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Evaluation of Drip Lateral Spacing on Yield and Economic Return of Onion (*Allium cepa* L.) at Awash Melkassa, Ethiopia

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ABSTRACT

Water availability is becoming a critical issue in Ethiopia in semi-arid climate mainly in Rift Valley areas. Field experiment was carried out during the dry cropping season of 2019/2020 to evaluate the performance of drip lateral spacing on onion yield and its net return with two adjustments of drip lateral spacing at full irrigation application viz., lateral placed in every row and between two rows. The performance of drip lateral spacing system was evaluated on the basis of parameters like emitter flow rate (q), emission uniformity (EU), emitter flow rate (qvar), coefficient of variation (CV), uniformity coefficient (CU). The mean values of upper, middle, and lower lateral spacing showed non-significant ($P \geq 0.05$) difference in emission uniformity of drip lateral spacing. An average emitter uniformity parameter value was 93.66%, 96.28%, 12.05 %, 1.68 % for emission uniformity, uniformity coefficient, emitter flow variation and coefficient of variation respectively. The designed drip lateral spacing was operated excellently as all values of emitter uniformity parameter were in the recommended range in each case. The average basic infiltration rate was found to be 18 mm/hr. From the result, onion yield and yield parameters was affected by the effects of drip lateral spacing. Maximum onion bulb yield of 41.44t ha⁻¹ and 25.83t ha⁻¹ were obtained from lateral spacing in every row and between two rows respectively. Total bulb yield was reduced by 37.65% when drip lateral between two rows was used. But the cost of drip lateral between two onion plant rows was 26.14% less than drip lateral in every onion plant rows. Therefore, onion could be irrigated by drip lateral spacing in every row to get better onion bulb yield.

INTRODUCTION

In Ethiopia, irrigation aims to increase agricultural productivity and diversify the production of food and raw materials for agro-industry as well as to ensure that agriculture plays a pivot for driving the economic development of the country (Mekonen, 2011). Drip irrigation system is one of the most efficient forms of irrigation technology. The experience from many countries shows that farmers who switch from furrow system to drip system can cut their water use by (30 - 60) % and crop yields often increase at the same time (Sijali, 2001). Drip irrigation adoption increases water use efficiency (60-200%), saves water (20-60%), reduces fertilization requirement (20-33%), produces better quality crops and increases yield (7-25%) as compared with conventional irrigation (Kaushal *et al.*, 2012). The initial investment of drip irrigation is considerably higher as compared to conventional surface irrigation methods. The cost of laterals and emitters are the major factors influencing initial investment. Therefore, it is necessary to develop strategies in order to reduce the cost of lateral networks and emitters per hectare to make drip irrigation affordable to the farming community (Kumar and Imtiyaz, 2007). Excessive irrigation can be seen especially in field areas with cheap irrigation water (Karasu *et al.*, 2015). Appropriate irrigation scheduling is to increase irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to desired level, save water resources and energy (Singh *et al.*, 2015). In the Central Rift Valley, most of the farmers produce

onion during the dry season (October-April) by irrigation due to high domestic and export markets, its yield per unit area, availability of suitable cultivable variety, and ease of propagation by seed and lower incidence of diseases. The activity was accomplished with the objective of enhancing and evaluating onion production and water productivity through application of drip lateral spacing technology under Awash Melkassa climatic condition.

MATERIALS AND METHODS

Description of the Study Area

Field experiment was carried out at Melkassa Agricultural Research Center (MARC) during the dry cropping season of 2019/20. Its location is 8°24'05" and 8°25'58"N latitude and 45°18'55" and 45°20'04"E longitude with an average altitude of 1550 m.a.s.l (Figure 1).

Procedure of Drip Installation

One overhead plastic tanker for all replication was used to provide a pressurized water source for drip irrigation system. The stand for placing tanker was constructed at a height of 1.5 m above the ground from locally available wood (FAO, 2007). Main line with 32 mm, and manifold with 25 mm both made of HDPE pipe used to deliver irrigation water through in-line LDPE laterals of 16 mm was used. A control valve was provided to each plot and the laterals were connected to the manifold line at 0.60 m spacing for drip lateral between two rows and at 0.20 m spacing for drip lateral in every row.

