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Research Article

Determination of Optimum Bed Width and Hydraulic Performance of Furrow Irrigation for Wheat at Dambi Dima Irrigation Scheme, Western Oromia, Ethiopia

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Abstract

The use of furrow irrigated bed width method has increased due to its capability of saving massive amounts of irrigation water. Based on these field experiments were conducted to evaluate the impact of furrow irrigated bed width and flow rate on irrigation efficiency, wheat grain yield and crop water productivity under surface irrigation system. The experimental field was arranged factorial experiments in randomized complete block design with three replications. The result indicated that, effect of bed width of furrow and flow rate were highly significant ($p<0.01$) on wheat grain yield, yield component, crop water productivity, application efficiency and distribution uniformity, but effect of bed width of furrow were no significant effect on grain per spike and Plant height. The result of interaction analysis showed that interaction between bed width of furrow and flow rate were significant ($p<0.05$) affected by wheat grain yield, crop water productivity, application efficiency and distribution uniformity, but non-significant influencing wheat yield component. The mean maximum wheat grain yield, crop productivity, application efficiency were obtained with treatment interaction of BW 80cm X Q_2, were 6.87 tons/ha, 2.88 kg/m^3, and 87.52%, respectively. The mean maximum distribution uniformity of 90.35% was obtained with treatment interaction of BW 80cm X Q_3. From economic analysis point of view the maximum net benefit of 189,820 ETB per hectare with 1.05 benefit cost ratio was obtained at optimum bed width (80cm) and flow rate (Q_2). At optimum bed width (80cm) and flow rate (Q_2), 1234 m^3/ha amount of water was saved and this saved water was able to irrigate 0.5 ha and from this hectare, farmers able to get net return of 93,653.72 ETB. Therefore, it can be concluded that, application of 80cm bed width of furrow and flow rate of Q_2 (2L/s) at Dambi Dima irrigation scheme was found to be the most efficient and also economically viable.

Keywords

Bed Width of Furrow, Application Efficiency, Crop Water Productivity, Irrigation Efficiency

1. Introduction

Surface irrigation is the most commonly used irrigation method and indispensable in Ethiopia because it is easy in operation and maintenance but while having a serious defect that decreases irrigation efficiency ranged from 40 to 60% [1]. Farmers use surface irrigation systems to irrigate wheat through furrow, technique due to those systems being low in cost, easier to the farmers to construct, operate and maintain. But the efficiency of surface irrigation, however, is lower and

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in some cases, farmers may lose up to 50% water delivery in deep percolation and runoff [2]. This method is the most common technique being practiced throughout the world, implying that water distribution is uncontrolled and inefficient. Therefore, implementation of optimal irrigation management practices such sizing bed width of furrow, using pressurized distribution system, and selection of correct inflow rates based on field parameters was important. The use of pressurized distribution system in bed width was used to regulate and control water application which affect overtopping of bed width of furrow. Bed planting is an innovative technique to save irrigation water and increase wheat grain yield and water productivity. However, saving irrigation water and increasing crop yield was depend on management of bed furrow size according to soil and field conditions. Wider beds can lead to poor lateral infiltration in the bed middle. The effect of bed width of furrow on yield of wheat saving water up to 50% in wheat and 30% in maize [3, 4]. In Ethiopia farmer's competition for irrigation water use among the upstream and downstream small scale irrigation scheme is very high. Therefore, the objective of this study was to determine optimum bed width and hydraulic Performance of furrow irrigation to enhance yield and water productivity of wheat at Dambi dima irrigation scheme, Western Oromia, Ethiopia.

2. Materials and Methods

2.1. Description of Study Area

The study area was located at Bako Tibe Woreda at Dambi Dima irrigation scheme, West Shewa Zone, Oromia National Regional State with an altitude of 1590m above sea level and lies in 9°06' N and 37°09' E Latitude and longitude, mean monthly minimum and maximum temperature in the area are 13.7°C and 28.4°C respectively. Dependable mean monthly annual and effective rainfall in the area was 808.5mm and 482mm respectively.

