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Effect of Furrow Irrigation Technical Parameters on Field Application Performances of Short Furrow and Yield of Onion Crop in Bako, Ethiopia

Gudeta Genemo Kore[1]
[1]Soil and Water Engineering Research Case Team, Bako Agricultural Engineering Research center,
Oromia Agricultural Research Institute

Abstract*: - Flow rate and Furrow length are the main irrigation technical Parameters currently affecting field application performances and management of irrigation system at farm level. Improper selection of these parameters produces an over use of water and loss in crop production. The general objective were to investigate the effect of furrow irrigation technical Parameters on field Application performances of short furrow and yield of onion crop, with specific objective of analyze the effect of flow rate and furrow length on application efficiency , storage efficiency , distribution uniformity , deep percolation ratio and onion yield . The field experiment was laid out in RCBD factorial arrangement of three levels of flow rate (0.7, 0.98 and 1.3l/s) and three levels of furrow length (25, 35 and 50m) with three replication. For the purpose of field performance evaluation Soil moisture content was determined by using gravimetric method. Field application performance parameters such as application efficiency (Ea), storage efficiency (Es), distribution uniformity (DU), deep percolation ratio (DPR) and onion yield were used for evaluation. The analysis of field application performance parameters indicated that the effect of furrow length and flow rate were highly significant (P<0.01) on all performance indicators. The minimum and maximum values for Ea, Es, DU and DPR were 53.60 and 65.87%, 78.05 and 94.98% , 80.42 and 92.17% , 34.35% and 46.40% ,respectively. The ranges of mean yield gained from furrow length and flow rate were 14.75 to 15.96ton/ha and 13.59 to 16.94ton/ha, respectively. The effect of furrow length on yield were not significant (p<0.05). However, the flow rate showed highly significant (p<0.01) effect on yield of onion. Therefore, it is concluded that, in the utilization of fragmented farm size a 50m furrow length is suitable to 1.3 L/s flow rate for better field application performances and onion yield around the study area.

Keywords: Field Application Performance, Furrow Irrigation, Flow Rate, Technical Parameter

I. INTRODUCTION

Water scarcity is a growing global problem challenging sustainable development and placing a constraint on producing enough food to meet increasing food requirements. Ethiopia is also a country which has vast water resources estimated in 122 billion meters cube with an annual groundwater recharge of 28 Billion meters cube [1]. Moreover, the potentially irrigable land is 3.6 million ha. However, only about 5.6 billion meters cube of the water resource and 290,000 ha of the potentially irrigable land are utilized so far [1] and [2]. Despite Ethiopia's large agricultural sector and water potential, growing human population, recurrent droughts and periodic floods, complicated with climate change that has been accompanied by severe soil and landscape degradation in some regions contributed to a situation of national food insecurity [3].

In spite of its enormous potential to ensuring long-term food security in Ethiopia, irrigation is facing several problems. Such as inadequate water management at farm level and poor efficiency with which water resources have been used for irrigation. Inappropriate management of irrigation has contributed, not only to food insecurity but also to environmental problems including excessive water depletion, water quality reduction, water logging and salinization [4].

Furrow irrigation, recounted to be one of the least efficient methods compared with other irrigation methods [5], is still one of the most widely used forms of surface irrigation. Despite its application efficiency remaining relatively low [6] not enough effort is being made to keep improving its management and efficiency. There is a need for basic technical parameters such as flow rate, furrow length and cut off time that easily applied to furrow irrigation system design in order to optimize for local condition [7]. Flow rate and furrow length are the main management and design parameters affecting irrigation efficiency [8]. However, proper selections of these parameters are not well practiced in the study area. The possibility of using optimum or longer furrow length in the farmers is very low. Therefore, appropriate selections of these parameters were significant element for improving the field application performances and crop yield under framers field. The main objectives of this study were to investigate the effect of furrow irrigation technical Parameters on Field application performances and yield of Onion crop around the study area.

II. MATERIALS AND METHOD

A. Description and Climatic characteristics of the study area

The study area was located Bako Woreda, West Shewa Zone ,Oromia Regional State with an altitude of 1590m above sea level and lies in 9°06' N and 37°09' E Latitude and longitude has mean monthly minimum and maximum temperature in the area are 13.7^{o}c and 28.4^{0}c respectively. Mean monthly annual dependable and effective dependable rainfall in the area were

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808.5mm and 482mm**,** respectively. Figure 1 below shows the monthly distributions of reference evapotranspiration (ETO) and effective dependable rainfall of the study area for 31years (1987_2017). The potential evapotranspiration of the study area calculated using the CROPWAT Model is more than the effective dependable rainfall in most of the months and in this case, rainfall is insufficient to compensate for the water lost by evapotranspiration. This indicated that most of the crops planted in these months need supplemental irrigation. The effective dependable rainfall is more than ETO during June and July, meaning that no irrigation is required during these months.

