



## Effect of Irrigation Regime On Yield and Water Productivity of Maize (*Zea Mays*) in the Lake Tana Basin, North West Ethiopia

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### ABSTRACT

Proper scheduling gave water to the crop at the right time in the right quantity to optimize production and minimize adverse environmental impact. Therefore, the objective of this study is to quantify the effects of irrigation regimes on yield and yield components of Maize in the Lake Tana basin during 2016-2018. CROPWAT 8.0 model was used to determine the crop water requirement. Almost all parameters were adopted the default value of CROPWAT 8.0. Field data including; field capacity (FC), permanent wilting point (PWP), initial soil moisture depletion (%), available water holding capacity (mm/meter), infiltration rates (mm/day), and local climate data were determined in the study area. The treatments were arranged in factorial combinations with five irrigation depths (50, 75, 100, 125 and 150% of ETc) and two irrigation intervals (14 and 21 days) laid out in a randomized complete block design with three replications. The result was analyzed using SAS 9 software and significant treatment means separated using least significant difference at 5%. The result showed that the interaction of irrigation depth and irrigation frequency has no significant effect on the average grain yield and water use efficiency of maize. At Koga, the highest grain yield (7.3 t ha<sup>-1</sup>) and water use efficiency (0.9 kg m<sup>-3</sup>) obtained from 100% ETc. while, at Ribb the highest grain yield (10.97 t ha<sup>-1</sup>) and water use efficiency (1.9 kg m<sup>-3</sup>) obtained from 21 days irrigation interval. Therefore, for Koga and similar agro ecologies maize can irrigated with 562 mm net irrigation depth and 21-day irrigation interval and at Ribb and similar agro ecologies maize can irrigated with 446.8 mm net irrigation depth and 21- days irrigation interval.

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### Introduction

Water demand increases globally more than the rate of population increases (UN 2018). Besides, expansion of irrigated agriculture, change in consumption pattern and climate change aggravate the condition (Ercin et al. 2014). However, most farmers who live in developing country cultivate crops using flood, border and furrow irrigation techniques that results in lose up to 50% water through deep percolation and tail water loss (Tewabe et al. 2020).

To meet food demand by 2050, sub-Saharan Africa maize output must increase up to four fold (Hein et al. 2019). Introducing appropriate water management is pertinent to provide sufficient food for the rapid population growth.

Ethiopia produces 9492770.8 tons in 2,367,797.4 hectares in 2019 (CSA, 2019). The current national average productivity of farmers' is 4 t ha<sup>-1</sup> while yields up to 12 t ha<sup>-1</sup> recorded on research plots (Hein and Martin, 2019). Timely management of plant pests, weeds, fertilizers and proper water application are essential during the production period of maize. As a thumb rule application of over irrigation

water to the crop increase leaching of nutrients, reduce grain and biomass yield which results in a reduction of water productivity (Eneyewe et al. 2020). Besides, delivering appropriate water for crops can improve nutrient availability, aeration and water productivity (Tewabe et al. 2020). CROPWAT software model is a computer program used for irrigation planning and management developed by FAO and; is widely used to estimate reference evapotranspiration (ET<sub>0</sub>) and crop evapotranspiration (ET<sub>c</sub>) (Abdalla et al., 2010). It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation (Clarke et al., 2001). Implementing sound irrigation water management practices is essential. Therefore, the objective of this study was to quantify the effects of optimum irrigation regime on yield and water use efficiency of Maize in the Lake Tana basin.

## Materials and Methods

### Description of The Study Area

The field trial conducted for two years during the dry season of 2016/17 and 2017/18 in the Lake Tana basin, North West Ethiopia. Koga irrigation scheme is located in Mecha district at 37°7'29.72" Easting and 11°20'57.85" Northing and at an altitude of 1953 m a.s.l. The average annual rainfall of the area is about 1343 mm. The mean maximum and minimum temperatures are 26.8°C and 9.7°C respectively.

