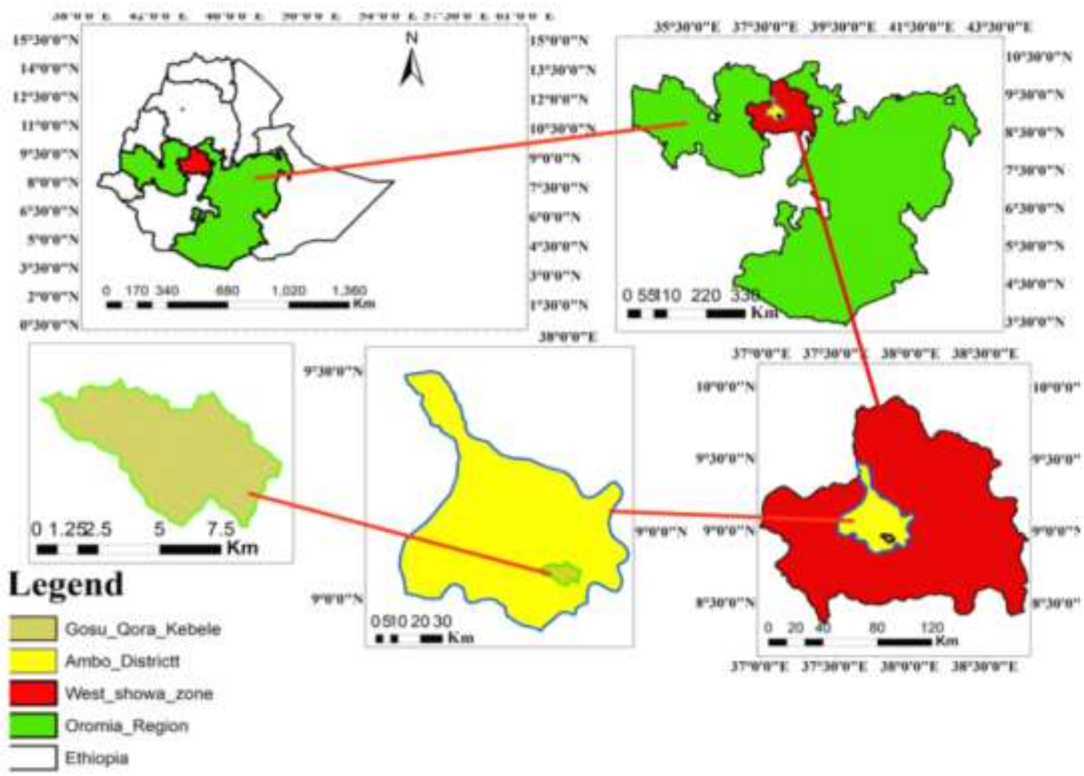

Figure 1. Map of the study area.

2001/2002 as cited in Taha, 2007).

Farmers in the study area produce vegetable crops especially onion two times per dry season using traditional furrow irrigation method for their consumption and market. But lack of modern irrigation system, poor irrigation water management practices and lack of modern technologies and farm land production and productivity is very low. Loss of farm land, less net return income and un-optimized irrigation production were the created conflict among irrigators. A number of researches have been done to evaluate performance of drip irrigation practices in this country. However, none of these researches have attempted to evaluate the combined effects of drip lateral spacing and mulching on onion production in the study area. Therefore, the experiment was conducted to evaluate the feasibility of drip lateral spacing and mulches for onion cultivation in terms of yield, water use efficiency and economics for improving crop and irrigation water productivity in drip irrigated agriculture.

MATERIALS AND METHODS

Description of study area

The experiment was conducted at West Shoa Zone, Ambo Woreda in Ambo Agricultural Research Center Farm site from October 2017 to May 2018. The geographical location is 37.5135°E and 08. 5816°N with an altitude of 2144 m a.s.l. The area is about 115 km from Addis Ababa. Mean annual precipitation of 1029 mm and the mean temperatures of the area range from 26.4 and 10.3°C. Its soil texture is clay (Figure 1).