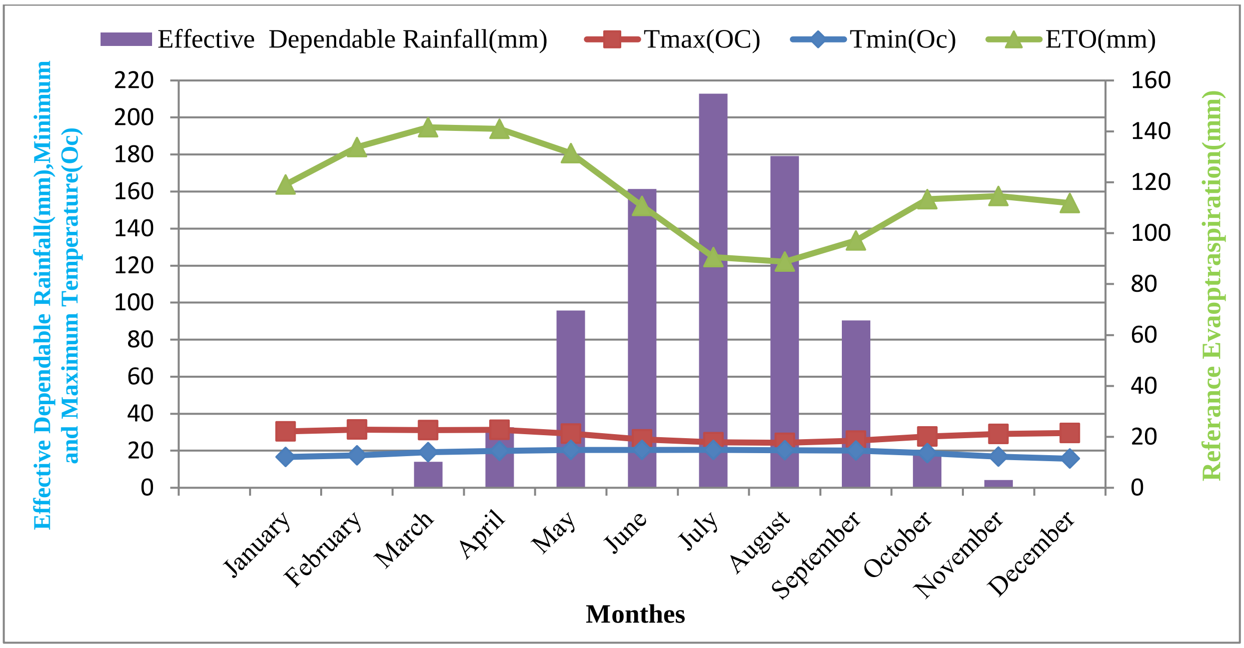

Fig 1. Monthly Distribution of Reference Evapotranspiration and Effective Dependable rain fall of study area

B. Experimental Design and treatments

The treatments include two factors namely furrow length and flow rate. The levels of treatments include three level of both furrow length (F1, F2, and F3) and flow rate (Q1, Q2, Q3). The furrow length was 25m, 35m and 50m. The flow rate was made by rating of 50%, 75% and 100% of the maximum non erosive flow rate. The experimental field was arranged 3x3 factorial experiments in randomized complete blocks design with three replication. Each replication had nine treatments or plots and each plot had four furrows with 2.4m width. The treatments were assigned randomly into three blocks. The block and plot spacing were 1.5m and 0.5m respectively.