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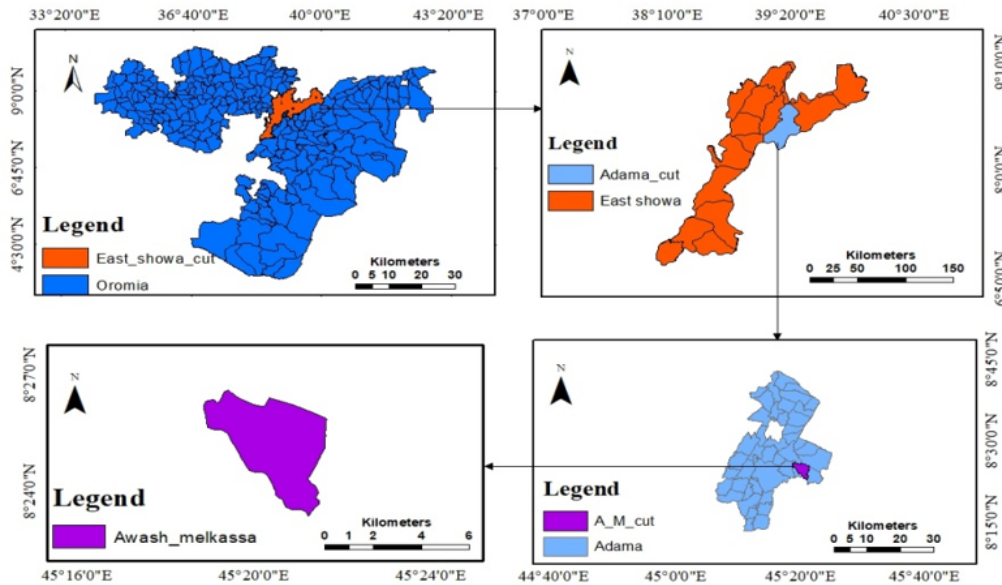


Figure 1: Map of study area

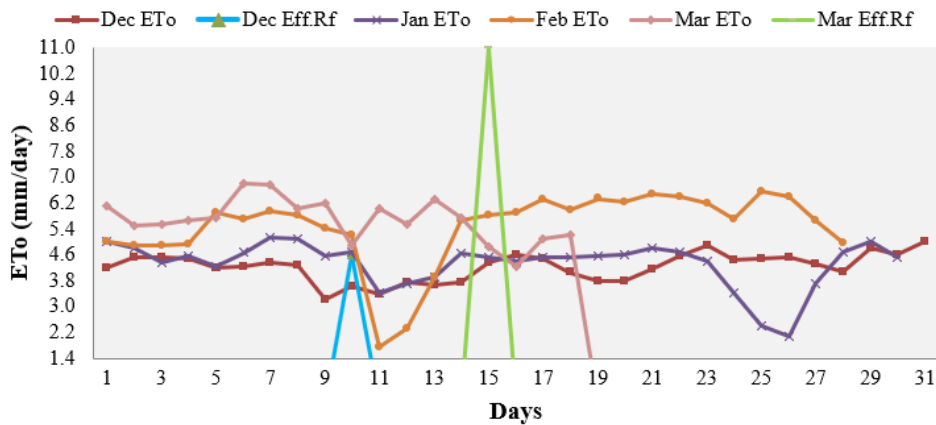


Figure 2: Study area daily ET0

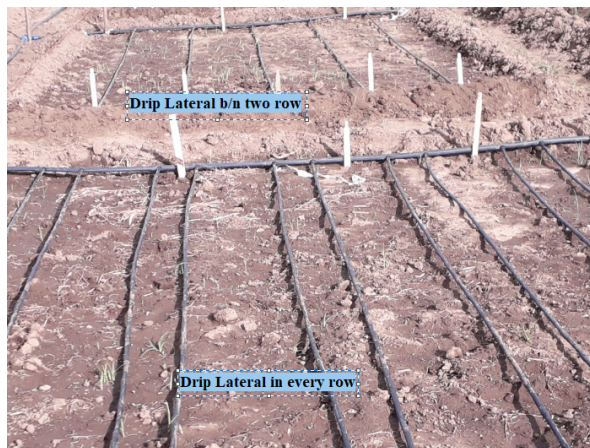


Figure 3: Drip lateral space adjustment

Irrigation Scheduling

Total available water (TAW) was computed from the moisture content of field capacity and permanent wilting point using the following Eq. (1).