Experimental design

The experiment was a two factor factorial experiment arranged in RCBD with three replications. The two factors were drip lateral spacing and mulch types. The drip lateral spacing was 2 levels and mulch types were 4 levels. The sizes of experimental plots were 3×1.2 m with 8 plots per each replication with inter-row 30 cm and intra-row spacing of 10 cm with 4 plant rows per each plot (Figures 2 and 3).

Application of mulch

Wheat straw mulch was applied uniformly to the experimental plots at the layer of 10 cm depth and at 15 days after transplanting (Michael, 2013). Black and White Plastic mulch treatments of 1.5 mm thick were applied over the ground surface of experimental plots at 15 days after transplanting.

Irrigation water application procedure

The experiment water from Huluka river was conveyed from river to the experimental site through lined canal and diverted to the field through unlined canal. Water was collected into the barrel manually to irrigate the experimental plot. Crop water requirement of onion

Figure 2. Field layout of the study area.

Figure 3. Field layout of family drip irrigation system.

crop during different growth stage was computed by CROPWAT8.0 software. Climate data of the study area, test crop data and soil data were used to compute crop evapotranspiration (ETc). The frequency and duration of irrigation was determined using FAO (1998).

Drip installation procedure

Overhead barrel system was used to supply water to the system. The barrel was constructed 1.5 m above the ground from locally available wood and ¾" socket was welded onto it at 5 cm above its bottom. A mainline with a diameter of 25 and 20 mm was connected to the drain outlet. Manifold of 16 mm was connected to main line. The size of lateral was 16 mm, and dripper spacing was 30 cm. The laterals were connected to the manifold at 0.60 m for drip lateral between two onion rows and 0.30 m for that of drip lateral in every onion plant rows.

Test crop management

An onion seed of "Adama Red" variety was used as test crop from Melkas Agricultural Research Center. The seeds were sown in the well prepared nursery seed bed field on 1st January 2018. The seedlings were transplanted onto the experimental plots on 16th January 2018. The recommended fertilizers rates of 150 kg/ha for Urea and 200 kg/ha for TSP were applied during transplanting in this experiment (Getachew et al., 2011). Amount of fertilizer applied per each plot was calculated from the recommended fertilizer rate. 0.054 kg of Urea and 0.075 kg of TSP were applied for the 3.6 m^2 experimental plot at the time of transplanting. Hand weeding was used to control weeds. The data of yield and total amounts of water applied were used to evaluate the effects of drip lateral spacing and mulching on onion crop and water use efficiency.

Yield data collection

The test plant was up rooted from two central rows of each plot at its optimum maturity (June 6th) and it was field dried for 5 days under sunny conditions (George et al., 2014). After it was dried the bulb yield was cut from its above ground plant part and the weight of its bulb yield was taken and converted to hectare base and bulb yield per hectare (kg ha^{-1}) was used for the analysis to determine effects of drip lateral spacing and mulching on bulb yield.

Water use efficiency

Onion crop water-use efficiency was determined in terms of marketable bulb yield produced per unit volume of water. It was calculated from the ratio of mean weight of bulb yield to that of total volume of water consumed. And the values were used for analysis. Water use efficiency was calculated using Equation 1 (Oweis and Zhang, 1983) as:

$$WUE = \frac{Y}{\mathrm{ETa}} \quad (1)$$

where WUE = water use efficiency (kg m^3), Y= yield of onion (kg), and ETa = actual evapotranspiration (mm).

Economic analysis

Economic analysis of the experiment was analyzed by taking the

Table 1. Main effects of drip lateral spacing on onion yield.