2.2. Materials Used

Different UPVC Pipe Size, UPVC TEE different size, UPVC Reducer, UPVC Elbow, Transparent plastic tube, Line level, Stop watch and Parshall flume.

2.3. Experimental Design and Treatments

The treatments considered for this experiment were four irrigated bed width (B1 = 40cm, B2 = 60cm, B3 = 80cm, and B4 = 100cm) and three levels of furrow discharge rates, viz., (Q1, Q2 and Q3). The furrow discharge was made by rating 80%, 100% and 120% of the maximum non erosive flow rate. The maximum non-erosive flow rate was determined based on soil textural class and furrow bed slope [5]. The experimental field had an average of furrow bed slope of 0.27% and clay loam in textural class which categorized as medium-heavy textured soil group [6]. Based on these Coefficient parameters for furrow maximum flow rate were α=0.988 and β=0.55. Accordingly, maximum non erosive flow rate (Qmax) obtained was 2 L/s. Based on this the three levels of flow rate were (Q1=1.6 L/s, Q2=2L/s and Q3 =2.4 L/s), respectively. The pressurized water distribution system with integrated furrow irrigated bed width was used to control the flow of water at specified bed width furrow. Finally, experimental field was arranged 3 x 4 factorial experiments in RCBD with three replications.

2.4. Soil Sample Collection

Soil moisture content before and after irrigation were collected from each plot at three depths of wheat crop 0-30cm, 30-60 cm, and 60-90cm by using soil auger and core sampler holder for undistributed soil samples. To determined gravimetric moisture content, the standard method known as the gravimetric moisture determination method was used [1].

2.5. Determination of Hydraulic Parameters of Furrow Irrigation

Furrow Cross sectional Area

The Parameters characterizing the furrow geometry was measured by furrow profilometer. The measured data using furrow Profilometer were used to derive the relationship between depths of water in the furrow and corresponding top width. For selected furrow bed width evaluation, the furrow cross-sectional area was measured at each station. Finally, flow cross sectional area and wetted perimeter of furrow were estimated as parabolic channel shape by the following empirical equations [7].

$$A = \frac{2}{3}td \quad \text{and} \quad p = t + \frac{8d^2}{3}$$

Where, d= flow depth (m), t=top flow width (m), A = flow cross sectional area (m^2) and P=wetted perimeter (m).

Advance and Recession time measurement

The time required for the water to advance to the end of the field length or to cover the field completely is an important consideration in managing furrow irrigation systems. The advance and recession was recorded at the distance of 5, 10, 15, 20 25, 30m along furrow irrigated bed width.

Infiltration characteristics of Soil

To determine the infiltration characteristics along length of furrow irrigated bed width, double ring infiltrometer and two-point method of volume balance method was used [8]. Finally, the depth of water infiltrated along length of furrow irrigated bed width (z) was determined by using this equation.

$$Z = K\tau^{a} + fo\tau$$

Where, Z = the cumulative infiltration per unit length of furrow (m^3/m/m), r= intake opportunity time (min), for any point, fo = basic intake rate (m^3/min/m), K and a = infiltration parameters.

2.6. Application Efficiency and Distribution Uniformity

Efficiency of water stored or utilized at crop root zone at the center and side of furrow irrigated bed width was determined based on application efficiency (Ea,) and it was determined as the follow

$$Ea = \frac{Zs}{Z} \times 100$$

Where; Zs = depth of water retained in the root zone (mm), and Z = depth of water applied to the furrow (mm).

Efficiency distributed at the center and side of furrow irrigated bed width was determined based on distribution uniformity, and it was determined based on the following equations;

$$Du = \frac{Z\min}{Zav} \times 100$$

Where; Du=distribution uniformity (%), Zmin =minimum infiltrated depth (mm) and Zav = mean of depths infiltrated over the furrow length (mm).

2.7. Yield Component, Yield and Crop Water Productivity

Plant height (cm): The height wheat was measured from the soil surface to the tip of a spike from 10 randomly tagged plants in the net plot area at physiological maturity.