Rib irrigation site is located in Fogera district 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 1480 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 agro ecology. The basin weather data, crop parameters, soil physical and chemical properties and others describe in Table 1.

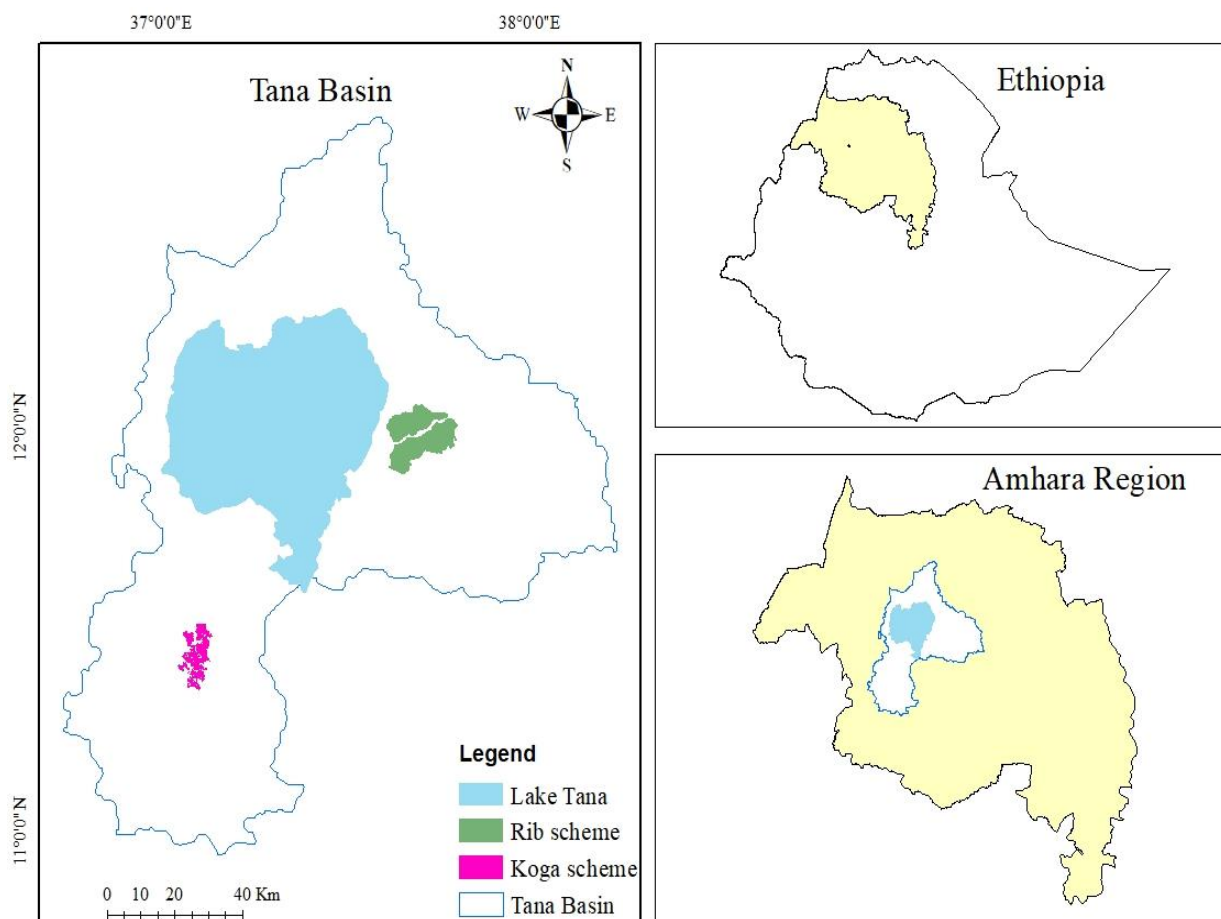


Figure 1. Site description of the study area

Table 1. Facts and figures of experimental input

	Ribb	Koga
<b>Soil physical property</b>		
Soil type	Fluvisols	Nitisols
Soil texture	Silty clay	Silty clay
drainage	Moderately well drained	Well drained
Field Capacity (% w/w)	59.2	32
Permanent Wilting Point (% w/w)	21	18
Infiltration rate (mm/day)	30	40
Soil rooting depth(cm)	600	90
Initial soil moisture depilation (%)	100	100
<b>Soil chemical property</b>		
Available Phosphorous by Olsen methods (ppm)	36.71	6.12
Nitrogen by Micro-Kjeldahl method (%)	0.003	0.21
Cation Exchange Capacity by ammonium acetate method (cmol/kg)	33	1.9
PH(1:2.5H <sub>2</sub> O)	6.7	4.6
<b>Irrigation water</b>		
Electrical conductivity(μScm <sup>-1</sup> )	161	124.9
PH(1:2.5 H <sub>2</sub> O)	8.2	8.17
Sodium absorption ratio (SAR)	0.51	0.18
Total Dissolved Solvent(mg/l)	188	85

Table 2. Crop water and irrigation requirements of maize in Koga and in Ribb

Month	Decade	Stage	Kc coeff	ETc (mm/day)	ETc (mm/dec)	Eff rain (mm/dec)	Irr. Req. (mm/dec)
<b>Koga</b>							
Dec	2	Init	0.3	0.99	1	0	1
Dec	3	Init	0.3	1.01	11.1	0	11.1
Jan	1	Deve	0.31	1.06	10.6	0	10.6
