Determination of Optimal Bed Width of furrow irrigated wheat at Koga and Rib Irrigation schemes, North West, Ethiopia

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Abstract

Water scarcity and irrigation methods are the major factors limiting the production of crops in agricultural irrigation farming. Improving effective water utilization is a serious challenge for water management experts. Field experiments were conducted to determine an optimal bed width of furrow irrigated wheat at Koga and Rib irrigation scheme within Lake Tana Sub-basin in Amhara regional state. The schemes represent silt clay soil at Koga and clay loam alluvial deposited soil at Rib. The experiments were conducted during the 2016/17-2017/18 irrigation seasons. The experiment was arranged in Randomized Complete Block Design (RCBD) having seven-bed widths of 40, 60, 80, 100, 120, 140, and 160 cm. It was found that bed width managed in different soil textures had significantly affected yield and water productivity of wheat. The results revealed that under silt clay soil (Koga), the 80 cm optimal bed width gave 26 % grain yield advantage and consumes 25% less water compared to the farmer practice. Similarly, Plant height has a significant difference but the panicle length and 1000 seed weight of wheat have no significant difference. The optimum bed width under alluvial deposited soil (Rib) was 120 cm which gave 27 % yield and 27 % water productivity advantage relative to the farmer practice. In addition, the plant height showed a significant difference but panicle length and 1000 seed weight of wheat have no significant difference. Therefore, we recommend optimum raised bed width of 80 cm and 120 cm for Koga (silt clay texture) and Rib (clay loam alluvial deposit soil) irrigation schemes for better yield and water productivity respectively.

Keywords: *Furrow irrigation, Koga, Optimal Bed width, Rib, wheat,*

Introduction

Irrigation is an essential agricultural practice for food, pasture, and fiber production in semiarid and arid areas (Koech and Langat, 2018). Farmers use surface irrigation systems to irrigate wheat through furrow, border strip, and basin techniques. However, the efficiency of surface irrigation is lower and farmers may lose up to 50 % of water delivery by deep percolation and runoff (Tadesse et al., 2016). This method is the most common technique being practiced throughout the world, implying that the water distribution is uncontrolled and inefficient (Bilibio et al., 2011). When water demand is increasing in irrigated agriculture, the need to increase water productivity is crucial. Therefore, it required prior consideration for implementing water management practices. Generally, wheat is sown in the traditional method on flat land, which often endangers the crop by excess irrigation. While in raised bed, wheat are plant on the bed which is practiced by dividing the field into narrow strips of raised beds separated by furrows (Soomro et al., 2017). In raised bed irrigation system, the plants are grown on the beds which use irrigation water efficiently and ensure better crop growth under heavy rains (Berkout et al., 1997). Wheat is an important staple food crop in Ethiopia. Today, wheat is among the most important crops grown both as a source of food for consumers and as a source of income for farmers (Minot et al., 2019). Wheat production has grown significantly to drive agricultural growth and food security; set it as one of the fourth most important food grains in Ethiopia (Gebreselassie et al., 2017). However, wheat production in Ethiopia is relatively small by global standards due to poor utilization of modern technology including improved seed, fertilizer, chemicals, irrigation, and mechanization (Minot et al., 2019).

Conventional flatbed planting and flood irrigation are commonly used for growing wheat production. However, it leads to the ineffective use of applied nitrogen, poor aeration and leaching, crop lodging, lower water use efficiency, and crusting of the soil surface (Majeed et al., 2015). On the other hand, the raised bed planting system improves the method of weed control and facilitates mechanical cultivation during the crop growing season. It also provides an opportunity for easy field entry resulting from row orientation on the beds, and irrigation water management is more efficient, less labor required with the use of furrows than conventional flood irrigation (Sayre and Moreno Ramos, 1997, Fischer et al., 2005). The furrow bed irrigation method permits more efficient use of irrigation water as compared to the basin or border irrigation (Hassan et al., 2005). Raised bed irrigation in wheat production, save more than 30-35% of irrigation water, 13.4% higher grain yield than the flat border irrigation method (Ahmad et al., 2010, Hussain et al., 2018). Similarly, the average irrigation duration decreased by 35.6 % in the case of bed and furrow irrigation method (Hassan et al., 2005, Ahmad and Mahmood, 2005) and improves 15% higher fertilizer use efficiency (Majeed et al., 2015). Kalwij et al. (1999) found that 30.6 % decrease in time spent on irrigation water application in bed and furrow irrigation method for cotton production. When water is applied to a furrow, it moves vertically under the influence of gravity and laterally by capillarity. Clay soils have more lateral movement of water than sandy soils which favors capillary action (Watson et al., 1995).