Number of grain per spike: recorded as an average of 10 randomly taken spikes from the net plot area.

Thousand grain weight: was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot and weighed with electronic sensitive balance.

Above-ground dry biomass yield: The wheat biomasses were determined through weighting plants harvested from the net plot area.

Wheat Grain yield: These were also taken by harvesting and threshing the grain yield from net plot area. The yield were adjusted to 12.5% moisture content and expressed as yield in kg/ha.

Wheat Crop water productivity: was computed as the ratio of yield obtained to the depth of water applied to the field.

2.8. Economic Analysis

For Economics analysis, the price of grain wheat in the area is taken during time of harvest was 55 Birr /kg and the price for water was 1.00 Birr per 0.5m^3 of water. The indigenous farmers in the study area do not pay for irrigation water of their farms. Therefore assumption was made for the costs of water unit price which was estimated to be 1 Birr per 0.5m^3 of water Gross revenue has been calculated by multiplying total yield in kg/ha of wheat market price per kilogram. The farm-gate price for wheat in this study was 55 ETB/kg (averaged local price). Net return (NR) and benefit-cost ratio (BCR) due to irrigation were calculated according to following equations.

Net return (NR) and benefit-cost ratio (BCR) due to irrigation was calculated as

$$\text{NR} = \text{Gross revenue} - \text{Total cost}$$

The benefit cost ratio (BCR) measures the increase in net return (NR) which was generated by total cost expenditure (TC).

$$BCR = \frac{NR}{TC}$$

2.9. Data Analysis Techniques

Collected data such as wheat grain yield, yield component, application efficiency, distribution efficiency, water productivity were analyzed factorial Randomized Complete block design (RCBD) using R statistical software. For comparing means of the treatments that showed significant result, least significant difference (LSD) test at 5% probability level were used.

3. Results and Discussions

3.1. Soil Physical Properties Analysis

The result of the soil analysis from the experimental site showed, the soil has an average percentages of sand, silt and clay were 36.67, 25.33, 36.33, and 42%, respectively. The soil texture of experimental site was classified as clay Loam soil. TAW is the amount of water that a crop can extract from its root zone is directly related to variation in FC and PWP, 212.8, 204 and 229.35 mm/m for 0-20cm, 20-40cm and 40-60cm, respectively. Average of total Available Water for experimental site was 215.38 mm/m and bulk density of 1.36 g/cm^3 which was below the critical threshold level (1.4g/cm^3) (Table 1).

Table 1. *Soil physical Properties of the experimental site.*

Soil Depth	Bd (g/cm^3)	FC (%)	PWP (%)	TAW (mm/m)	Particle size Distribution (%)			Textural class
					sand	silt	clay	
0-20cm	1.33	38.50	22.50	212.80	38	28	34	Clay loam
20-40cm	1.36	38.30	23.30	204.00	36	24	40	Clay
40-60cm	1.39	40.60	24.10	229.35	24	24	52	Clay
Average	1.36	39.13	23.30	215.38	32.67	25.33	42	clay loam

3.2. Evaluation of Hydraulic Parameters of Furrow Irrigated Bed Width

Furrow geometry

The furrow geometry was determined by measuring flow depth, bottom width, and top flow width along the furrow length of 30 m at 5m intervals as shown in Table 2. The flow depth in the furrows ranged from a minimum depth of 0.194 m to a maximum depth of 0.235 m and the average flow depth was found as 0.212 m. Top width of flow section varied from 0.194 m to 0.687 m with an average value of 0.678m. It was found that flow area varied from 0.086m^2 to 0.103m^2 with an average flow area as 0.093m^2. The wetted perimeter also showed a variation ranging from 0.768 m to 0.819 m with an average wetted perimeter of 0.790 m (Table 2).