Jan	2	Deve	0.51	1.79	17.9	0	17.9
Jan	3	Deve	0.81	3.01	33.1	0.1	33
Feb	1	Deve	1.1	4.37	43.7	1	42.7
Feb	2	Mid	1.29	5.37	53.7	1.4	52.3
Feb	3	Mid	1.29	5.56	44.5	1.7	42.8
Mar	1	Mid	1.29	5.73	57.3	1.9	55.4
Mar	2	Mid	1.29	5.9	59	2.2	56.8
Mar	3	Late	1.21	5.66	62.3	2.8	59.5
Apr	1	Late	0.9	4.3	43	1.3	41.7
Apr	2	Late	0.58	2.86	28.6	0.8	27.8
Apr	3	Late	0.38	1.84	5.5	2.9	0.7
Total					471.3	16.1	453.3
<b>Ribb</b>							
Dec	2	Init	0.3	0.93	0.9	0	0.9
Dec	3	Init	0.3	0.94	10.3	0	10.3
Jan	1	Deve	0.31	0.96	9.6	0	9.6
Jan	2	Deve	0.49	1.53	15.3	0	15.3
Jan	3	Deve	0.75	2.43	26.8	0	26.8
Feb	1	Deve	1.01	3.4	34	0	34
Feb	2	Mid	1.17	4.07	40.7	0	40.7
Feb	3	Mid	1.17	4.21	33.6	0	33.6
Mar	1	Mid	1.17	4.33	43.3	0	43.3
Mar	2	Mid	1.17	4.45	44.5	0	44.5
Mar	3	Late	1.1	4.26	46.8	0.1	46.7
Apr	1	Late	0.83	3.25	32.5	1.8	30.8
Apr	2	Late	0.56	2.21	22.1	2.6	19.5
Apr	3	Late	0.38	1.51	4.5	1.2	2.6
Total					365	5.7	358.6

Table 3. Treatment combination

Treatment	Frequency(day)	Total net irrigation depth(mm)	
		Koga	Ribb
1	14	307	277
2	14	435	373
3	14	562	469
4	14	690	566
5	14	818	662
6	21	267	276
7	21	368	361
8	21	469	447
9	21	570	532
10	21	670	618

### **Crop Water Requirement and Irrigation Scheduling**

All calculation procedures used in CROPWAT 8.0 based on the two FAO publications No. 56 and No. 33. Then the generated crop water and irrigation requirements values show in Table 2. Besides dependable rainfall, (FAO/AGLW formula) method was used for the estimation of effective rainfall.

