Frontiers
2021; 1(3): 40-48
http://www.sciencepublishinggroup.com/j/frontiers
doi: 10.11648/j.frontiers.20210103.12

Effect of Drip Lateral Spacing and Water Levels on Yield and Water Use Efficiency of Onion (*allium cepa l.*) Under Awash Melkassa Climatic Condition

Asnake Tilaye[1, *], Teshome Seyoum[2], Tilahun Hordofa[3]

[1]Oromia Agricultural Research Institute, Asella Agricultural Engineering Research Center, Asella, Ethiopia

[2]Haramaya Institute of Technology, Haramaya University, Haramaya, Ethiopia

[3]Ethiopia Agricultural Research Institute, Melkassa Agricultural Research Center, Adama, Ethiopia

Email address:
asnake127@gmail.com (A. Tilaye)

[*]Corresponding author

To cite this article:
Asnake Tilaye, Teshome Seyoum, Tilahun Hordofa. Effect of Drip Lateral Spacing and Water Levels on Yield and Water Use Efficiency of Onion (*allium cepa l.*) Under Awash Melkassa Climatic Condition. *Frontiers.* Vol. 1, No. 3, 2021, pp. 40-48.
doi: 10.11648/j.frontiers.20210103.12

Received: August 10, 2021; **Accepted**: August 20, 2021; **Published**: August 31, 2021

Abstract: Water being scarce resources, irrigation water is the most limiting factor for vegetable production in the central rift valley of Ethiopia. Drip irrigation technique together with deficit irrigation application improves crop yield and water use efficiency. Hence, the objective of this study was to enhance onion production and WUE through the application of drip irrigation technology and deficit irrigation application. Field experiment was conducted at Melkassa agricultural research center during the cool cropping season of 2019/2020 to investigate the effects of drip lateral spacing and irrigation levels on onion yield, water use efficiency and net return. Two levels of drip lateral spacing viz., lateral placed in every row and between two rows, and three levels of deficit irrigation viz., 80% ETc, 70% ETc and 55% ETc, and one-full irrigation (100% ETc). The treatments were arranged in split plot with three replications. Data were analyzed using statistical package appropriate to split plot with the help of SAS software. The result showed that onion yield, yield parameters and water use efficiency was affected by the effects of drip lateral spacing and irrigation water levels but not affected by their interaction effect. Onion bulb yield decreased with increased levels of water deficit. In contrast, both water use efficiency and irrigation water use efficiency increased with increase in water deficit level. Maximum onion bulb yield of 41.43 t ha^{-1} were obtained from lateral spacing in every row and full irrigation application level of 100% ETc and has no a significant difference with every row lateral spacing, and 85% and 70% ETc irrigation application levels. The highest water use efficiency of 13.33 Kgm^{-3} was recorded from every row drip lateral spacing and irrigation application of 70% ETc. Therefore, onion could be irrigated every row drip lateral spacing with 70% ETc application to increase water use efficiency without a significant total bulb yield reduction.

Keywords: Bulb Yield, Deficit Irrigation, Drip Lateral Spacing, Irrigation Level, Water Use Efficiency

1. Introduction

In Ethiopia, irrigation development is increasingly implemented more than ever to supplement the rain-fed agriculture. It aims to increase agricultural productivity and diversify the production of food and raw materials for agro-industry as well as to ensure the agriculture to play a pivot for driving the economic development of the country [1].

Drip irrigation system is one of the most efficient forms of irrigation technology. The experience from many countries show that farmers who switch from furrow system to drip system can cut their water use by 30% to 60% and crop yields often increase at the same time [2].

One of the irrigation management practices which could result in water saving is through deficit irrigation. It is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. It aims at stabilizing yields and plays an important role in increasing water use efficiency (WUE) [3]. The expectation is that any yield reduction resulting from the water stress will be insignificant compared with the benefits gained through diverting the saved water to irrigate other crops [4].

Ethiopia has a great potential to produce onion throughout the year both for local consumption and export. The total area under onion production was estimated to be 24, 375.7 ha with an average yield of about 9.02 tons per hectare and a total production of greater than 2, 19, 735.27 tons [5].

2. Materials and Methods

Field experiment was carried out at Melkassa Agricultural Research Center (MARC) during the dry cropping season of 2019/20. The mean annual rainfall in the area is about 827 mm. The site has mean maximum and minimum temperatures of 28.7°C and 13.8°C, respectively.