Treatment	YD ($kg\ ha^{-1}$)	WUE ($kg\ L^{-1}$)	BM ($kg\ ha^{-1}$)	PH(cm)	PP	BD (cm)	HI (%)
DLER	34990[a]	1.14[a]	37769	57.97[a]	119	7.99[a]	92.63[a]
DLBTR	30230[b]	0.99[b]	35277	50.32[b]	119	6.24[b]	85.80[b]
LSD (%)	2437.1	0.079	Ns	1.96	Ns	0.9	1.37
CV (%)	8.54	8.49	8.35	4.13	1.41	6.22	1.75

YD = Bulb yield, BM = biomass, WUE = water use efficiency, PH = plant height, PP = plant population, BD = bulb diameter, HI = harvest index, DLER = drip lateral in every row, DLBTR = drip lateral between two rows, LSD (%) = least significant Difference at 5% of significance, CV (%) = coefficient of variation, ns = no significant difference.

average of three years cost of drip lateral, mulching cost and manpower cost for weeding, drip lateral installation and mulching and removal. Each cost was calculated for each treatment separately. The mean bulb yield ($kg\ ha^{-1}$) was adjusted for yield losses by subtracting 10% of the bulb yield from total yield. The total net return was calculated by multiplying bulb yield with its production cost separately for each treatment. It was determined using partial budget analysis (Equations 2, 3, and 4):

$$TR = Y \times P \quad (2)$$

$$NI = TR - TC \quad (3)$$

$$TC = FC + VC \quad (4)$$

where TR = total return, Y = crop yield, P = unit price, NI = net income, TC = total cost, FC = fixed cost, and VC = variable cost.

Data analysis

In order to evaluate main effects of drip lateral spacing and mulching on onion bulb yield and water use efficiency data of yield components, cost of production and water applied were collected. The data were subjected to ANOVA using SAS 9.0 software with significance level $p \leq 0.05$. LSD test was applied for statistically significant parameters to compare means among the treatments (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Main effects of drip lateral spacing on onion yield and water use efficiency

The summarized mean values of bulb yield of onion shown in Table 1 showed that there was significant ($P \leq 0.05$) difference on mean bulb yield of onion, water use efficiency, plant height, bulb diameter and harvest index due to main effects of drip lateral spacing. Significantly higher bulb yield of 34990 $kg\ ha^{-1}$ onion was recorded from onion grown under drip lateral in every row and the lowest bulb yield was recorded from onion grown under drip lateral spacing between two rows (30230 $kg\ ha^{-1}$). Bulb yield was reduced by 13.6% when drip lateral between two rows were used. This result is in agreement with finding of Solomon et al. (2013) reporting drip lateral spacing in every row yields more. Similarly, Himanshu et al. (2012) reported the highest mean marketable bulb yield of onion was recorded from lateral spacing in every row. On the contrary, Wondatir et al. (2013) discussed that the highest marketable bulb yield was obtained due to the effects of 1 m drip lateral spacing and the lowest were obtained due to the effects of 0.5 m drip lateral spacing. Effects of drip lateral spacing on bulb yield and yield components of onion is discussed in terms of its effect on availability of irrigated water for plant roots. Drip lateral spacing in every row was irrigated near the root zone of onion as compared to that of drip laterals between two onion plant rows. Because drip laterals installed at 0.6 m apart from the plant (drip laterals between two rows) cause onion plant roots unable to extract the water as it drips beyond the root zone.

The highest water use efficiency of 1.14 $kg\ L^{-1}$ was recorded from onion grown under drip lateral spacing in every row and the lowest water use efficiency (0.99 $kg\ L^{-1}$) was recorded from onion grown under drip lateral spacing between two rows. The mean value of biomass and plant population showed non-significant ($p \leq 0.05$) difference due to the main effect of drip lateral spacing (Table 1).

In case of plant height and bulb diameter, mean values have shown significant ($P \leq 0.05$) difference due to main effect of drip lateral spacing (Table 1). The highest mean value of plant height (57.97 cm) was recorded from onion grown under drip lateral in every rows and the lowest mean value (50.32 cm) was from onion grown under drip laterals between two rows. Bulb diameter of 7.99 and 6.24 cm were recorded from onion grown under drip lateral spacing in every row and drip lateral between two rows, respectively. Harvest index also showed significant difference ($P \leq 0.05$) due to the main effects of drip lateral spacing (Table 1). The highest mean value of 92.63% harvest index was recorded from onion grown under drip laterals in every row and the lowest mean value of 85.80% harvest index was obtained from drip lateral between two rows. The highest yield component results under drip lateral spacing in every row were due to the highest water use efficiency observed from the treatment.

Table 2. Main effects of drip lateral spacing on onion yield.