### **Experimental Setup**

The on-farm trial was conducted with ten different treatments as shown in Table 3. Two irrigation intervals i.e. 14 and 21 days and five irrigation depths (50, 75, 100, 125 and 150% ETc) of variable depths at four growth stages selected based on CROPWAT 8.0. Besides, we used 70 percent field application for the trial. Thus, the following

treatments were set and evaluated for verification of the CROPWAT prediction with field experimentation.

The test crop maize a variety of BH-545 planted on 3 m by 6 m plot size, spacing between treatments and block was 1 and 2m respectively. The test crop maize had 0.75 m and 0.3m spacing between row and plants respectively. P<sub>2</sub>O<sub>5</sub> fertilizer applied at a rate of 92 kg ha<sup>-1</sup> at planting and 46 kg N ha<sup>-1</sup> applied half at planting and the remaining half at 45 days after planting.

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 was estimated using the volumetric method. This has done by collecting water in a tank of known volume.  $Q = V/t$  where, V = volume of container (m<sup>3</sup>), t = time taken (hr) and Q = discharge of

irrigation water ( $m^3 hr^{-1}$ ) for both experimental sites Gore & Banning, (2017). Water use efficiency calculated as the ratio of crop yield over applied irrigation water using Micro soft excel Oweis and Zhang, (1998).

**Data Analysis**

The collected data subjected to analysis of variance (ANOVA) using SAS version 9. Mean comparison was done by using least significant difference test at 5% probability level.

**Results and Discussion**

**Dynamics of Soil Volumetric Moisture Contents**

Changes in the volumetric soil water content of the irrigation regime treatments during the first year experimental periods shown in Figure 2. Although the experiment conducted during the dry season, there was a rainfall (31mm at Ribb and 42 mm at Koga) during middle stage of the crop both years, leading to increase soil moisture content of the entire treatments. Even though both 14 and 21-day irrigation interval received the same rainfall, irrigation depths of 21-day interval is below FC due to less irrigation volume as compared to 14-day irrigation interval.

**Effect of Irrigation Regime on Grain Yield, Yield Component and Water Use Efficiency**

Most parameters showed no significant difference for the interaction of irrigation interval and irrigation depth at ( $P<0.05$ ).

**Grain Yield**

Effect of variable irrigation regime on yield is presented in Table 4, irrigation depth alone significant ( $P<0.05$ ) in Koga. The maximum ( $7.3 t ha^{-1}$ ) grain yield was scored at 100 %ETc. this implies application of optimum irrigation regime increased the grain yield over the deficit and excess irrigation regime. This is in close agreement with Ekubay (2020) who report the maximum grain yield ( $7.3 t ha^{-1}$ ) achieved in 100% ETc in northern Ethiopia.

At Ribb, irrigation interval showed significant difference and the maximum ( $10.97 t ha^{-1}$ ) grain yield was scored at 21-day irrigation interval and the minimum ( $9.97 t ha^{-1}$ ) at 14-day irrigation interval as described in Table 4. Maximum yield response to 21-day irrigation interval might be high water holding capacity of the soil and manageable volumetric soil moisture content during the experimental season as shown in Figure 2a. Besides 75% ETc gives maximum yield ( $10.88 t ha^{-1}$ ) as compared to full irrigation. This might be the occurrence of rainfall during middle stage of the crop, lead to increase soil moisture content of the deficit treatments. The finding is in line with to Demelash and Ranamukhaarachchi (2004), Ekubay (2020), Libing et al (2019), who report irrigating sufficient water during the reproductive period of maize increase the grain yield.

The grain yield production at Koga irrigation scheme is low as compared to Ribb. This might be due to poor soil fertility and acidification at Koga and good nutrient content at Ribb as described in Table 1. Maize is sensitive to soil acidity and its suitable pH ranges from 5.8 to 7, while at Koga, it was about 4.6 that are below the critical level. Besides, the soil organic matter and available phosphorus was very low based on (Clements and McGowen, 1994) category.