Table 2. *Flow dimensions and wetted perimeter along the furrow length.*

Distance	Follow depth (m)	Top follow depth (m)	Flow area (m^2)	Wetted perimeter (m)
5	0.215	0.687	0.098	0.812
10	0.202	0.674	0.090	0.782
15	0.198	0.675	0.088	0.774
20	0.194	0.668	0.086	0.768
25	0.225	0.684	0.103	0.819
30	0.235	0.681	0.091	0.787
Average	0.212	0.678	0.093	0.790

The relationship was developed to determine cross sectional area, wetted perimeter and top width with respect to depth of flow. The best fit statistical relationships between these parameters with respect to flow depth were found as a power function relationship (Table 3).

Table 3. *Relationship between furrow cross section area, wetted perimeter and top width with respect to depth of flow.*

No	Furrow Parameters	Functional Relationship	Coefficient of Determination
1	Cross section Area in m^2	A=0.5882d1.167	R^2=0.99
2	Wetted perimeter (p) in m	P=1.5779d0.4369	R^2=0.96
3	Top width (T) in m	T=0.9869d0.237	R^2=0.94

Advance Time

The advance and recession was recorded at the distance of 5, 10, 15, 20, 25, 30m along furrow irrigated bed width. The furrow irrigated bed width of 80cm accomplished faster advance time compared with furrow irrigated bed width of 100cm; which may be due to increased lateral movement of irrigation water under BW=100cm is more than BW= 80cm since the bed is wider which led to slowing in water advance. In general the longest advance time is formed with (BW 100cm X Q1) and the shortest advance time is formed with (BW 40cm X Q3). In general increases flow rate and bed width of furrow, decreases the time required for the water to advance to the end of the field length. These results have the same trend to those obtained in many research studies [9, 10].

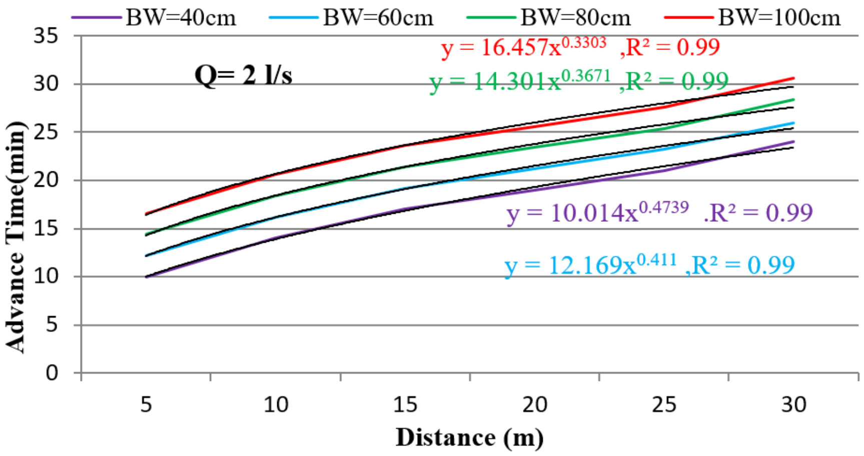

Figure 1. *Advance time for different furrow irrigated bed width and flow rates of 2L/s.*

Infiltration characteristics

Double ring infiltrometer and two-point method or volume balance Method was used [8] to determine IFC along length of furrow irrigated bed width. From double ring infiltrometer basic infiltration rate of 3.42 mm/hr (0.000057 m/min) obtained and from two-point method infiltration parameters K and a was determine (K = 0.00365 m/min and a = 0.347). Finally, the depth of water infiltrated along length of furrow irrigated bed width (z) was determined by using this equation.

$$Z = 0.00365r^{0.347} + 0.000057r$$

3.3. Effect of Bed Width of Furrow and Flow Rate on Yield and Water Productivity of Wheat

According to the analysis of variance, the effect of bed width of furrow and flow rate were highly significant at ($p<0.01$) on wheat grain yield, yield component, Crop water productivity, application efficiency and distribution uniformity, But effect of bed width of furrow were no significant effect on grain per spike and Plant height. The result of combined/interaction analysis showed that interaction between bed width of furrow and flow rate were significant ($p<0.05$) affected by wheat grain yield, Crop water productivity, application efficiency and distribution uniformity, But non-significant influencing wheat yield component (Table 4).