Table 1. Combinations of Experimental Treatment

Flow rate (l/s)	**Furrow Length(m)**		
	F1	F2	F3
Q1	F1Q1 (T1)	F2Q1 (T4)	F3Q1 (T7)
Q2	F1Q2 (T2)	F2Q2 (T5)	F3Q2 (T8)
Q3	F1Q3 (T3)	F2Q3 (T6)	F3Q3 (T9)

The maximum non-erosive flow rate was determined using equation developed by [9] .

$$Qmax = \frac{\alpha}{S^{\beta}} \qquad (1)$$

Where: Qmax = Maximum flow rate, l/s
S = Furrow slope, %
A and β are coefficient of parameters based on soil group

Table 2 . Coefficient parameters for furrow maximum flow rate

Soil group	**α(l/s)**	**β**
Heavy textured soil	0.892	0.937
Medium heavy textured	0.988	0.55
Medium Texture	0.613	0.733
Light texture	1.111	0.615
Very Light texture	0.665	0.548

(Source: Hamad and Stringham 1978 or [9])

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The experimental field had an average of furrow bed slope of 0.6% and clay loam in textural class which categorized as medium heavy textured soil group [10]. Based on these the Coefficient parameters for furrow maximum flow rate were α=0.988 and β=0.55. Therefore the maximum non erosive flow rate (Qmax) obtained above formula was 1.31L/s and based on this values the three levels of flow rate 50%, 75% and 100% of Qmax were 0.7 ,0.98 and 1.31L/s respectively. These flow rates were diverted to the furrows by using calibrated parshall flume having appropriate opening diameter of three inch (3"). The calibration was done by volumetric measurement. Equations obtained from field calibration was checks with the standard of [11] . The different head discharge relation and results were presented in figure below.

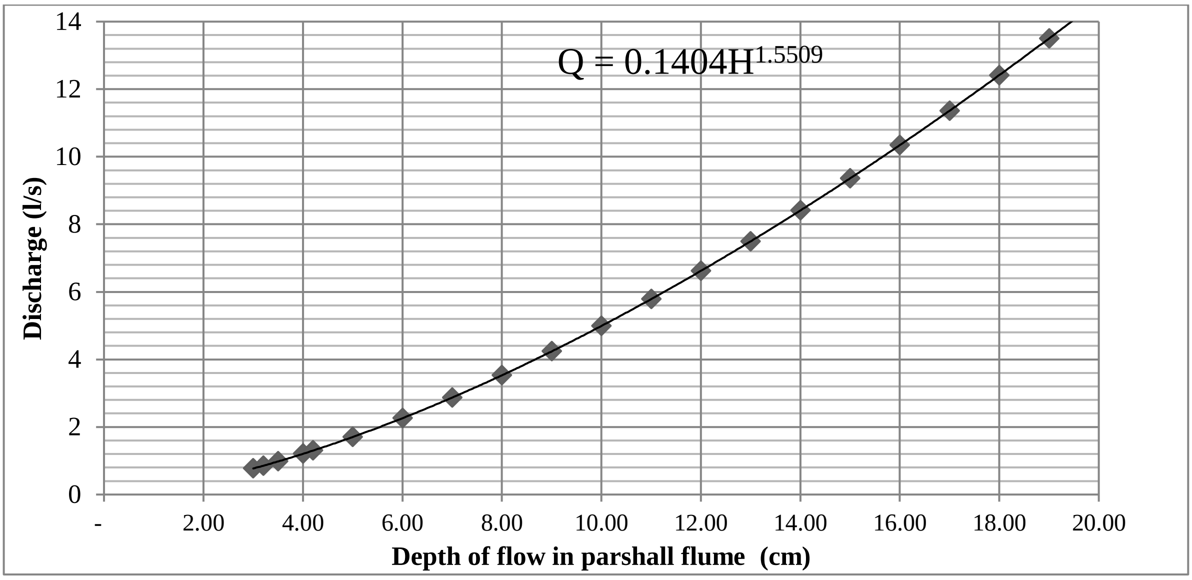

Fig 2. Head Discharge Relationship of 3 inch parshall flume

C. Determination of Crop water Requirement and Irrigation Requirement

Crop water requirement of onion for the growing season was determined from the reference evapotranspiration and crop coefficient using Equation (1) by using FAO CROPWAT version_8 program. After then the net irrigation Requirement was determined [12]. Dependable Rain (FAO/AGLW) Formula was used to determine effective rain fall. Finally gross irrigation requirement was calculated by considering 60% of field application efficiency [13].

$$ET_C = ET_O \times K_C \tag{2}$$

Where: ET_C = crop water requirement or crop evapo transpiration (mm/day)
K_C= crop coefficient (dimensionless)
ET_O= reference crop evapotranspiration (mm/day)

D. Soil Sample Collection and Analysis Methods

The disturbed and undisturbed composite soil sample before planting were collected at a depth of 0-20 and 20-40 and 40-60cm. Bulk density, soil texture, PH Electrical conductivity, Field capacity and permanent wilting point were done by core sampler method, pipette method, pH meter, Electro conductivity meter, pressure plate apparatus by applying a suction of 1/3 and 15 bars to a saturated soil sample, respectively. Infiltration Characteristics of the soil of the soil was determined by using inflow out flow method [14].