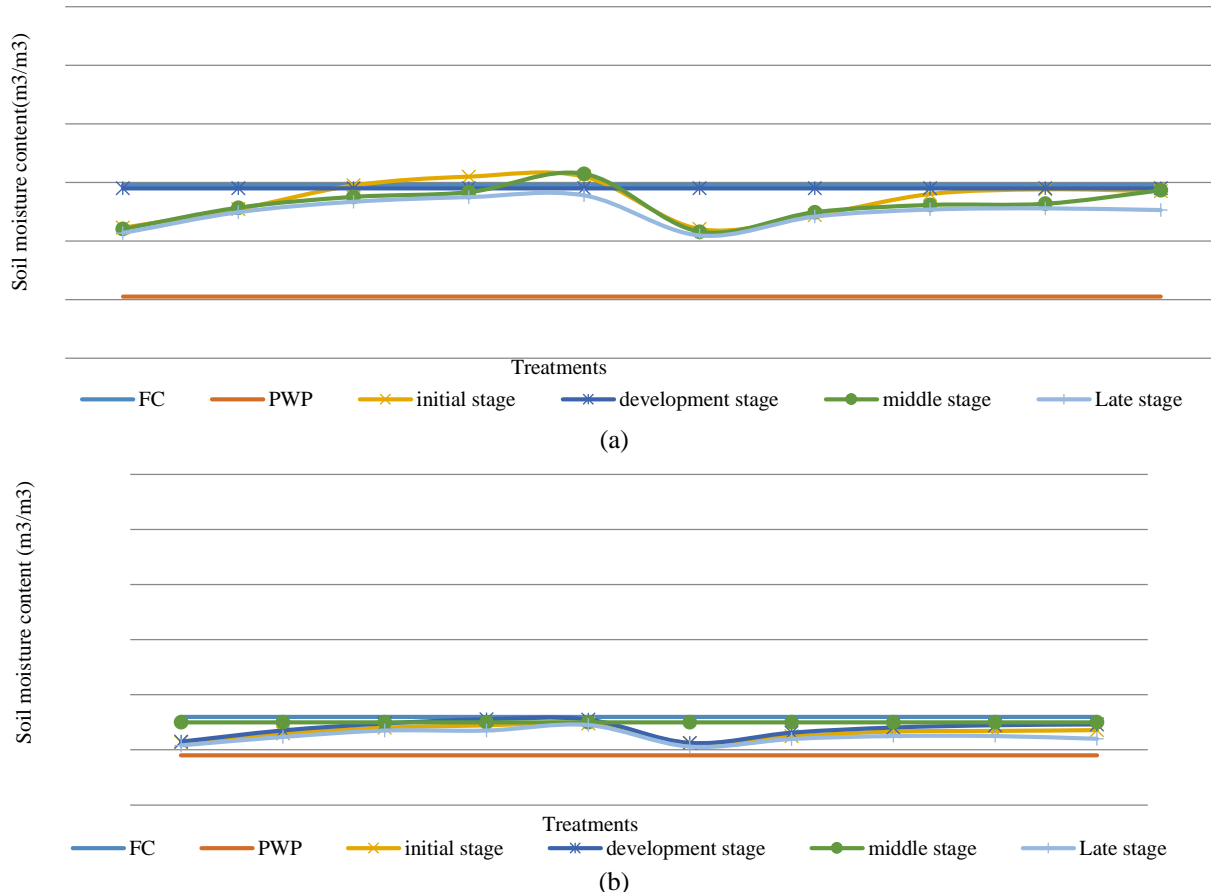


Figure 2. Average volumetric soil moisture content in four-crop growth stage vs irrigation regimes during 2016/17 experimental season a) Ribb irrigation scheme b) Koga irrigation scheme

Table 4. combined mean of yield and yield component in Koga and in Ribb irrigation scheme