Table 4. *Analyses of variance effect of bed width of furrow on wheat yield, water Productivity and Irrigation Efficiency of wheat.*

Source of variation	MS df	GY (ton/ha)	BMY (ton/ha)	TGW (g)	PH (cm)	Grain/spik	CWP (kg/m^3)	AE (%)	DU (%)
Replication	2	0.428***	1.182***	26.14	12.80***	12.24	0.025***	29.42***	22.64***
Flow Rate (FR)	2	19.844***	45.307***	2797.35***	1977.01**	678.64***	1.147***	2824.45***	2163.67***
Bed width (BW)	3	4.841***	7.736***	149.88***	4.96^{Ns}	5.08^{NS}	0.279***	352.04 ***	269.21***

Source of variation	MS df	GY (ton/ha)	BMY (ton/ha)	TGW (g)	PH (cm)	Grain/spik	CWP (kg/m^3)	AE (%)	DU (%)
BW X FR	6	0.192**	0.248^{NS}	1.87^{NS}	5.13^{NS}	15.96^{NS}	0.011**	29.14**	22.34**
Error	22	0.047	0.172	19.97	12.52	7.21	0.0027	4.61	3.53
CV		4.72	3.92	10.52	4.87	8.09	4.78	2.92	2.47
R^2 (%)		98.2	96.9	93.3	93.9	90.4	98.2	96.6	98.6

3.4. Effect of Bed Width of Furrow and Flow Rate on Yield Component of Wheat

Plant Height

Plant height of wheat as influenced by only furrow irrigation flow rate rather than bed width of furrow. It was observed that the tallest plant height (84.63cm) was obtained at maximum furrow irrigation flow rate (Q3). The shortest plant height (59.08cm) was observed at minimum furrow irrigation flow rate (Q1) (Table 5). This result is in line with [11] who found that plant height and dry matter accumulation increased significantly with increase in number of irrigations because of more water availability to the crop plants.

Grain per spike

Number of grains per spike at harvest was significantly influenced by only furrow irrigation flow rate rather than bed width of furrow. It was observed that the highest number of grains per spike at harvest (33.00) was obtained at maximum furrow irrigation flow rate (Q3). The lowest number of grains per spike at harvest (27.11) was observed at minimum furrow irrigation flow rate (Q1)(Table 5). This result is in accord with that of [12] who found that irrigation with no deficit throughout the growth stages recorded the more gains per spike.

Thousand- grain weight

Effect of bed width of furrow and gate flow rate on TGW of wheat were highly significant (P<0.01). But, their interaction was non-significant. The TGW of wheat was significantly influenced by size of width of furrow and irrigation flow rate. The maximum TGW of wheat (47.37g) was obtained at (B100cm) and (58.72g) was obtained at Q3 (Table 5).

Dry Biomass of wheat Yield

Effect of bed width of furrow and flow rate on biomass of wheat were highly significant at (P<0.01). Effect of bed width of furrow and flow rate on biomass of wheat were highly significant at (P<0.01). But, their interaction was non-significant. The biomass of wheat grain was increases from 40cm to 80cm bed width of furrow and also increases from flow rate of 1.6l/s to 2l/s. The maximum biomass of wheat yield was obtained at 80cm width of furrow and 2 l/s flow rate where 11.72 ton/ha and 12.61 ton/ha, respectively (Table 5). This may be due to the influences of Variation of applied water on each treatment. This result in line with [13].