E. Determination of Field Application performance Parameters

Application Efficiency: was determined as [15] .

$$\mathrm{Ea} = \frac{\mathrm{Zs}}{\mathrm{Z}} \times 100 \tag{3}$$

Where: Ea = Application efficiency (%)
Zs = depth of water retained in the root zone (mm) and
Z = depth of water applied to the furrow (mm)

Storage Efficiency: was determined as [15] .

$$Es = \frac{ZS}{Zreq} \times 100 \tag{4}$$

Where: Es = storage efficiency (%),
ZS = depth of water stored in the root zone (mm) and
Zreq= Water required in root zone prior to irrigation (mm)

Distribution uniformity: was determined as [16].

$$DU = \frac{Zmin}{Zav} \times 100 \quad (5)$$

Where: DU = distribution uniformity (%)
Zmin = the minimum infiltrated depth (mm) and
Zav = the mean of depths infiltrated over the furrow length (mm)

Deep percolation ratio : was determined as [17].

$$DPR = 100 - Ea - RR \quad (6)$$

Yield Collection

$$\text{Onion yield (ton/ha)} = \frac{\text{plot yield(kg)} \times 10}{\text{plot area } (m^2)} \quad (7)$$

F. Statistical Analysis

The collected data were analyzed using SAS 9.0 statistical software. For comparing means of the treatments that showed significant result, the least significant difference (LSD) test at 5% and 1% probability level was applied.

III. RESULTS AND DISCUSSION

A. Crop water requirements and irrigation scheduling of onion

Crop water requirements and irrigation scheduling of onion were calculated by multiplying the reference evapotranspiration values with the onion crop coefficient [12] and computed as 438.39mm. The net crop water requirement was computed by deducting effective rainfall from ETc while Gross water requirement was computed by adopting a field application efficiency of 60% were 416.53 mm and 694.21mm , respectively.

B. Effect of flow rate and furrow length on Field Application performances

According to the analysis of variance (Table 1), the effect of furrow length and flow rate were highly significant at ($p<0.01$) on field Application performances and their interaction were significant at ($p<0.05$). Also the effect of flow rate were highly significant at ($p<0.01$) on yield of onion but the effect of furrow length and their interaction were non-significant on yield of onion.

Table 1. Analyses of variance (ANOVA) For Field Application Performances and yield

Source of variation	Field Application Performances and yield				
	E_a (%)	E_S (%)	D_U (%)	D_{PR} (%)	Y(ton/ha)
Furrow length(F)	21.46^{**}	44.96^{**}	9.93^{**}	21.46^{**}	1.92^{ns}
Flow Rate(Q)	48.60^{**}	89.08**	30.68**	48.66**	11.36^{**}
FXQ	3.15^{*}	7.1**	5.40^{**}	3.01^{*}	0.41^{ns}
CV	2.61	1.82	1.98	4.04	9.9
LSD(0.05)	0.53	0.52	0.59	0.53	1.49

Where: ^{NS} Non significant, *Significant, ** Highly significant, F=Furrow length, Q =Flow rate, FXQ= Interaction of Furrow length and flow rate, E_a = Application Efficiency, E_S= Storage Efficiency, D_U= Distribution uniformity, D_{PR}= Deep percolation ratio, y = yield

1. Application Efficiency (Ea)

The effect of furrow length was highly significant ($p<0.01$) on application efficiency (Table 1). Application efficiency has shown a decreasing trend as furrow length increased and the mean values of application efficiency were 63.28, 60.70 and 57.48% for F1, F2 and F3 furrow lengths (Table 2). This trend is in agreement with the finding of [19] and [8] .

The effect of flow rate was highly significant ($P<0.01$) on application efficiency (Table 1). Application efficiency has shown an increasing trend as flow rate increased as shown in below and Mean values of application efficiency were 57.62, 59.85 and 64.00% for Q1, Q2 and Q3 flow rates, respectively (Table 2). This is might be due to faster advance time at higher flow rate, leads to make minimum deep percolation loss below root zone of onion crop contribute to increase the application efficiency.

This is consistent with trend of [19] and [20] their result associated with an increasing trend of application efficiency with increase of flow rate.