Treatment	YD (kg ha^{-1})	WUE (kg L^{-1})	BM (kg ha^{-1})	PH (cm)	PP	BD (cm)	HI (%)
NM	31795^{bc}	1.04^{c}	37119	53^{bc}	119	6.22^{b}	85.66^{c}
WSM	32498^{b}	1.06^{b}	35352	55^{b}	119	6.00^{b}	91.82^{b}
WPM	35117^{a}	1.15^{a}	36949	51^{c}	118	7.18^{a}	95.04^{a}
BPM	32030^{b}	1.05^{c}	36672	57^{a}	119	6.16^{b}	87.33^{c}
LSD (%)	2520	0.08	Ns	1.77	Ns	0.8	1.94
CV (%)	8.54	8.49	8.35	4.13	1.41	4.13	1.75

YD = Bulb yield, WUE = water use efficiency, PH = plant height, BD = bulb diameter, HI = harvest Index, PP = plant population, NM = no mulch, WSM=wheat straw mulch, WPM=white plastic mulch, BPM=black plastic mulch, LSD (%) = least significant difference at 5% of significance, CV (%) = coefficient of variation, ns=non-significant at 5% probability level.

Main effects of mulching on onion yield and water use efficiency

Bulb yield of onion has shown significant (P ≤ 0.05) difference due to the main effects of mulching (Table 2). The highest mean bulb yield of 35117 kg ha^{-1} was obtained from white plastic mulch and the lowest (31795 kg ha^{-1}) was from no mulch. But there is no significant (P ≤ 0.05) difference in bulb yield between no mulch, wheat straw mulch and black plastic mulch treatment. This result indicates that white plastic mulch has 9.5% yield advantage than no much, wheat straw mulch and black plastic mulch treatment (Table 2). Similarly, Vavrina and Roka (2000) also reported that the benefits associated with the use of plastic mulches for vegetable production include higher yields, earlier harvests, improved weed control, cleaner fruit and increased efficiency in the use of water and fertilizers. The mean values of water use efficiency showed significant (P ≤ 0.05) difference due to the main effects of mulching (Table 2). The highest mean value of water use efficiency of 1.15 kg L^{-1} was recorded from white plastic mulch and the lowest score of 1.04kg L^{-1} was from no mulch treatments. The mean values of plant height, bulb diameter and harvest index showed significant (P ≤ 0.05) difference due to the main effects mulching. The highest mean value of plant height of (57 cm) was recorded from black plastic mulch and the lowest (51 cm) was from white plastic mulch. In case of bulb diameter, the highest mean value of bulb diameter of 7.18 cm onion was recorded from onion grown under white plastic mulch and the lowest mean values of bulb diameters (6, 6.16 and 6.22 cm) was recorded from onion grown under wheat straw, black plastic and no mulches, respectively. The highest mean value of 95.04% harvest index was recorded from white plastic mulch and the lowest (85.66%) score was from no mulch. This is due to the highest mean bulb yield obtained from white mulch. The mean value of biomass and plant population showed non-significant (p ≤ 0.05) difference due to the main effect of drip lateral spacing and mulching (Table 2). Researchers have demonstrated that in comparison to not mulched soil, the crop yields of mulched soils (depending on factors such as geographic location, soil type and nature of mulch) can be enhanced two or three folds in vegetables (Pollack et al., 1969; Bhella, 1986). Bulb size under white plastic mulch treatment was significantly larger than in the other treatments. It is apparent that the large size of bulbs translated into heavy bulbs and enhanced bulb yield. White plastic mulch affects not only bulb size, but also attractive in color and shape. There are many reports confirming the stimulation of growth and consequent yield increases by the use of plastic mulches. Plastic mulches substantially reduce evaporation of water from the soil surface especially under trickle/drip irrigation (Anusuya and Betsy, 2001). Among its advantages in use is increase in soil temperature, reduced fertilizer leaching, reduced evaporation, cleaner product and reduced weed problems. Vavrina and Roka (2000) also reported that the benefits associated with the use of plastic mulches for vegetable production include higher yields, earlier harvests, improved weed control, cleaner fruit and increased efficiency in the use of water and fertilizers. Mulches may increase or decrease root zone temperature, depending on how the mulch affects the energy balance of the soil (Liakatas et al., 1986). Black plastic mulch resulted in the highest root zone temperature, which is consistent with numerous reports that show root zone temperature under black plastic mulch may be at least 2°C higher as compared to bare soil (Diaz-Perez and Batal, 2002; Lamont, 1993). No consistent differences in root zone temperature between bare soil and straw mulch. Total yield, marketable yield, total number of bulbs and weight of individual bulbs increased with increasing seasonal root zone temperature up to an optimum at 15.8°C, followed by reductions in yields and individual bulb weight at >15.8°C (Juan et al., 2004).