Table 5. *Main effect of bed width of furrow and Flow rate on Yield and yield Component of Wheat.*

Treatment	Plant Heightm (cm)	Grain per spike	Thousand- grain weight (gram)	Dry Biomass of wheat Yield (tons/ha)
B1 (40cm)	71.7a	32.33a	37.80c	9.58d
B2 (60cm)	72.6a	32.85a	40.94bc	10.16 c
B3 (80cm)	72.8a	33.48a	43.83ab	11.72a
B4 (100cm)	73.4a	34.06	47.37a	10.89b
Mean	72.59	33.18	42.49	11
CV	4.87	8.09	10.52	3.92
LSD (0.05)	NS	NS	4.37	0.405
Q1 (1.6l/s)	59.08c	27.11c	28.41c	8.74c
Q2 (2.0l/s)	74.08b	30.83b	40.33b	12.61a
Q3 (2.4l/s)	84.63a	41.59a	58.72a	10.41b

Treatment	Plant Heightm (cm)	Grain per spike	Thousand- grain weight (gram)	Dry Biomass of wheat Yield (tons/ha)
Mean	72.59	33.18	42.49	11
CV	4.87	8.09	10.52	3.92
LSD (0.05)	2.99	2.27	3.78	0.351

3.5. Interaction Effect of Bed Width of Furrow and Flow Rate on Yield, Crop Water Productivity of Wheat and Irrigation Efficiency

Wheat grain yield

From Anova result, effect of bed width of furrow flow rate and their interaction on wheat grain yield were highly significant at (P<0.01). The highest wheat grain yield of (6.27 tons/ha) was obtained with treatment interaction of (BW80cm X Q_2) and the lowest wheat grain yield (3.45 tons/ha) was obtained with treatment interaction of (BW40cm X Q_1). From Interaction (Table 6) increases bed width from 40cm to 80cm increases wheat grain yield but decreases from 80cm to 100cm, this due to increasing size of bed width of furrow, the center of the bed width did not get the required quantity of water, hence remained unsaturated. The results in line with the similar findings of [14].

Similarly increases flow rate from 1.6l/s to 2l/s increases wheat grain yield but decreases from 2 l/s to 2.4 l/s. As shown in (Table 6) wheat grain yield increases as the furrow irrigation inflow rate increased until it reached the design discharge limit (Q_{max}), at which point yield began to fall. This occurs as a result of excessive water application, which leaches off vital plant nutrients, stressing the plant's nutrition [15, 16].

Wheat Crop water Productivity

From Anova result, effect of bed width of furrow flow rate and their interaction on crop water productivity were highly significant at (P<0.01). The highest crop water productivity of (2.88kg/m^3) was obtained with treatment interaction of (BW80cm XQ_2) and the lowest crop water productivity (0.93kg/m^3) was obtained with treatment interaction of (BW40cm X Q_3) as compared to other treatment (Table 6). In general Increases bed width of furrow increases water crop productivity and increases flow rate decreases crop water productivity (Table 6). The results in line with the similar findings of [17, 18].

Application Efficiency and Distribution uniformity

Effect of bed width of furrow, flow rate and their interaction on application efficiency and distribution uniformity were highly significant at (P<0.01). Increasing flow rate from 1.6 to 2.0 l/s increased application efficiency for under different bed width of furrow and application efficiency decreases from 2 to 2.4 l/s (Table 6). When irrigation application amounts exceed the maximum non erosive flow rate of the soil the application losses increases and the efficiency of irrigation system begins to decline. Increases bed width from 40cm to 80cm increases application efficiency but decreases from 80cm to 100cm, this due to increasing size of bed width of furrow, the center of the bed width did not get the required quantity of water, hence remained unsaturated.

In this study, the highest application efficiency was observed for treatment interaction of (BW80cm + Q2) with mean value of 87.52% and minimum application efficiency was recorded at (BW40cm + Q3) with mean of 60.45%. This is might be due to faster advance time at higher flow rate make minimum deep drainage loss below root zone of wheat crop which contribute to increase the application efficiency. The same trend were observed by [19]. Increasing flow rate from 1.6 to 2.4 L/s increased distribution uniformity under different Bed width of furrow. In this study, the highest distribution uniformity was observed for treatment interaction of (BW80cm + Q3) with mean value of 90.35% and minimum distribution uniformity was recorded at (BW40cm + Q1) with mean of 72.2% (Table 6). This might be due to increases orifice discharge/flow rate, increase advance time and decreases the variation of infiltration opportunity time, which contribute to increases the distribution uniformity on bed width of furrow. The same trend were observed by [20].