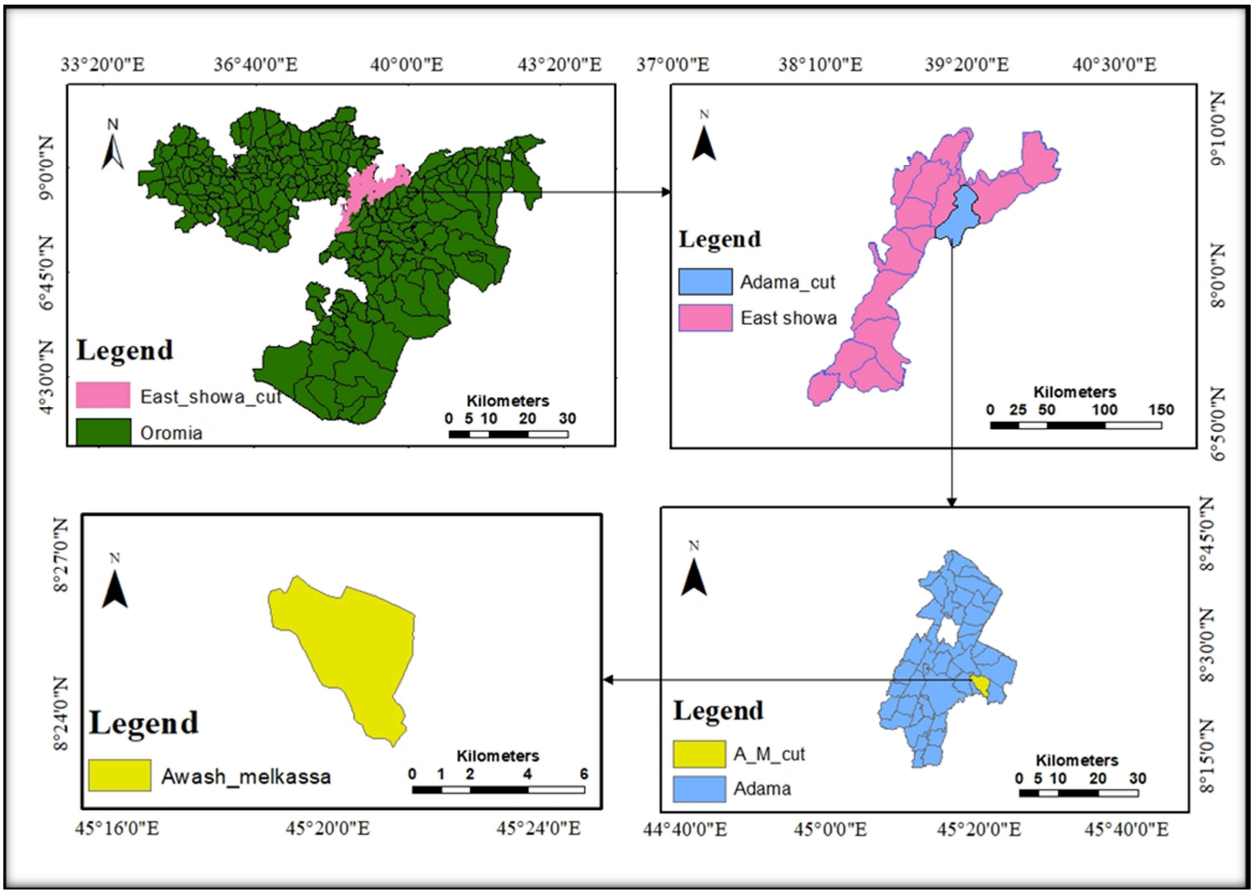

Figure 1. *Location map of the study area.*

2.1. Experimental Treatment and Design

The experimental treatments include two drip lateral arrangements, viz., the drip laterals placed in every plant row and one drip lateral placed at equal distance between two rows, and three deficit irrigation application levels, viz., 85% ETc, 70% ETc and 55% ETc and a control irrigation of 100% ETc application. The experimental design was a split plot design with three replications.

Table 1. *Treatment combination.*

Lateral arrangement (sub-plot)	Irrigation Level (main-plot)			
	100% ETc	**85% ETc**	**70% ETc**	**55% ETc**
Every row	T_1	T_3	T_5	T_7
Between rows	T_2	T_4	T_6	T_8

The experimental field was divided into 24 plots of 3.6 m by 5.5 m to accommodate five double and single laterals with 5 m length and representing a single treatment. The plots and replications had a buffer zone of 1.5 m and 3 m length respectively.