Table 2 .Effect of flow rate and furrow length on application efficiency

	Mean of Application Efficiency (%)			
	Flow rate(l/s)			
Furrow length(m)	Q1	Q2	Q3	Mean
F1	61.32[cd]	62.87[bc]	65.87[a]	63.28[k]
F2	57.94[e]	59.34[de]	64.64[b]	60.70[l]
F3	53.60[f]	57.35[e]	61.49[cd]	57.48[m]
Mean	57.62[t]	59.85[r]	64.00[s]	60.49
	F	Q	FXQ	
SEM(±)	0.523	0.523	0.9	
LSD(0.05)	0.53	0.53	1.58	

* Means with the same letter are not significantly different

2. Storage Efficiency (Es)

The effect furrow of length and flow rate were highly significant ($p<0.01$) on Storage efficiency (Table 1). Storage efficiency has shown an increasing trend for increase in furrow length and mean values of E_S were 81.89, 88.02 and 89.13% for furrow length of F1, F2 and F3 respectively(Table 2). Similarly, [20] has got an increasing trend of Storage efficiency with increases of furrow length.

Storage efficiency has shown decreasing trend as flow rate increase and mean values of storage efficiency were 90.38, 87.68 and 80.97 % for Q1, Q2 and Q3 flow rates respectively (Table 2). This probably due to small discharge has slow advance time which give longer intake opportunity time and lead to better infiltration rate which can improve irrigation storage efficiency. Also [18] has got decreasing trend of Storage efficiency as flow rate increases.

Table 3. Effect of flow rate and furrow length on Storage efficiency

	Mean of Storage efficiency (%)			
	Flow rate(l/s)			
Furrow length(m)	Q1	Q2	Q3	Mean
F1	85.59[d]	82.03[f]	78.05[g]	81.89[j]
F2	90.58[bc]	89.03[c]	84.47[d]	88.02[k]
F3	94.98[a]	92.00[b]	80.39[e]	89.13[l]
Mean	90.38[h]	87.68[i]	80.97[k]	86.35
	F	Q	FXQ	
SEM(±)	0.523	0.523	0.908	
LSD(0.05)	0.52	0.52	3.5	

* Means with the same letter are not significantly different

3. Distribution uniformity (Du)

The effect of furrow length and flow rate were highly significant ($p<0.01$) on distribution uniformity (Table 1). The mean DU with respect to furrow length was found to 90.16, 88.33 and 86.30 % for Furrow length of F1, F2 and F3 respectively and that of flow rate was 84.79 , 88.57 and 91.37 % for Q1, Q2 and Q3, respectively(Table 4). The value of DU increases as the flow rate increased regardless of furrow lengths and decrease as the furrow length increase (Table 4). The reason might be small flow rate has slow advance time and high infiltration opportunity time which contribute to lowest distribution uniformity. This is agree with the reports of [18], [7] and [20] which stated as uniformity is an increasing function of flow rate and a decreasing function furrow length.

Table 4 . Effect of flow rate and furrow length on distribution uniformity

	Mean of Distribution uniformity (%)			
	Flow rate(l/s)			
Furrow length(m)	Q1	Q2	Q3	Mean
F1	87.89[bcde]	90.41[abc]	92.17[a]	90.16[m]
F2	86.06[e]	87.83[de]	91.11[abcd]	88.33[k]
F3	80.42[f]	87.49[cde]	90.85[ab]	86.30[n]
Mean	84.79[g]	88.57[h]	91.37[i]	88.3
	F	Q	FXQ	
SEM(±)	0.58	0.58	1.007	
LSD(0.05)	0.59	0.59	1.79	

* Means with the same letter are not significantly different

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4. Deep percolation Ratio (DPR)

The effect of furrow length and flow rate were highly significant at (p<0.01) on deep percolation ratio (Table 1). DPR increased as the furrow length increase and mean of DPR with respect to furrow length was found to be 36.72, 39.29 and 42.52% for furrow length of F1 , F2 and F3, Respectively(Table 5). This is congruent to the general principle [22] . DPR has shown decreasing trend as flow rate increases and mean value of DPR were 42.55, 40.08, and 36.07% for Q1, Q2 and Q3 flow rate(Table 5). This might be due to small flow rate has slow advance time on longer furrow length takes longer infiltrated opportunity time that could provide higher deep percolation ratio. Similarly [18] and [20] has got decreasing trend of deep percolation ratio as flow rate increases.