$$TAW = (FC - PWP) \times BD \times Dz \quad (1)$$

where, TAW is the total available water in the root zone (mm), FC and PWP are moisture content at field capacity and permanent wilting point (%) on weight basis

respectively and Dz is the root zone depth of onion at times of each irrigation.

For maximum crop production, irrigation schedule was fixed based on p-value. The 'p' value for onion used in this study was 25% of TAW ($p = 0.25$).

Hence, RAW was computed from the Eq. (2).

$$RAW = TAW \times p \quad (2)$$

where, RAW is the readily available water or net irrigation depth, IRn (mm), p is allowable permissible soil moisture depletion fraction

Irrigation Water Application and Discharge Measurement for Plots

Water was pumped into the overhead tank using water pump to irrigate the experimental plot. Full irrigation application was calculated as the net depth of irrigation required to recharge soil moisture to field capacity.

For the experimental test, volume of irrigation water application (liter) to each plot was computed by multiplying the net wetted area (m^2) of each plot (80% of plot area for lateral spaced in every row and 50% of plot area for lateral spaced between two rows) and gross irrigation depth (m). The gross irrigation depth (mm) was calculated by divided the net irrigation depth (mm) by



Figure 4: Experimental field layout

application efficiency (90%). Net irrigation application was obtained by subtracting the effective rainfall (mm/day) from crop water requirement (mm/day) that was a multiplication of daily reference evapotranspiration and the respective stage of kc value.

The discharge measurement was varied based on the treatment with lateral adjustment (Lateral spaced in every row and lateral spaced between two rows). For both lateral space adjustments, the discharge (l/hr) was obtained by multiplying the mean discharge of an emitter and the total number of emitters per plot. The time (hr) required to irrigate each plot was calculated by dividing volume of irrigation water (liter) by the respective laterals space discharge (l/hr) (mean discharge of an emitter x the total number of emitters on each plots).

Uniformity of Water Application

The American Society of Agricultural and Biological Engineers (ASABE) had developed a standard for the uniformity of water application in drip irrigation. Design for a uniformity level less than the designed value will result in a reduction in the irrigation efficiency; and cause loss of water and fertilizer due to poor uniformity of water application. The application of water is by means of drippers that are located at desired spacing on a lateral line (Goyal, 2013).

Proper design and management of water are essential conditions to ensure uniformity of application. If irrigation is not uniformly applied, some areas will get too much water and others will get too little. As a result, plant growth will also be non-uniform, and water will be wasted where too much is applied. Excess water may reduce crop yields as a result of leaching of plant nutrients, results in an anaerobic rooting environment as well as increased disease or failure to stimulate growth of economically valuable parts of the plant (Griffiths and Lecler, 2001).

Percentage Wetting Area

Drip irrigation do not *wet all* cropped field like that of surface and sprinkler irrigation methods and hence the term wetting area (w.a) was introduced for partial wetting of drip irrigated field. The percentages of wetted area

were determined using (Keller and Bliesner, 1990) method. It was the average horizontal area wetted in the top 15–30 cm of the crop root zone as a percentage of each lateral line area.

Data Collection

Drip Emitters Uniformity Parameters

After the installation of drip irrigation system, the hydraulic characteristics of the drippers that were determined include emitter flow rate, emitter flow variation, uniformity coefficient, coefficient of variation and emission uniformity. Water application uniformity test of irrigation system was determined for drip lateral spacing in every row and lateral spacing between two rows at the beginning and end of the experiment.