2.2. Procedure of Drip Installation

One overhead plastic tanker for all replication was used to provide the right pressure for the pipe system. The stand of plastic tanker was constructed at a height of 1.5 m above the ground from locally available wood. An overhead tank was used as a pressurized water source for drip irrigation system. 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 connected to

25 mm diameter manifold line to control the flow of water. 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.

2.3. Crop Water Requirements and Irrigation Water Management

2.3.1. Crop Water Requirement

Reference evapotranspiration, ETo was estimated using FAO Penman-Monteith equation from daily meteorological data collected from MARC meteorological station with the help of CROPWAT 8.0 model software. The daily crop water requirements, ETc was estimated by multiplying the daily ETo value with the established Kc value (Eq. 1).

$$ET_C = ET_O \ x \ K_c \tag{1}$$

where, ETc is Crop evapotranspiration (mm/day); ETo is Reference crop evapotranspiration (mm/day) and Kc is Crop coefficient (fraction).

Due to differences in evapotranspiration during the various growth stages, Kc for a given crop varies over the growing period. The growing period can be divided into four distinct growth stages: initial, crop development, mid-season and late season.

Table 2. *Onion growth stage and crop coefficient (Kc) under MARC climatic condition.*

Growth stage	Initial	Development	Mid	Late
Development days	20	30	40	20
Kc value	0.53	0.79	1.05	0.88
Root depth (m)	0.30 - 0.42	0.43 – 0.60	0.60	0.60

2.3.2. Irrigation Water Management

The soil moisture level in all plots was brought to field capacity for each treatment in the last irrigation during the common irrigation time. The soil water availability in the experiment was tested from routine measurements of soil moisture content by the gravimetric method. The wet soil samples were weighed and placed in an oven dry at a temperature of 105°C and dried for 24 hours. The gravimetric water content was converted to equivalent depth (D) from the Eq. (2).

$$\mathrm{D} = \frac{W_w - W_d}{W_d} \ x \ BD \ x \ drz \tag{2}$$

where, D is the depth of available soil moisture (mm); Ww is wet soil weight (gm); Wd is dry soil weight (gm); BD is the soil dry bulk density (gm cm^{-3}) and drz is the sampling depth within the crop root depth (mm).

The soil moisture depleted between irrigation was obtained from Eq. (3).

$$\mathrm{IRn} = (\mathrm{FC} - D) \tag{3}$$

where, IRn is the net irrigation requirement (mm) and FC is the soil moisture content at field capacity (mm).

Irrigation scheduling

Total available water (TAW) was computed from the moisture content of field capacity and permanent wilting point using the following Eq. (4).

$$\mathrm{TAW} = (\mathrm{FC} - PWP) \ x \ BD \ x \ Dz \tag{4}$$

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 that was used in this study was 25% of TAW (p=0.25).

Hence, RAW was computed from the Eq. (5).

$$\mathrm{RAW} = \mathrm{TAW} \times \mathrm{p} \tag{5}$$

where, RAW is the readily available water or net irrigation depth, IRn (mm), p is allowable permissible soil moisture depletion fraction and TAW is total available water in the root depth (mm).

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 [6] 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.

Since the experimental soil is loam soil and the crop is closely grown, a wetted area (w.a) of 80% was used for lateral spacing in every row and 50% for the lateral spacing between two rows was used to determine the net depth of irrigation water requirement under drip irrigation method. Hence, the IRn of irrigation was computed from Eq. (6).

$$\mathrm{IR}_n = \mathrm{TAW} * \mathrm{P} * \mathrm{W.a} \tag{6}$$

where, IRn is the net irrigation requirement (mm) and w.a. is wetting area (fraction).

Irrigation interval, f, was estimated using the following Eq. (7).

$$f = \frac{IRn}{ETc} \tag{7}$$

where, f is irrigation interval (day) and ETc is mean daily crop water requirement (mm day^{-1})

Whenever there is rainfall between irrigation, the IRn could be obtained from the Eq. (8).

$$\mathrm{IRn} = \mathrm{ETc} - \mathrm{P_{eff}} \tag{8}$$

where, P_{eff} is effective rainfall (mm)

The effective rainfall, P_{eff} was estimated using the method given as:

$$P_{eff} = 0.6 \times P - \frac{10}{30/31} \text{ for month} \leq \frac{70}{30/31} \text{ mm} \quad (9)$$

$$P_{eff} = 0.8 \times P - \frac{24}{30/31}\ for\ month > \frac{70}{30/31}\ mm \quad (10)$$

where, P is daily rainfall (mm)

The gross irrigation requirement, IRg was computed by adopting field application efficiency, Ea of 90% for drip irrigation method. The gross irrigation requirement was computed using Eq. (11).

$$IR_g = \frac{IR_n}{E_a} \quad (11)$$

where, IR_g the gross irrigation requirement (mm) and E_a is the field application efficiency (%).