Wheat is the most dominantly cultivated cereal crop under irrigation in the Koga irrigation scheme and the newly introduced Rib irrigation scheme by farmers. In the traditional system, farmers cultivate wheat using their traditional know-how, the tools, and resources available. Farmers cultivate wheat using the flat panting technique, flooding irrigation method, and irrigate a series of the furrow with narrow bed (two rows with furrow irrigation). This leads to the application of excess water, which results in a water shortage problem at the scheme. Therefore, the aims of this study were to introduce the production of wheat using a raised bed method and determine optimal bed width in clay and loam soil structure.

Materials and Methods

Description of the study area

The experiment was conducted at Koga and Rib irrigation schemes in Lake Tana basin, Ethiopia, for two years, 2016/17 and 2017/18. The soil characteristics of the Koga and Rib experimental field are silt clay and clay loam soil textures respectively (Table 1). Koga irrigation scheme is located in the Northwest of Ethiopia at Mecha district, 41 km to the West of Bahir Dar city and 543 km to the North of the capital city, Addis Ababa at 37°7'29.72" latitude and 11°20'57.85" longitude and an altitude of 1953 m a.s.l. The average annual rainfall of the area is about 1438 mm. The mean maximum and minimum temperatures are 26.8 ^{0}C and 9.7 ^{0}C respectively. Rib irrigation site is located in Fogera district Northwest of Ethiopia, 60 kilometers to the East of Bahir Dar city and 644 km North of the capital city, Addis Ababa at 37°25' to 37°58' Easting and 11°44' to 12°03' Northing and an altitude of 1794 m a.s.l (Figure 1). It receives 1400 mm mean annual rainfall. The mean daily maximum and minimum temperature of the study area was 30°c and 11.5°c. The area is characterized as mild altitude agroecology. In both locations, farmers use flooding, furrow, and border irrigation system to cultivate field crops.

Table 1. Soil characteristics of the study area

Site	FC (%)	WP (%)	CEC	N (%)	P (ppm)	Sand (%)	Silt (%)	Clay (%)
Koga	30.8±1.7	18.9±1.2	20.1±2.7	0.2±0.03	18.4±10.7	20.2±4.8	22.4±2.7	57.3±4.5
Rib	59.0±1.3	21.0±1.4	33.0±3.4	-	34.7±2.4	24.0±2.4	36.0±3.5	40.0±5.2

Experimental setup

The irrigation method consisted of bed and furrow irrigation techniques having seven treatments using different bed widths with a furrow width of 40 cm. The treatments were arranged in a randomized complete block design with three replications. The raised beds and furrows were made manually and the height of the beds was 10 cm. The irrigation water applied was measured using a flume. The seed rate used for the experiment was 150 kg ha^{-1} and the spacing between rows was 20 cm applied by drilling. In both locations, the recommended variety of TAY was used. A fertilizer rate of 121.1 kg ha^{-1} NPS at planting and 150.13 kg ha^{-}1 Urea (50.13 kg ha^{-1} at planting and 100 kg ha^{-1} at the tillering stage) were applied equally for all treatments. All agronomic practices (weeding, pesticide, and insecticide) were done in accordance with the recommendation made for the area. The experimental trial was conducted in the dry season (November to March) and the optimum recommended depth of 33 mm and 44 mm every 14 and 21 days at Koga and Rib were applied respectively.

Table 2. Treatment setup

Treatment	Bed width	No of Rows	Treatment	Bed width	No of Rows
T1	40 cm	2	T5	120 cm	6
T2	60 cm	3	T6	140 cm	7
T3	80 cm	4	T7	160 cm	8
T4	100 cm	5			