Emitter flow rate, q - the average flow rate of emitters used in the experiment was measured from plots using catch cans and volumes of flow caught over a time period. The discharge, or flow rate out of a single outlet emitter at a specified head was estimated using eq. (3).

$$q = v/\Delta t \quad (3)$$

where, q is single emitter discharge (liter/hour); V is volume of water collected from emitter, (liters) and Δt is time duration (hour).

Emission Uniformity, EU

Emission uniformity is a measure of the uniformity for all emitter emissions along drip irrigation lateral line. The most useful system performance indicator for drip systems is the emission uniformity EU (%) which, in the case of field evaluation is defined as distributions uniformity, DU and calculated using Eq. (4).

$$EU = 100 (q_{\min}/q_a) \quad (4)$$

where: - Eu is Emission uniformity (%); q_{\min} = minimum emitter flow rate (l/h) and q_a is average discharge rate of all observed emitters (l/hr).

Emitter Flow Variation, q_{var}

It is calculated using Eq. (5)

$$q_{var} = ((q_{\max} - q_{\min})/q_{\max}) \quad (5)$$

where, q_{\max} is maximum emitter flow rate (l/h); q_{\min} is minimum emitter flow rate (l/h)

Coefficient of Variation, CV

It is used to identify the relative variability among the treatments and calculated using Eq. (6)

$$CV = S/q_a \quad (6)$$

where: S is standard deviation of emitter flow rates (l/h) and q_a is average emitter flow rate (l/h)

Uniformity Coefficients, UC

It is often described in terms of the coefficient of variation defined as the ratio of the standard deviation to the mean and is calculated using Eq. (7)

$$UC = (1 - S_q/q_a) * 100 \quad (7)$$

where, UC is uniformity coefficient (%); S_q is average absolute deviation of all emitters flow from the average emitter flow (l/h) and q_a is average emitter flow rate (l/h).

Growth Parameters

Growth parameters of onion such as Plant height (cm), Leaves height (cm) and Number of leaves per plant was collected at physiological maturity stage.

Yield and Yield Parameters

The matured onion bulbs were harvested after more than 75 % of its necks falls/bends down with its necks and after putting under shade for about three to four days to dry/cure and then necks was cut at 2 cm height from the bulb neck (Olani and Fikre, 2010). Yield and yield parameters collected was Bulb diameter (cm), Bulb height (cm), Average weight of bulb (gm) and total yield of bulb (t/ha).

Economic Analysis

Economic analysis was computed by using the results of this study based on investment, operation and production costs. Based on the irrigation amount of each treatment in the growing season; irrigation duration and labor cost were estimated. The mean bulb yield (kg ha⁻¹) was adjusted for yield losses by subtracting 10% of the bulb yield from total yield (CIMMYT, 1988).

The production costs were computed by considering all production inputs (i.e. cost of seeds, cost of drip material, drip installation, plowing of land, transplanting, cultivating, weeding, pesticide, pesticide application, fertilizer, harvesting). Finally, adjusted yield was

multiplied by field price to obtain gross field benefit of onion. The field price of onion during the harvesting season was 13 Birr kg⁻¹ and 3.8 Birr m⁻³ value for water was taken (Jansen *et al.*, 2007).

Statistical Analysis

Data collected were subject to analysis of variance (ANOVA) appropriate to RCBD using SAS software. Whenever treatment effects were found significant, treatment means were compared using the least significant difference, LSD.

RESULT AND DISCUSSION

Uniformity of In-Lined Emitter Lateral System

Uniformity parameters were determined by measuring emitter flow rates. The flow rate test of irrigation system was carried out at the beginning and end of the experiment. For all experimental plots, three laterals at center and three emitter (upper, middle and lower) positions was selected randomly for the two lateral spacing adjustments.

Uniformity of water application was calibrated from the dripper outflow collected in the buried plastic bottle under the lateral line for 30 minutes. A graduated cylinder was used to measure the volume of water. The mean values of upper, middle and lower lateral spacing showed non-significant ($P \geq 0.05$) difference in emission uniformity of drip lateral spacing (Table 1).