2.4. Data Collection

2.4.1. 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. (12).

$$q = \frac{v}{\Delta t} \quad (12)$$

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. (13).

$$EU = 100\ (\frac{q_{min}}{qa}) \quad (13)$$

where: - Eu is Emission uniformity (%); qmin=minimum emitter flow rate (l/h) and qa is average discharge rate of all observed emitters (l/hr).

Emitter flow variation, q_{var}

It is calculated using Eq. (14).

$$qvar = (\frac{qmax - qmin}{qmax}) \quad (14)$$

where, qmax is maximum emitter flow rate (l/h); qmin 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. (15).

$$CV = \frac{S}{qa} \quad (15)$$

where: S is standard deviation of emitter flow rates (l/h) and qa 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. (16).

$$UC = \left(1 - \frac{sq}{qa}\right) * 100 \quad (16)$$

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

2.4.2. 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.

2.4.3. 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 - four days to dry/cure and then necks was cut at 2 cm height from the bulb neck [7]. Yield and yield parameters collected was Bulb diameter (cm), Bulb height (cm), Average weight of bulb (gm) and total yield of bulb (t/ha).

a) Total Yield of Bulb (t/ha)

The matured onion bulbs were harvested from the middle three double rows within a net area of (1.8 x 4) m^2 and the leaves were cut at 2 cm above the neck. The bulb was then categorized into marketable and unmarketable. The marketable onion bulb yield was sorted out of the total onion bulb yield depending twins/split and rotten and counted weighed separately using analogue balance. Total bulb yield per net plot was recorded and converted into ton per hectare as given in Eq. (17).

$$\text{Bulb yield}(\frac{t}{ha}) = \frac{\text{Bulb yield}\left(\frac{kg}{plot}\right)x10}{\text{Net harvested area of plot }(m^2)} \quad (17)$$

b) Water Use Efficiency

Water Use Efficiency was calculated by dividing harvested total onion yield in kilogram to unit volume of water in cubic-meter or hectare-meter. The water use efficiency (WUE) also known as water productivity (Kg m^{-3}) and Irrigation Water Use Efficiency (IWUE, Kg m^{-3}) was also estimated using Eq. (18) and (19), respectively.

$$WUE = \frac{Y_a}{ET_C} \quad (18)$$

$$IWUE = \frac{Y_a}{d_{gross}} \quad (19)$$

where, Ya is actual bulb yield obtained (Kg); ETc is actual water applied to the soil throughout onion growing period (mm or m^{-3}) and dgross is gross irrigation water applied throughout onion growing period (mm or m^{-3}).

2.5. Statistical Analysis

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

2.6. Economic Analysis

Economic analysis was computed by using the results of this study based on investment, operation and production costs. The mean bulb yield (kg ha^{-1}) was adjusted for yield losses by subtracting 10% of the bulb yield from total yield [8].

3. Results and Discussions

3.1. Soil Analyses

3.1.1. Physical Properties of Soil

The laboratory results of the average soil physical properties of the experimental site were presented in (Table 3) below.

Table 3. *Average soil physical properties of experimental site.*

Depth	Bulk density	FC (%)	PWP (%)	TAW	TAW	Texture			
(cm)	(g/cc)	(V/V)	(V/V)	(mm/m)	(mm)	% Clay	% Silt	% Sand	Class
0 – 15	0.95	29.06	13.37	156.96	23.54	15.4	41.7	42.9	Loam
1 6 – 30	1.13	34.74	16.56	181.77	27.27	20.4	48.3	31.3	Loam
31 – 60	1.20	36.67	17.63	190.49	57.15	18.8	45.0	36.3	Loam
Aver.	1.09	33.49	15.85	176.41	35.99	18.2	45.0	36.8	Loam

The average result of the soil physical properties from the experimental site showed that the soil textural classification is dominated by loam.

Bulk density at the lower root zone layers are more compacted and have less organic matter, less aggregation, and less root penetration compared to top root layers, therefore contain less pore space. The weighted average bulk density of the experimental site was 1.09 g/cm^3.