The extent of the increase in soil temperature depends on the color of the film and the intensity of solar radiation. The other advantage associated with plastic mulch is that, the movement of water is directed upwards in soil

Table 3. Interaction effects of drip lateral spacing and mulching on onion yield and water use efficiency of onion.

Sources of variation	DF	Mean square						
		Bulb yield (kg ha^{-1})	WUE (kg L^{-1})	Biomass (kg ha^{-1})	Plant height (cm)	Plant population	Bulb diameter (cm)	HI (%)
Replication	2	33181552.2	0.0351125	50598550.7	12.6467	1.04167	0.13013	5.90975
Drip lateral spacing	1	135929733.8*	0.14726667*	37250416.7	351.135*	0.375	0.38506667*	280.059467*
Mulching	3	6566.12.9*	0.00664444*	3862280.5	33.521666*	2.04167	0.05246111*	55.6753425*
Drip lateral spacing × Mulching	3	4347333.2	0.00446667	5849658.8	10.5928	2.375	0.02324	3.00633

DF = Degree freedom, WUE = water use efficiency, HI = harvest index, * = significantly different.

under plastic mulch. So, the moisture content of soil under plastic mulch becomes lower in the long term. Plastic mulching prevents the leaching of fertilizer, because it acts as a physical barrier to irrigation water and/or rainfall and prevent leaching of nutrients. Plastic mulch reduces the splattering of soil on onion leaves during rains or sprinkling. This can reduce losses due to soil-borne diseases (Steiner et al., 1998; Derpsch, 2001; Westerfield, 2013). Similarly, Hamma (2013) reported that the highest bulb yield was observed from white plastic mulch than no mulch and other treatments. Anusuya and Betsy (2001) found that vegetable yields were significantly higher, heads larger, and harvest earlier for plants grown under white plastic mulch compared to the control and other mulch treatments. Allen et al. (1998) reported that mulching with polyethylene did significantly improve bulb yield of onion than straw mulch. But Allen et al. (1998) indicated that no yield advantage was observed using white as against black plastic mulch. From field observation of this experiment, almost no onion flower was observed from onion grown under white plastic mulch and the growth of above ground plant parts was shorter in height. Onion grown under white plastic mulch was matured earlier than others. But onion grown under wheat straw mulch, black plastic mulch and no mulch were almost all flowered. The effect of flower was reduced bulb yield. The observation indicates that white plastic mulch conserved moisture and is transparent thereby allowing the penetration of light through it which enhanced the photosynthetic activities of plants resulting in the production of higher treatment means than the rest of the treatments. Field observations during the trials indicated that there is high weed germination under wheat straw mulch treatment resulting in high labor consumption for weeding operation, relatively high moisture competition and crop-damage as a result of soil disturbance during hand weeding. These contribute to lower mean bulb yield. In the control treatment, there was no moisture conservation in which the plants under this treatment were denied adequate moisture for normal growth and developmental processes due to excessive evaporation thus resulting in the production of lower treatment means as earlier reported by Baten et al. (1995) and Duranti and Cuocolo (1989). It is observed that weed germination under no mulch was almost less than that of wheat straw mulch due to moisture stress.