Table 5. Effects of flow rate and furrow length on deep percolation ratio

	Mean of Deep percolation ratio (%)			
	Flow rate(l/s)			
Furrow length(m)	Q1	Q2	Q3	Mean
F1	38.68^{cd}	37.13^{de}	34.35^{f}	36.72^{j}
F2	42.57^{b}	40.46^{bc}	35.36^{ef}	39.29^{k}
F3	46.40^{a}	42.65^{b}	38.51^{cd}	42.52^{m}
Mean	42.55^{h}	40.08^{j}	36.07^{k}	38.51
	F	Q	FXQ	
SEM(±)	0.53	0.53	0.92	
LSD(0.05)	0.53	0.53	1.58	

* Means with the same letter are not significantly different

C. Effect of Flow Rate and Furrow Length on Yield of Onion

The effect of flow rate on yield was highly significant (p<0.01) But the effect of furrow length and its interaction with flow rate could not show any significant effect (P<0.05) on the onion yield (Table 1). The mean of onion yield obtained were 13.59, 14.95 and 19.61 ton/ha for Q1, Q2 and Q3 flow rate, respectively (Table 6). The better yield was obtained at higher flow rate and increases as flow rate increases (Table 6). This might be due to greater performance of application efficiency and distribution uniformity on higher flow rate. This report agreed with the trend of [23] and [24].

The effect of furrow length on yield of onion could not show any significant effect (P<0.05) on the onion yield (Table 1). The Minimum and maximum onion yield obtained from the furrow length F1 (14.75 ton/ha) and F3 (15.96 ton/ha) as shown Table 6. In fact as irrigation is more uniform and meets crop water requirements, the crop production increases. This indicates an increase in crop yield is linked with water distribution uniformity rather than increases of furrow length. Similar trend were reported with [18] and [20] their study showed there was no statistically significance difference of yield of crop except flow rate.

Table 6. Effect of Flow Rate and Furrow Length on Yield of Onion

Flow Rate(l/s)	Yield (ton/ha)	Furrow Length(m)	Yield (ton/ha)
Q1	13.59^{h}	F1	14.75^{b}
Q2	14.95^{h}	F2	14.77^{b}
Q3	19.61^{g}	F3	15.96^{b}
SEM(±)	0.500	SEM(±)	0.500
LSD(0.05)	1.49	LSD(0.05)	1.49

* Means with the same letter are not significantly different

IV. CONCLUSIONS AND RECOMMENDATION

Furrow irrigation is not only the primary consumer of water but it is also the most inefficient user. Considering this issues, a study was conducted to evaluate effect of Furrow Irrigation Technical Parameters on Field Application performances and yield of Onion Crop under small scale farmers' condition.

Results of the Field Application performances showed that the effect of furrow lengths and flow rates on application efficiency was highly significant (p<0.01). The best result of 65.87% was achieved for treatment combination of 1.3 l/s flow rate (Q3) and 25m furrow length (F1) and the least 53.60% for treatment combination of 0.7l/s (Q1) and 50m furrow length (F3).

The effects of furrow length and flow rate on Storage efficiency was highly significant (p<0.01). The highest value of storage efficiency is formed 94.98% for treatment combination of 50m furrow length (F3) and 0.7l/s flow rate (Q1) and the lowest value of 78.05% for treatment combination of 25m furrow length (F1) and 1.3l/s flow rate (Q3).

The effect of furrow lengths and flow rates on Distribution uniformity was highly significant (p<0.01). The highest value of distribution uniformity of 92.17% for treatment combination of 25m furrow length (F1) and 1.3l/s flow rate (Q3) and the lowest value of 80.42% for treatment combination of 50m furrow length (F3) and 0.7l/s flow rate (Q3).

Similarly, the effects of both furrow length and flow rates on Deep percolation ratio was highly significant (p<0.01). The maximum deep percolation losses 46.40% was observed in treatment combination of 0.7l/s flow rate (Q1)and 50m furrow length(F3) while the least value of deep percolation was 34.35% for treatment combination of 25m furrow length (F1) with

1.3l/s flow rate(Q3). The effect of furrow length on yield of onion was not significant ($p<0.05$). However, the flow rate showed highly significant ($p<0.01$) effect on yield of onion. The best onion yield was obtained at Q3 which gave 19.61ton/ha.
In this study, the use of short furrow length was the major contributor of water loss either deep percolation or surface run off and reduced crop yield. Hence, in the utilization of fragmented farm size, a 50m furrow length is suitable to use 1.3l/s flow rate field application performances and onion yield.

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