Table 6. *Mean Interaction Effect of bed width furrow and flow rate on yield, Crop water productivity of Wheat and Irrigation Efficiency.*

Bed width of furrow	Flow rate (l/s)	Grain yield (ton/ha)	Crop water productivity (kg/m^3)	Application Efficiency (%)	Distribution Uniformity (%)
B1 (40cm)	Q1 (1.6l/s)	3.45h	0.94 1i	60.75b	72.2e
	Q2 (2.0l/s)	3.83ef	1.01f	64.99fg	74.5ef

Bed width of furrow	Flow rate (l/s)	Grain yield (ton/ha)	Crop water productivity (kg/m^3)	Application Efficiency (%)	Distribution Uniformity (%)
	Q3 (2.4l/s)	3.34f	0.93 d	60.45c	76.74g
	Q1 (1.6l/s)	4.63 j	1.79 h	65.87hi	77.62gh
B2 (60cm)	Q2 (2.0l/s)	5.83bc	2.26ef	78.29e	82.1de
	Q3 (2.4l/s)	4.20e	1.52 bc	70.35c	86.45c
	Q1 (1.6l/s)	6.17a	2.62j	75.46ef	87.21bc
B3 (80cm)	Q2 (2.0l/s)	6.27ab	2.88cd	87.52a	88.65b
	Q3 (2.4l/s)	5.97c	2.29 a	83.48c	90.35a
	Q1 (1.6l/s)	4.29eg	1.53 g	65.35gh	78.45ig
B4 (100cm)	Q2 (2.0l/s)	6.02d	2.25e	74.57f	80.26e
	Q3 (2.4l/s)	4.63j	1.97 b	80.75b	83.48fd

3.6. Economic Analysis

Table 7. Economic analysis.

Treatment		Water Applied (m^3/ha)	Avy (ton/ha)	AdjY (ton/ha)	TC (ETB/ha)	GR (ETB/ha)	NR (ETB/ha)	BCR	WS (m^3/ha)	AAI (ha)	NR _AAI (ETB/ha)
60	Q3	3175	4.84	4.356	155,571.43	239,580.00	84,008.57	0.54	432	0.14	11,430.46
40	Q1	3651	3.45	3.105	109,471.15	170,775.00	61,303.85	0.56	-	-	-
60	Q2	2839	6.43	5.787	192,900.00	318,285.00	125,385.00	0.65	782	0.28	34,537.19
80	Q1	2583	6.77	6.093	183,708.54	335,115.00	151,406.46	0.82	1068	0.41	62,602.44
40	Q2	3621	3.67	3.303	103,808.57	181,665.00	77,856.43	0.75	-	-	-
100	Q1	3197	4.89	4.401	160,036.36	242,055.00	82,018.64	0.51	454	0.14	11,647.31
80	Q2	2387	6.87	6.183	154,575.00	340,065.00	185,490.00	1.20	1234	0.52	95,892.19
100	Q2	2945	6.62	5.958	191,165.78	327,690.00	136,524.22	0.71	676	0.23	31,337.99
40	Q3	3607	3.34	3.006	111,709.46	165,330.00	53,620.54	0.48	-	-	-
100	Q3	3226	6.34	5.706	218,063.69	313,830.00	95,766.31	0.44	381	0.12	11,310.28
60	Q1	2914	5.23	4.707	161,382.86	258,885.00	97,502.14	0.60	737	0.25	24,659.94
80	Q3	2875	6.57	5.913	181,010.20	325,215.00	144,204.80	0.80	732	0.25	36,715.79

Note: AVY = average yield (ton/ha), Adjy = adjusted yield (ton/ha), Tc = Total cost (ETB/ha), GR = gross return (ETB/ha), NR = net return (ETB/ha), WS = amount of water saved (m^3/ha), AAI = Additional area irrigated (ha), NR _AAI = net return from additional area irrigated (ETB/ha)