3.1.2. Chemical Properties of Soil

Table 4. *Average chemical properties of soil at the experimental site.*

Depth (cm)	pH	Total organic matter (% OM)	Total organic carbon (% OC)	Total nitrogen (% TN)	ECe (ds/m)
0 – 15	7.8	5.2	3.0	0.09	1.2
16 – 30	8.5	4.8	2.8	0.09	1.6
31 – 60	8.5	7.0	4.1	0.06	1.1
Average	8.3	5.7	3.3	0.1	1.3

The average pH value of the experimental site through the analyzed soil profile was found to be highly alkaline with average value of 8.3% (Table 4). According to Olani and Fikre (2010) onion can grow best in soils with pH range of 6.0 to 8.0. An average electrical conductivity of an experimental soil is 1.3 ds/m soils and that had ECe < 2 (ds/m) was non saline [9].

3.2. Drip Emitters Uniformity Test

Uniformity was 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 dripper (upper, middle and lower) positions was selected randomly for the two lateral spacing adjustments. A total of 216 reading were recorded for analysis. Uniformity of water application was calibrated from the dripper outflow collected in the buried plastic bottle under the lateral line for 30 minute. 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 5).

Table 5. *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 (%)	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.

The average emission uniformity value (Table 6) was 93.66. Emission uniformity (90% – 100%) was categorized as excellent [10]. The average UC values (i.e., 96.28%) depicted that uniformity coefficients under the experiment were classified as excellent.

Table 6. *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

Field evaluation of emitter flow variation having (10 – 20)% classified as acceptable [11]. The average emitter flow variation of the experiment was 12.05% (Table 6). 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.

3.3. Irrigation Water Requirement of Onion

Crop water requirement of onion was determined based on the seasonal water application depth from transplantation to harvest and vary based on the treatments irrigation water levels. The highest and minimum seasonal crop water requirement obtained was 421.92 mm and 232.06 mm at 100% ETc and 55% ETc respectively (Table 7).

Table 7. *Seasonal net irrigation water depth applied for each treatment.*

Treatments	Dnet (mm)	Ea (%)	w.a (%)	Dgross (mm)
100% ETc DLER	421.92	90	80	375.04
85% ETc DLER	358.63	90	80	318.78
70% ETc DLER	295.34	90	80	262.52
55% ETc DLER	232.06	90	80	206.27
100% ETc DLBTR	421.92	90	50	234.40
85% ETc DLBTR	358.63	90	50	199.24
70% ETc DLBTR	295.34	90	50	164.08
55% ETc DLBTR	232.06	90	50	128.92

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

3.4. Effects of Lateral Spacing and Water Levels on Growth, Yield and Yield Parameter of Onion

As shown in (Table 8) all onion parameter shows significant ($P \leq 0.05$) difference due to effects of drip lateral spacing adjustment and irrigation water levels. The highest mean value of all parameter of onion was recorded under drip lateral space in every row and full irrigation application (100% ETc).

The highest value of onion growth and yield parameter was recorded under lateral spaced in every row [12]. Lower volume of irrigation water applied by drip lateral spaced in between two rows results in lower value of all parameter. The yield was reduced by 31.05% when drip lateral between two rows were used.

Plots which received the greatest volumes of water yielded with percentages of large-size bulbs whereas water shortages led to higher percentages of small-size bulbs. As deficit irrigation application increase the mean value of all growth and yield parameter decrease. Increasing irrigation water level, plant growth parameter was increased [13]. When plants respond to water stress by closing their stomata to slow down water loss by transpiration, gas exchange within the leaf is limited, consequently, photosynthesis and growth was slow down [14].

Table 8. *Effect of Irrigation water levels and Lateral spacing on onion growth parameter.*

Treatment	PH (cm)	LH (cm)	LN	BD (cm)	BH (cm)	BW (gm)	MBY (t/ha)	TBY (t/ha)	WUE (kg/m^3)
Lateral Spacing (LS)									
DLER	61.97^a	58.93^a	11.67^a	7.10^a	6.00^a	81.00^a	28.47^a	35.47^a	12.33^a
DLBTR	53.33^b	50.47^b	9.00^b	5.77^b	5.73^b	70.67^b	19.63^b	21.30^b	11.79^b
S.Em±	0.93	0.89	0.24	0.20	0.02	1.03	0.69	0.41	0.07
CV	2.79	2.81	3.95	5.42	0.70	2.35	4.96	2.50	1.02
LSD (5%)	5.64	5.40	1.43	1.22	0.17	6.25	4.19	2.49	0.43
Irrigation Water Levels (IR)									
100% ETc	59.63^a	57.23^a	11.67^a	6.83^a	6.13^a	81.67^a	29.21^a	33.64^a	11.03^c
85% ETc	58.70^{ab}	55.37^{ab}	10.67^b	6.67^{ab}	5.97^{ab}	79.33^{ab}	27.76^b	31.85^b	12.25^b