Figure 5: Water collection using catch can

Table 1: The mean emission uniformity (%) of the system for emitter position

Lateral space	Upper	Middle	Lower
Laterals in Every Row	94.96	93.79	93.82
Laterals Between Two Row	95.14	95.08	95.18
S.Em±	1.52	0.90	0.38
LSD (5%)	Ns	Ns	Ns
CV (%)	2.77	1.64	0.69

LSD (%) = least significant difference at 5% of significance, CV (%) = Coefficient of variation and Ns = non-significant difference, S.Em± = standard error of mean.

Table 2: Application uniformity measures for the drip system

Uniformity parameter	Unit	Replication 1			Replication 2			Replication 3			Aver.
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower	
EU	%	94.61	95.15	93.02	93.19	93.64	93.05	94.02	92.51	93.78	93.66
UC	%	96.81	96.82	95.52	96.49	96.68	96.25	96.05	96.38	95.50	96.28
qvar	%	10.08	9.86	11.04	10.03	9.60	10.94	13.84	16.28	16.79	12.05
CV	%	1.35	1.43	2.11	1.45	1.39	1.53	1.84	1.90	2.15	1.68

Table 2 shows the average field evaluation of all uniformity parameters (emission uniformity, uniformity coefficient, emitter flow variation and coefficient of variation) were 93.66%, 96.28%, 12.05% and 1.68% respectively. Emission uniformity (90 – 100) % was categorized as excellent (ASABE, 1999). Therefore, in all replication and the average result for this experiment for uniformity parameters was classified as excellent. Uniformity coefficient value (>90%) classified as excellent. (Bralts, 1984) classified field evaluation of emitter flow variation having (10 – 20) % as acceptable. Moreover, a mean coefficient of variation (Cv) for the experiment was 1.68 % and categorized as excellent (<5) %. Generally, the overall average results obtained on application uniformity parameters were within the best

recommended categories. This could be due to proper pressure head, good water quality, good installation and management. The average basic infiltration rate was found to be 18 mm/hr. The range of infiltration rate of loam soil is 10 - 20 mm/hr (FAO, 2001).

Irrigation Water Requirement of Onion

Crop water requirement of onion determined based on the seasonal water application depth from transplantation to harvest and vary based on the lateral spacing. Crops evapotranspiration loss should be supplemented at 50% to 100% to attain maximum production (Ines *et al.*, 2023). The seasonal water applied was 375.04 mm and 234.40 mm for lateral spacing in every row and lateral between two rows respectively (Table 3).

Table 3: Seasonal net irrigation water depth applied

Treatments	Dnet (mm)	Ea (%)	w.a (%)	Dgross (mm)
DLER	421.92	90	80	375.04
DLBTR	421.92	90	50	234.40

DLER = Drip lateral in every row, DLBTR = Drip lateral between two rows

Effects of Lateral Spacing on Onion Growth Parameter

Drip lateral spacing had significant ($P \leq 0.05$) effect on onion growth parameter such as plant height, leaf height and leaf number as shown in (Table 6).

The mean values of plant height showed significant ($P \leq 0.05$) difference due to the effects of drip lateral spacing (Table 4). The highest mean value (63.80cm) of onion was recorded under drip lateral spaced in every row and the lowest mean value (55.43 cm) was recorded under drip lateral spaced between two rows as (Oli *et al.*, 20019).

Plant Height (cm)

Table 4: Effect of Irrigation water levels and Lateral spacing on onion growth parameter

Treatment	PH (cm)	LH (cm)	LN	Dgross (mm)
Lateral Spacing (LS)				375.04
DLER	63.80a	61.40a	13.67a	234.40
DLBTR	55.43b	53.00b	9.67b	
S.Em±	1.04	0.96	0.41	
CV	3.03	2.92	6.06	
LSD (5 %)	6.34	5.87	2.48	

PH = plant height, LH = Leaf height, LN = Leaf number

Leaf Height (cm)

From (Table 4), there was a significant ($P \leq 0.05$) difference observed on leaf height due to drip lateral spacing. The highest mean value of leaf height (61.40cm) of onion was recorded under drip lateral spaced in every row and the lowest mean value (53.00cm) was recorded from onion grown under drip lateral spaced between two

rows. Lower volume of irrigation water applied by drip lateral spaced in between two rows results in lower value of leaf height.