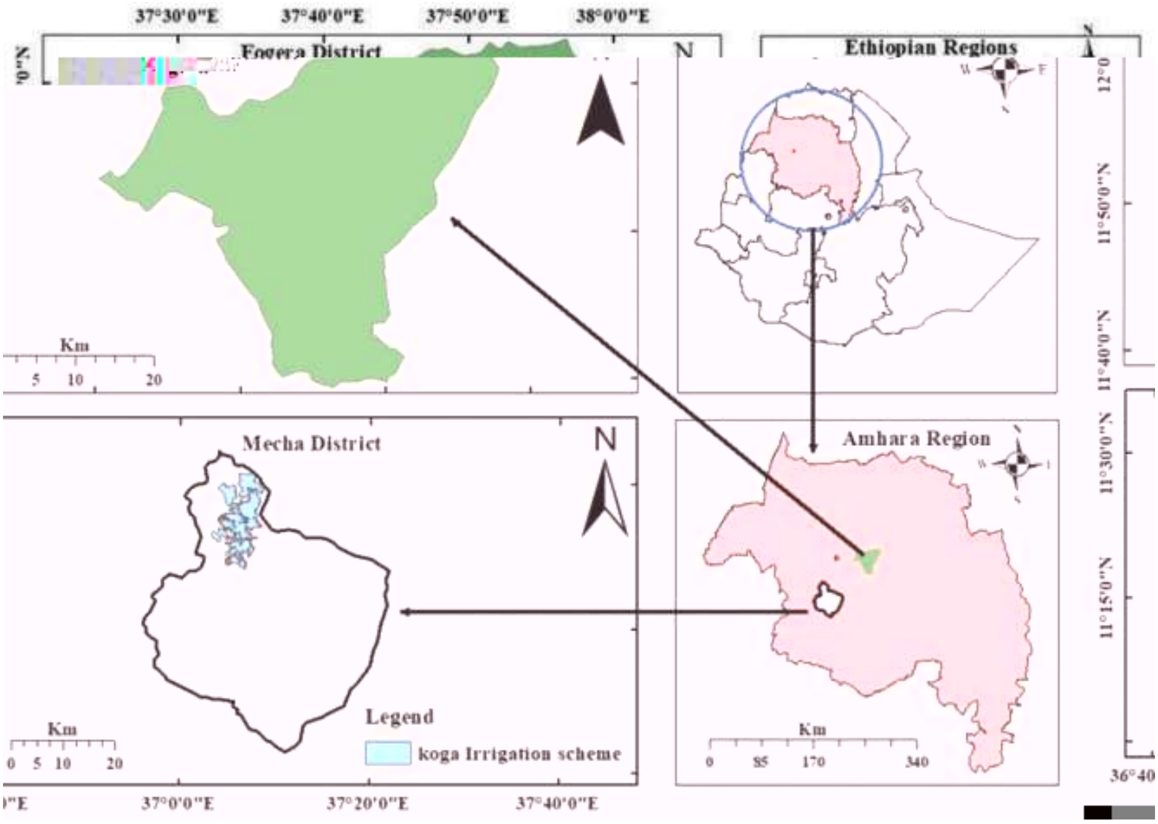

Figure 1. The location map of the study areas

The water application method was surface irrigation technique that applies through furrow and a siphon hose was used for measuring the amount of water we applied using a constant head. The flow rate of the irrigated water was measured and calculated using the volumetric method of discharge determination. This had done by collecting water in a container of known volume.

Q = V/t where, V = volume of container (m^3), t = time taken (hr) and Q = discharge of irrigation water (m^3 hr^{-1}) for both experimental sites (Gore & Banning, 2017). The field layout of the experiment is illustrated in Figure 2.