Treatment	PH (cm)	LH (cm)	LN	BD (cm)	BH (cm)	BW (gm)	MBY (t/ha)	TBY (t/ha)	WUE (kg/m^3)
70% ETc	56.97^{bc}	54.00^{bc}	9.67^{c}	6.40^{b}	5.77^{bc}	74.00^{b}	22.50^{c}	27.69^{c}	12.88^{a}
55% ETc	55.27^{c}	52.30^{c}	9.33^{c}	5.80^{c}	5.70^{c}	67.67^{c}	16.73^{d}	20.39^{d}	12.08^{b}
S.Em±	0.55	0.64	0.17	0.10	0.06	1.61	0.40	0.48	0.09
CV	1.66	2.02	2.79	2.61	1.81	3.69	2.91	2.92	1.30
LSD (5%)	1.91	2.21	0.58	0.33	0.21	5.58	1.40	1.66	0.31

PH=plant height, LH=Leaf height, LN=Leaf number, BD=Bulb diameter, BH=bulb height, BW=bulb weight, WUE=Water use efficiency, MBY=Marketable bulb yield, TBY=Total bulb yield, LSD (%)=least significant Difference at 5% of significance, CV (%)=Coefficient of variation, S.Em±=Standard error of mean

High application of irrigation levels increased photosynthetic area of the plant (height of plants and number of leaves), which increased the amount of assimilate partitioned the bulbs and increased bulb diameter [15].

Total bulb yield was reduced by 39.95% when drip lateral between two rows were used. Lateral spacing in every row gave highest mean crop yield [16] that is similar to this study.

Among the treatment combinations of irrigation water levels and drip lateral space, lateral space in every row with 100% ETc recorded higher all onion parameter (Table 9). These results associated with plots which received larger amount of water showed significantly larger plant parameter compared with plots which received lower amounts at the same date of sampling.

Table 9. *Interaction effect of Irrigation water levels and lateral spacing on onion growth parameters, yield and yield parameters.*

Treatment	PH (cm)	LH (cm)	LN	BD (cm)	BH (cm)	BW (g)	MBY (t/ha)	TBY (t/ha)	WUE (kg/m^3)
Interaction (IL x LS)									
100% ETc x DLER	63.80^{a}	61.4^{a}	13.67^{a}	7.47^{a}	6.27^{a}	86.40^{a}	33.98^{a}	41.43^{a}	11.05^{e}
85% ETc x DLER	63.00^{a}	59.63^{ab}	11.67^{b}	7.30^{a}	6.07^{ab}	84.13^{ab}	33.06^{a}	39.86^{a}	12.51^{b}
70% ETc x DLER	61.63^{ab}	57.97^{b}	10.53^{c}	7.07^{a}	5.83^{c}	79.20^{bc}	27.27^{b}	35.00^{b}	13.33^{a}
55% ETc x DLER	59.40^{b}	56.73^{b}	9.53^{d}	6.40^{b}	5.80^{cd}	73.30^{cd}	19.54^{d}	25.65^{c}	12.44^{bc}
100% ETc x DLBTR	55.43^{c}	53.00^{c}	9.53^{d}	6.13^{bc}	5.97^{bc}	76.90^{c}	24.44^{c}	25.83^{c}	11.02^{e}
85% ETc x DLBTR	54.37^{cd}	51.07^{cd}	9.07^{d}	5.97^{bc}	5.80^{cd}	74.50^{cd}	22.45^{c}	23.84^{c}	12.01^{cd}
70% ETc x DLBTR	52.27^{de}	50.00^{cd}	9.00^{d}	5.70^{cd}	5.60^{de}	68.80^{d}	17.73^{d}	20.37^{d}	12.43^{bc}
55% ETc x DLBTR	51.10^{e}	47.80^{d}	9.00^{d}	5.23^{d}	5.57^{e}	62.00^{e}	13.94^{e}	15.14^{e}	11.72^{d}
S.Em±	0.95	1.08	0.25	0.22	0.06	1.18	0.72	0.55	0.15
CV	2.87	3.43	4.22	5.92	1.81	2.71	5.17	3.35	2.11
LSD (5%)	2.90	3.32	0.69	0.61	0.22	6.17	2.16	2.09	0.46

Total bulb yield was reduced by 37.65% when drip lateral between two rows were used at full irrigation application. Drip lateral between two rows combined with full irrigation level (100% ETc) is a better option for users that live in areas where there is scarcity of water and better saving of drip laterals.