Number of Leaf Per Plant

As shown in (Table 4), there was a significant ($P \leq 0.05$) difference observed on leaf number per plant due to

drip lateral spacing. The higher mean value (14) of leaf number per plant of onion was recorded under drip lateral spaced in every row and the lowest mean value (10) was recorded from onion grown under drip lateral spaced between two rows. (Bhasker *et al.*, 2018) reported that in drip irrigation system plant receive favorable conditions for enlargement of root system thereby plant growth and vigor is high. Leaf number per plant was increased under drip lateral spaced in every row due to sufficient depth of irrigation water.

Effects of Lateral Spacing on Yield and Yield Parameters of Onion

The data showed that there was significant ($P \leq 0.05$) difference on bulb weight due to effects for lateral spacing but no significant difference on bulb diameter and bulb height.

Average Weight of Bulb (gm)

There was significant ($P \leq 0.05$) effect of lateral spacing on average weight of bulb (Table 5). The higher mean value of average bulb weight (86.40 gm) was recorded from onion grown under drip lateral spacing in every row and the lowest mean value of average bulb weight (76.90 gm) was recorded from onion grown under drip lateral between two rows.

Table 5: Effect of Irrigation water levels and lateral spacing on onion yield, yield parameters and WUE

Treatment	BD (cm)	BH (cm)	BW (gm)	MBY (t/ha)	TBY (t/ha)	WUE (kg/m ³)
Lateral Spacing (LS)						
DLER	7.47 ^a	6.27 ^a	86.40 ^a	33.98 ^a	41.43 ^a	11.05 ^a
DLBTR	6.13 ^a	5.97 ^a	76.90 ^b	24.44 ^b	25.83 ^b	11.02 ^a
S.Em±	0.24	0.07	1.05	0.38	0.66	0.01
CV	6.09	2.00	2.23	2.28	3.38	0.23
LSD (5 %)	1.22	0.17	6.25	2.34	3.99	0.10

BD = Bulb diameter, BH = bulb height, BW = bulb weight, WUE = Water use efficiency, MBY = Marketable bulb yield, TBY = Total bulb yield

Marketable Bulb Yield (ton/ha)

Lateral spacing affected marketable bulb yield of onion as shown in (Table 5). There was high significant ($P \leq 0.05$) difference on mean marketable yield of onion due to effects of drip lateral spacing. Significantly higher marketable bulb yield of (33.98 t/ha) onion was recorded from onion grown under drip lateral in every row and the lowest marketable bulb yield (24.44 t/ha) was recorded from onion grown under drip lateral spacing between two rows. The yield was reduced by 28.07% when drip lateral between two rows were used. The result of onion yield agrees with (Kiptum and Ndungu 2018) who showed that water stress during the bulb formation affects yield and head size.

Total Bulb Yield (ton/ha)

As shown on (Table 5), there was significant ($P \leq 0.05$) difference on mean total bulb yield of onion due to effects of drip lateral spacing. Significantly higher total bulb yield of (41.43 t/ha) onion was recorded from onion grown under drip lateral in every row and the lowest total bulb yield (25.83 t/ha) was recorded from onion grown under drip lateral spacing between two rows. Total bulb yield was reduced by 37.65% when drip lateral between two rows were used. (Tirkey *et al.*, 2017) explained that lateral spacing in every row gave highest mean crop yield that is similar to this study. Yields up to 400 qt/ha for Bombay red were observed on farmer’s fields in CRV areas (Olani and Fikre, 2010) which is in agreement with this study.



Figure 6: Water collection using catch can

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 10 cm 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. This indicates that installing drip laterals spacing in every row (one drip lateral for one onion plant row) is more efficient in terms of water use than drip lateral spacing between two rows. So drip lateral spacing influenced the mean total bulb yield of onion. Which means total bulb

yield was increased as one drip lateral is installed for one onion plant row. This result indicates that as we put drip laterals far from plant root zone, water losses increase resulting in reduced yield. Therefore, drip lateral in every row performed best in reducing soil-water losses and increasing total onion bulb yield.