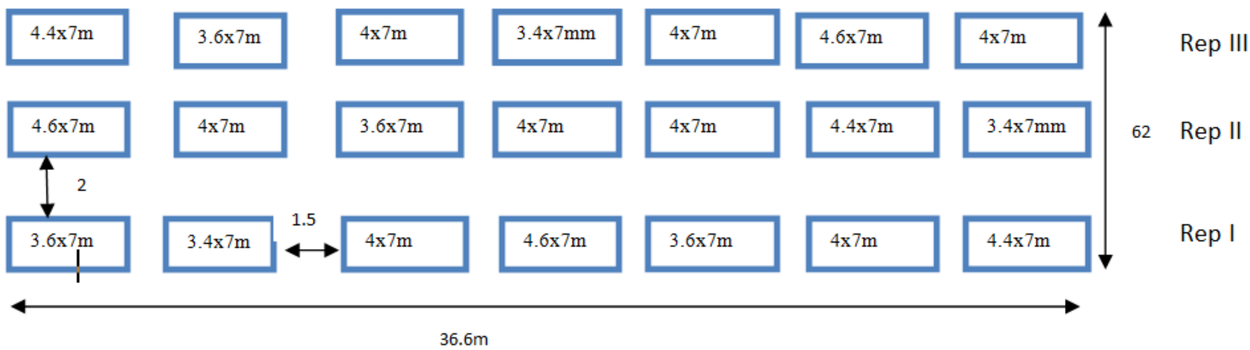

Figure 2. Field layout of the experiment

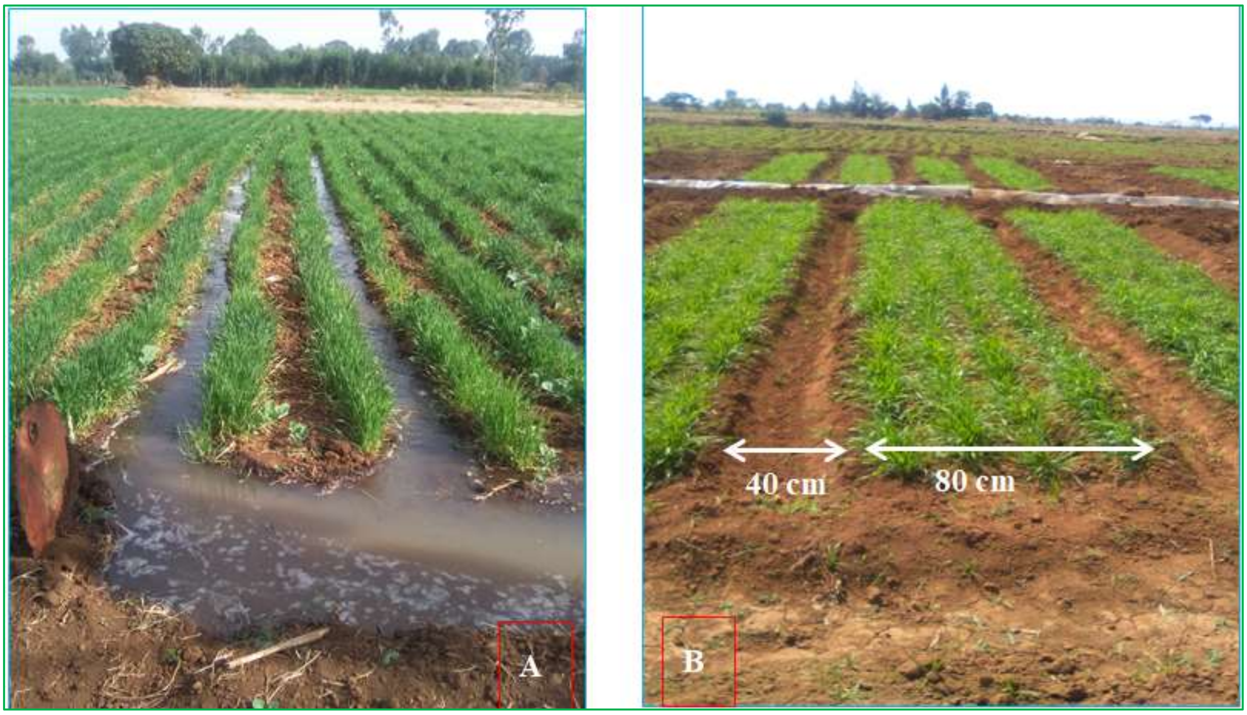

Figure 3. The farmer irrigation practice (A) and raised bed irrigation (B) at the site

Results and Discussion

Wheat yield

The study had conducted at silt clay soil (Koga) and loamy/alluvial deposited soil (Rib) to determine optimum bed width planted mid-November under irrigation. The results show that a significant difference between different bed widths has been observed on both sites (Table 3). The highest grain yield of 2.85 ton ha^{-1} at silt clay soil was obtained using 80 cm bed width at Koga while the lowest yield 2.26 ton ha^{-1} was obtained by using 40 cm bed width. On the other hand, in the alluvial deposited soil, a maximum of 4.99 ton ha^{-1} and a minimum 3.39 ton ha^{-1} grain yield, as shown in (Table 3) was obtained using 120 cm and 40 cm bed widths respectively. The production of wheat at the Koga scheme was too low due to strong acidic problems in the scheme. This result reveals that lateral movement in the Rib irrigation scheme (alluvial soil) was higher than in the Koga irrigation scheme. The panicle length and 1000 seed weight had not shown a significant difference among the different bed widths while plant height had a significant difference between bed widths at both locations. Generally, the results implied that the production of wheat under optimal raised bed width provided a 26 % yield advantage at Koga and 27 % at the Rib irrigation scheme as compared to the farmer practice. The farmer irrigation practice and raised bed irrigation at the study area is presented in Figure 3.