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. 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.

3.5. Effects of Water Levels and Lateral Spacing on Water Use Efficiency of Onion

The data in (Table 10) indicated that the interaction of level of irrigation and lateral spacing shows a significant ($P < 0.05$) difference on water use efficiency and irrigation water use efficiency. Water use efficiency was highest at (70% ETc) irrigation level under drip lateral space in every row and between two rows at which (13.33 kg/m^3 and 12.43 kg/m^3) were obtained respectively. Water use efficiency (yield per unit area per unit depth of water used) decreased with increase in irrigation levels i.e. (55% ETc, 70% ETc, 85% ETc and 100% ETc) for all treatments of drip later spacing in every row and between two rows.

Table 10. *Interaction effect of irrigation water levels and lateral spacing on WUE and IWUE.*

Irrigation water level	WUE (kg/m^3)		IWUE (kg/m^3)	
	Lateral spacing		Lateral spacing	
	DLER	DLBTR	DLER	DLBTR
100%	11.05^{e}	11.02^{e}	11.62^{c}	11.72^{bc}
85%	12.51^{b}	12.01^{cd}	13.03^{abc}	13.10^{abc}
70%	13.33^{a}	12.43^{bc}	14.07^{a}	13.83^{a}
55%	12.44^{bc}	11.72^{d}	13.44^{ab}	13.37^{abc}
Mean	12.33	11.80	13.04	13.01
S.Em±=0.15 LSD (5%)=0.46 CV=2.11			S.Em±=0.77 LSD (5%)=1.82 CV=10.2	

IWUE=Irrigation Water use efficiency, Means followed by the same letter in a column are not significantly different from each other at a 5% probability level.

3.6. Economic Analysis

3.6.1. Effect of Drip Lateral Spacing on Benefit to Cost Ratio and MRR of Onion Production

Table 11. *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	35,470	31,920	414,960	188,422.05	226,537.95	1.2	236.53
DLBTR	21,300	19,170	249,210	139,169.33	110,040.7	0.8	

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

Based on drip lateral spacing, the cost of treatment in which the drip lateral between two onion plant rows was 26.14% less than the treatment in the drip lateral in every onion plant rows but gave the maximum net income (Table 11). According to [17] investment costs in the design of one lateral for two crop rows were 27% less.

Table 12. *Partial budget and MRR analysis for lateral spacing in combination with irrigation level on Total yield of onion.*

Treatments	TC (ETB/ha)	UTY (t/ha)	ATY (t/ha)	GB (ETB/ha)	NB (ETB/ha)	MR	MC	MRR (%)
100% ETc x DLER	200,041	41,430	37,290	484770	284729.2	0	0	0
85% ETc x DLER	197,903.35	39,860	35,870	466310	268406.7	16322.5	2137.5	763.63
70% ETc x DLER	195,766	35,000	31,500	409500	213734.2	54672.5	2137.5	2557.78
55% ETc x DLER	193,628.35	25,650	23,090	300170	106541.7	107192.5	2137.5	5014.85
100% ETc x DLBTR	146,428.02	25,830	23,250	302250	155822	- 49280.3	47,200.3	-104.41
85% ETc x DLBTR	145,095.68	23,840	21,460	278980	133884.3	21937.66	1,332.34	1646.55
70% ETc x DLBTR	143,763.35	20,370	18,330	238290	94526.65	39357.67	1332.33	2954.05
55% ETc x DLBTR	142,431.02	15,140	13,630	177190	34758.98	59767.67	1332.33	4485.95

TC=Total cost, UTY=Unadjusted total yield, ATY=Adjusted total yield, GB=Gross benefit, NB=Net benefit, MR=Marginal return, MC=Marginal cost

3.6.2. Partial Budget and MRR Analysis for Lateral Spacing Combined with Water Level on Total Yield of Onion

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 under Awash Melkassa climatic condition (Table 12). The result is due to significantly higher bulb yield obtained from onion grown under drip laterals in every row. DLER with (70% ETc) is better water saving and net benefit and it is selected for this study at Awash Melkassa climatic condition.