Interaction effects of different drip lateral spacing and mulch types on onion yield and water use efficiency

The summarized mean values of onion yield and water use efficiency showed that there were non-significant ($P \leq 0.05$) difference due interaction effects of lateral spacing and mulch types. (Table 3)

Economic analysis and evaluation

Based on drip lateral spacing, the cost of treatment in which the drip lateral between two onion plant rows was 50.34% less than the treatment in the drip lateral in every onion plant rows (Table 4). Even though the total variable cost of implementing drip lateral in every row was greater than that of drip laterals between two rows, drip lateral in every row gave the maximum net income of 246,410 ETB ha^{-1}. On the other hand, less net income of 238,070 ETB ha^{-1} was obtained from drip lateral between two rows. This means farmers installing drip laterals in between two onion plant rows for production of onion under drip irrigation losses 8,340 ETB ha^{-1} under Ambo climate condition. Similarly, Himanshu et al. (2012) reported that drip lateral in every row resulted in higher gross return, net return and benefit cost ratio.

The mean values of marginal rate of return (MRR) revealed that no mulching gave the higher value than the control treatment (no mulch). Thus, the highest net benefit of 284,616 ETB ha^{-1} was recorded from no mulch and followed by 280,329

Table 4. Effect of drip lateral spacing and mulching on net benefit of onion production at Ambo.

Treatment	Mean bulb yield (kg ha^{-1})	Adjusted bulb yield (kg ha^{-1})	Gross field benefit (ETB ha^{-1})	TVC (ETB ha^{-1})	Net benefit (ETB ha^{-1})	Value to cost ratio	MRR (%)
Drip lateral between two rows	30230	27207	272070	34000	238070	7	-
Drip lateral in every row	34990	31491	314910	68500	246410	3.6	24.17
No mulch	31795	28615.5	286155	1539.35	284616	184.89	
Wheat straw mulch	32498	29248.2	292482	12152.8	280329	23.07	-0.4
White plastic mulch	35117	31605.3	316053	45037	271016	6.02	-0.28
Black plastic mulch	32030	28827	288270	48796.3	239474	4.96	-8.39

TVC = Total variable cost and ETB = Ethiopian Birr, MRR = marginal ret of return. The price of onion = 10 ETB kg^{-1}.

ETB ha^{-1} was recorded from no mulch and followed by 280,329 ETB ha^{-1} with wheat straw mulch for onion production (Table 4). The lowest net benefit 239,474 ETB ha^{-1} was obtained from black plastic mulch. The value to cost ratio for no mulch was 184.89 and that of black plastic mulch is 4.91. This result confirms the farmer's production practices (drip lateral in every row and no mulch) are economically feasible for onion production in sub humid areas of Ambo.

Conclusion

The results of this experiment indicated that interaction effect of drip lateral spacing and mulching on onion yield and water use efficiency showed non-significant difference (P ≤ 0.05). But the main effects of both drip laterals spacing and mulching showed significant difference (P ≤ 0.05) on bulb yield, water use efficiency, plant height, bulb diameter and harvest Index. On the other side the mean value of biomass and plant population showed non-significant (p ≤ 0.05) difference due to main effect of drip lateral spacing and mulching. The highest bulb yields of 34990 and 35177 kg ha^{-1} were recorded from drip lateral spaced in every row and white plastic mulching, respectively. The highest irrigation water use efficiency was 1.14 kg L^{-1} recorded from drip lateral in every row and 1.15 kg L^{-1} from white plastic mulching. Even though white plastic mulch yields more, the economic analysis result showed that no economic advantage was obtained by the use of wheat straw, white and black plastic mulches when compared with that of control (no mulch) for drip irrigated fresh marketable bulb yield of onion at Ambo. Drip irrigation method is also profitable for onion production with drip lateral spacing in every row with net benefit of 24640 ETB ha^{-1} and its marginal net of return is 24.17%.

It was observed that reducing drip laterals from one drip lateral for each onion plant row to one drip lateral for two onion plant row caused significant yield reduction which resulted in reduced net benefit in the study area. The use of white plastic mulch, black plastic mulch and wheat straw mulch for the production of drip irrigated onion have no net benefit than producing onion without mulching around Ambo.

Drip lateral spacing in every row and no mulch mulching is profitable for smallholder farmers' by providing different biological and economic advantages that enhance sustainable onion production.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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