For Economics analysis, the price of grain wheat in the area is taken during time of harvest was 60 Birr /kg and the price for water was 1.00 Birr per 0.5 m^3 of water. From Table 7, the minimum net benefit is 53,620.54 ETB per hectare with 0.48 benefit cost ratio was obtained at FIBW40cm X Q3 Trt. The maximum net benefit of 185,490.00 ETB per hectare with 1.2 benefit cost ratio was obtained at optimum bed width FIBW 80cm X Q2 Trt. At optimum bed width and flow rate (Q2), 1234 m3/ha amount of water was saved and used to irrigate an additional area 0.5 ha, gave net return of 95,892.19 ETB. Therefore, application of 80cm bed width of furrow and flow rate of Q2 (2l/s) at Dambi Dima irrigation scheme was found to be the most efficient and also economically viable. Therefore, application of 80cm bed width of furrow and flow rate of Q2 (2l/s) at Dambi Dima irrigation scheme could be considered to have an economic advantage over the other.

4. Conclusion and Recommendation

In Ethiopia, wheat irrigation by small scale farmers was conducted through Conventional furrow and flood irrigation. This leads to ineffective use of applied nitrogen, poor aeration and leaching, lower water use efficiency that leads to increased irrigation losses. Considering these issues, a study was conducted to determine Optimum bed width and hydraulic Performance of furrow Irrigation for Wheat at Dambi Dima Irrigation scheme, wesh shewa zone.

The result indicated that, effect of bed width of furrow and flow rate were highly significant at ($p<0.01$) on wheat grain yield, yield component, Crop water productivity, application efficiency and distribution uniformity, But effect of bed width of furrow were no significant effect on grain per spike and Plant height. The result of combined/interaction analysis showed that interaction between bed width of furrow and flow rate were significant ($p<0.05$) affected by wheat grain yield, Crop water productivity, application efficiency and distribution uniformity, But non-significant influencing wheat yield component. The mean maximum value of wheat yield 6.27 ton/ha was obtained with treatment interaction of bed width (80cm) of furrow and flow rate (Q_2) while minimum value of wheat yield 3.34 ton/ha was obtained with treatment interaction of bed width (40cm) of furrow and flow rate (Q_3), respectively. The mean maximum value of wheat water productivity 2.88 kg/m^3 was obtained with treatment interaction of bed width (80cm) of furrow and flow rate (Q_2) while minimum value of wheat water productivity 0.93 kg/m^3 was obtained with treatment interaction of bed width (40cm) of furrow and flow rate (Q_3), respectively.

The mean maximum application efficiency and distribution uniformity formed under different bed width of furrow were formed with treatment interaction of BW80cm X Q2 and BW80cm X Q3 were 87.52 and 90.35%, respectively and the mean minimum application efficiency and distribution uniformity formed under different bed width of furrow were formed with treatment interaction of BW40cm X Q3 and BW40cm X Q1 were 60.45 and 72.2%, respectively.

From economic analysis point of view the maximum net benefit of 189,820 Ethiopian birr per hectare with 1.05 benefit cost ratio was obtained at optimum bed width (80cm) and flow rate (Q2). In addition at optimum bed width (80cm) and flow rate (Q_2), 1234 m^3/ha amount of water was saved and this saved water was able to irrigate 0.5 ha and from this hectare, we able to get net return of 93,653.72 Ethiopian birr. Therefore, application of 80cm bed width of furrow and flow rate of Q_2 (2l/s) at Dambi Dima irrigation scheme was found to be the most efficient and also economically viable.

Recommendation

Finally, it was recommended to farmers of Dambi Dima irrigation scheme to use 80cm bed width furrow and 2l/s flow rate to increases wheat grain yield and water productivity in the study area.

It was also recommended that, similar experiment will be conducted on other irrigation scheme to identify the optimum bed width of furrow for irrigated wheat at different agro-ecology and soil type.

Abbreviations

ETB	Ethiopian Birr
RCBD	Randomized Completed Block Design
LSD	Least Significance Difference
PWP	Permanent Wilting Point
TAW	Total Available Water
BCR	Benefic Cost Ratio

Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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