Economic Analysis

Effect of Drip Lateral Spacing on B/C Ratio and MRR of Onion

Based on drip lateral spacing, the cost of treatment in

Table 6: Effect of drip lateral spacing on cost of production and net return of onion

Treatment	Total bulb yield (Kg/ha)	Adjusted bulb yield (Kg/ha)	Gross field benefit (ETB ha ⁻¹)	TVC (ETB ha ⁻¹)	Net benefit (ETB ha ⁻¹)	Benefit cost ratio	MRR (%)
DLER	41,430	37,287	484,770	200,041	284,729	1.4	240.44
DLBTR	25,830	23,247	302,211	146,428	155,783	1.1	

TVC = Total Variable Cost and ETB = Ethiopian Birr and MRR = Marginal Return Rate.

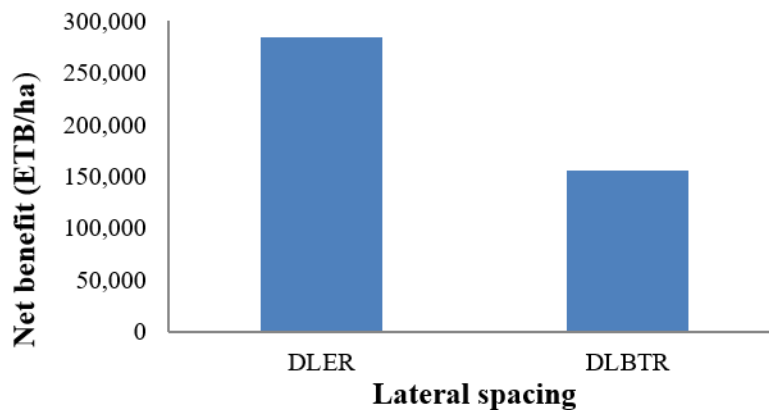


Figure 7: Economic return of drip lateral spacing

which the drip lateral between two onion plant rows was 26.80% less than the treatment in the drip lateral in every onion plant rows (Table 6). (Wondatir *et al.*, 2013) found that investment costs in the design of one lateral for two crop rows were 27% less. Even though the total variable cost of implementing drip lateral in every row greater than that of drip laterals between two rows, it gave the maximum net income 284,729 ETB ha⁻¹. On the other hand, less net income 155,783 ETB ha⁻¹ was obtained from drip lateral between two rows. Farmers installing drip laterals in between two onion plant rows for production of onion losses 128,946 ETB ha⁻¹ and the Net benefit were reduced by 45.3% in the study area.

The net benefit value to cost ratio for drip lateral in every row is 1.4 and for that of drip lateral between two rows is 1.1. This result generally revealed that drip lateral in every row gave high net income than the drip lateral between two rows for drip irrigated fresh marketable bulb yield of onion. The result is due to significantly higher total bulb yield obtained from onion grown under drip laterals in every row. Similarly, (Himanshu *et al.*, 2012) reported that drip lateral in every row resulted in higher gross benefit, net benefit and benefit cost ratio. In spite of high initial

investment, drip irrigation method is profitable for onion production with drip lateral in every row for the study area.

CONCLUSION

Analysis of the drip irrigation uniformity test showed that there is no significant uniformity variation between drip lateral in every row and drip lateral between two rows. All uniformity determination parameters are within the recommended range. The maximum onion bulb yield of (41.43 t/ha) was obtained from drip lateral spacing in every. The highest value of water productivity and highest net benefit were obtained at drip lateral spacing in every row. In conclusion, this study points out that drip lateral in every onion plant row is economically profitable for the production of onion around Awash Melkassa climatic conditions.

RECOMMENDATION

The following recommendations have been made based on the findings from one cropping season:

- Drip lateral in every row is economical for onion bulb producers under drip irrigation at Awash Melkassa climatic condition on loam soil since drip material can be reused.

- Onion production with drip lateral spacing between two plant rows of onion is used as an option method for onion producers of limited resource at this area.
- However, further work is required because lateral spacing adjustment have an effect on different soil type, climate, crop varieties and seasonal variation with drip irrigation to strengthen the study.

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