Our result is well agreed with the findings of Soomro et al. (2017), as they reported that the wheat crop produced a 24.65 % yield advantage. Similarly, Razaq et al. (2019) reported a 13.0 % higher grain yield under optimal raised-bed irrigation compared to the conventional irrigation system. Mollah et al. (2009) also reported wheat planting using 70 cm wide beds with two and three plant rows had 21 and 20 % yield increments respectively over the conventional method. The obvious reason for higher yield production under optimal bed width is due to effective utilization of land by reducing the number of furrows and lateral movement of the water. However, in Ethiopia, raised bed irrigation technique has not introduced until the study period.

Table 3. wheat yield and yield components

Bed Width (cm)	Yield (ton ha^{-1})		Plant height (cm)		Panicle length (cm)		1000 Seed Weight (g.)	
	Koga	Rib	Koga	Rib	Koga	Rib	Koga	Rib
40	2.26^{c}	3.93^{c}	85.2^{ab}	91.4^{b}	8.6	9.1	34	30.5
60	2.67^{ab}	4.51^{ab}	89.1^{a}	94.1^{ab}	9.3	9.5	33.6	29.4
80	2.85^{a}	4.45^{b}	86.6^{ab}	97.3^{a}	8.9	8.9	34	30.1
100	2.63^{ab}	4.54^{ab}	87.7^{ab}	94.6^{ab}	8.5	9.0	34	29.7
120	2.54^{b}	4.99^{a}	83.4^{ab}	94.3^{ab}	8.5	9.3	34.3	30.1
140	2.63^{ab}	4.64^{ab}	79.5^{b}	96.8^{ab}	8.0	9.5	33.6	30.6
160	2.52^{b}	4.31^{bc}	81.8^{ab}	94.3^{ab}	8.0	9.5	33.3	28.2
CV	6.9	8.6	7.6	4.6	7.6	11.2	2.8	10.4
LSD	**	**	*	*	ns	ns	ns	ns

Note: The (*) indicate significantly and (**) indicate highly significant at 5% and 1% level of confidence respectively

Wheat Water Productivity

Wheat cultivation on raised beds enhanced water productivity, crop grain yield, and yield components as compared to the traditional flat sowing method (Razaq et al., 2019). The results revealed that water productivity was significantly affected by soil characteristics and the width of the raised bed (Table 4). The optimal raised bed width produced 25 % in clay soil (0.82 kg m^{-3}) and 27 % in clay loam soil (1.57 kg m^{-3}) higher water productivity as compared to farmer practice (40 cm bed width), which was a similar finding with the report of Razaq et al. (2019) in Pakistan. The area and number of furrows per hectare in the wider beds (better land productivity) is lower than the narrow beds resulting in received a lower amount of irrigation water. Savings of irrigation water by bed planting of wheat ranged from 18%-50% as reported by scientists (Gupta et al., 2002, CHOUDHARY et al.). The evident reason for higher water productivity under optimal bed width is due to effective utilization of land by reducing the number of the furrow.

Table 4. Water productivity of wheat affected by bed width

Bed Width (cm)	Site	40	60	80	100	120	140	160	CV	LSD (5%)
Water productivity ($kg\ m^{-3}$)	Koga	0.74^{c}	0.87^{ab}	0.93^{a}	0.82^{ab}	0.78^{b}	0.81^{ab}	0.74^{b}	6.9	**
	Rib	1.22^{c}	1.40^{ab}	1.39^{b}	1.41^{ab}	1.56^{a}	1.45^{ab}	1.35^{bc}	8.6	**

Conclusions

In the study areas, wheat was growing using surface irrigation and a series of furrows with narrow beds leads to poor production and waste of water. The optimal raised bed width of wheat at Koga (clay soil) was 80 cm bed width while at Rib (loam soil) was 120 cm bed width which gave 26 % and 27 % grain yield advantage respectively as compared to farmer irrigation practice. In addition, using the optimal bed width, the water amount of saved water has increased by 25 % in clay soil and 28 % on loamy soil as compared to farmer irrigation practice. This result revealed that using the saved water, up to 25% to 28% additional land could be irrigated. The lateral movement of water in loamy soil was higher than clay soil which results in a possibility of production of wheat in a wider bed at Rib irrigation scheme. Generally, the cultivation of wheat using optimal raised bed width enhanced water productivity, crop yield, and its components as compared to the traditional flatbed sowing and a series of furrows with a narrow bed method.

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