4. Conclusion and Recommendations

4.1. Conclusion

Analysis of drip irrigation uniformity test showed that there is no significant uniformity variation between drip lateral in every rows 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) were obtained from drip lateral spacing in every row at full irrigation application (100% ETc).

Highest result of water use efficiency (13.33 Kgm^{-3}) was obtained at drip lateral spacing in every row at 70% ETc irrigation water level. Highest net benefit was recorded at drip lateral spacing in every row at full irrigation application (100% ETc) but consumes more irrigation water.

In conclusion, this study point out that drip lateral in every onion plant row and 70% ETc is economically profitable and water productivity is maximized than the other treatments for the production of onion under drip irrigation around Awash Melkassa climatic condition.

4.2. 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 rows of onion is not profitable at this area.

Water use efficiency is optimized with drip lateral spacing in every row at 70% ETc irrigation water level.

However, further work is required because water level have an effect on different soil type, climate, crop varieties and seasonal variation with drip irrigation to strengthen the study.

References

[1] Mekonen Ayana. 2011. Deficit irrigation practices as alternative means of improving water use efficiencies in irrigated agriculture: Case study of maize crop at Arba Minch, Ethiopia. African Journal of Agricultural Research 6 (2): 226-233.

[2] Sijali, I. V., 2001. Drip irrigation: Options for smallholder farmers in Eastern and Southern Africa. RELMA Technical Hand Book Series 24. Nairobi, Kenya.

[3] Mati, B. M., 2012. *In-Field Water Management in Irrigated Agriculture: Adaptable Best Practices.* Training Manual No. 8. Nile Basin Initiative (NBI), Nile Equatorial Lakes Subsidiary Action Program (NELSAP), Regional Agricultural Trade and Productivity Project (RATP).

[4] Eck, H. V., Mathers, A. C. and Musick, J. T., 1987. Plant water stress at various growth stages and growth and yield of soybean. Field Crop Res. 17: 1–16.

[5] CSA (Central Statistical Agency). 2014. Agriculture sample survey. Central Statistical Agency. Vol. 1, Addis Ababa, Ethiopia.

[6] Keller, J. and Bliesner, R. D., 1990. *Sprinkle and trickle irrigation*. New work.

[7] Olani, N. and Fikre, M. 2010. Onion seed production techniques. A Manual for Extension Agents and Seed Producers. Assela, Ethiopia.

[8] CIMMYT (International maize and wheat improvement center). 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition, DF, Mexico.

[9] Cass, A. 1998. Measuring and managing chemical impediments to growth. Australian Grape grower & Winemaker. 415, 13–16.

[10] ASABE (American Society of Agricultural and Biological Engineers), 1999. Field evaluation of micro irrigation system. ASAE standards. 46th Ed EP 458.

[11] Bralts, V. F. 1986. Operational principles Field performance and evaluation. In trickle irrigation for Crop Production, Amsterdam, *and Elsevier*. pp. 216-240.

[12] Oli, F., Teshome, S. and Fentaw, A. 2019. 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. *Journal of Horticulture and Forestry.* 11 (4): pp. 62-69. 2006-9782.

[13] Beniam, Y. M., 2019. Response of onion (Allium cepa l.) to deficit irrigation under surface and drip irrigation method in central rift valley of Ethiopia, MSc Thesis. School of Biosystem and Environmental Engineering. Hawassa University, Hawassa, Ethiopia.

[14] Currah, L. and Proctor, F. J. 1990. Onion in Tropical Regions. Natural Resources Institute. Chatham Maritime, Kent, UK. P 232.

[15] Mebrahtu, Y., Abraham, W. and Solomon, H. 2018. Response of onion (*Allium cepa* L.) to deficit Irrigation under different furrow irrigation water management techniques Raya valley, Northern Ethiopia. *African Journal of Plant Science.*

[16] Tirkey, S. V., Imtiyaz, M. and Kumar, J. L. G. 2017. Yield, irrigation production efficiency and economic return of tomato under variable irrigation and lateral spacing. *Annals of Plant Biology and Crop Research (APBCR).* 1 (1): PP 5-16.

[17] Wondatir, S., Belay, Z. and Desta, G. 2013. Effect of drip lateral spacing and irrigation regime on yield, irrigation water use efficiency and net return of tomato and onion production in the Kobo Girrana valley of Ethiopia, Rainwater management for resilient livelihoods in Ethiopia: Proceedings of the Nile Basin, Development Challenge science meeting, Addis Ababa. 204-203.