		Gy	Gcn	CL	CD	WUE
Koga						
D	1	6.2	44630	13.6	3.9	1.4
	2	5.6	47315	14	3.8	0.9
	3	7.3	49537	13.7	3.9	0.9
	4	6.9	48148	13.3	3.9	0.7
	5	7.1	46944	14	3.9	0.6
F	1	6.6	44481.5	13.5	3.9	1.2
	2	6.6	50148	14	3.9	1.4
Lsd(5%)	D	0.01	0.44	0.14	0.12	0.001
	F	0.86	0.001	0.008	0.66	0.13
	F×D	0.91	0.58	0.047	0.35	0.95
CV		19.6	13.5	5.7	3.6	19.1
Ribb						
D	1	10.49	44912	16.9	4.92	2.7
	2	10.88	45328	17.58	4.8	2.1
	3	10.34	47448	17.1	4.9	1.6
	4	10.57	45787	16.6	4.95	1.3
	5	10.1	47447	17.5	4.96	1.1
F	1	9.97	44858	16.8	4.9	1.6
	2	10.97	47527	17.5	4.92	1.9
Lsd (5%)	D	0.87	0.8	0.09	0.018	0.001
	F	0.04	0.12	0.004	0.57	0.0001
	F×D	0.3	0.19	0.04	0.11	0.2
CV		18.1	14.4	5.3	2.7	19.8

Note- F- irrigation water frequency(day), D- Irrigation depth(mm), Gcn-Green cob number (no/ha), Gy-Grain yield(t ha<sup>-1</sup>), CL- Cob length (cm) CD- Cob diameter (cm), and WUE- water use efficiency (kg m<sup>-3</sup>),

#### Green Cob Number

Application of optimum irrigation regime increased the green cob number over the deficit and excess irrigation regime plot as shown in Table 4. Irrigation interval showed significant difference ( $P < 0.05$ ) in Koga, the maximum 50148 and the minimum 44481 green cob number (approximately 1 cob per plant) was scored at 21 and 14-day irrigation interval respectively. The finding is in close agreement with Tesfaye et al. (2018); BH-545 gives one cob number per plant in Koga irrigation scheme. Despite the non-significance response of irrigation regime to cob number in Ribb, the maximum 47527-cob number scored at 21 - day irrigation interval. The finding is in close agreement with Tesfaye et al. (2018); BH-545 gives one cob number per plant in Koga irrigation scheme.

#### Cob Length and Cob Diameter

The maximum 14 cm cob length and 3.9 cm cob diameter scored at 21- day irrigation interval in Koga. Similarly, the maximum 17.5 cm cob length and 4.96 cm cob diameter scored at 21- day irrigation interval in Ribb. The result is in line with to (Tesfaye et al. 2018) who reported the mean average cob length 15.9 cm and cob diameter 5.1 cm. Cob length and cob diameter has not strong correlation with the grain yield. This might be the occurrence of rainfall in sensitive stage of the maize as described in Figure 2a, b.

#### Water Use Efficiency

Interaction effect between irrigation interval and depth showed a non-significant ( $P < 0.05$ ) in both locations. Increasing the water depth from 50 to 150% ETc resulted in a decrease of water productivity from 2.7 to 1.1 kg m<sup>-3</sup> in Ribb and 1.4 to 0.6 kg m<sup>-3</sup> in Koga. By reducing

frequency of irrigation from 14 to 21 days' water productivity increased from 1.6 to 1.9 kg m<sup>-3</sup> in Ribb and 1.2 to 1.4 kg m<sup>-3</sup> in Koga. Compared with optimum irrigation regime, the deficit irrigation treatments saved significant depth of water with a minimum yield loss. This is in close agreement with the finding of Ekubay (2020), Libing et al. (2019) and Enyew et al. (2020) who reported that when irrigation water becomes a limiting factor, yield losses due to reduced soil moisture could be compensated for by water use efficiency.

#### Conclusion and Recommendations

The result of current study revealed that the effect of irrigation regime was not significant on grain yield, cob number, cob length, and cob diameter and water use efficiency. In koga the maximum green cob number 50148 and grain, yield 7.3 t ha<sup>-1</sup> was found with 21-day irrigation interval. In case of Ribb 21 day, irrigation interval gives 47527 green cob numbers, 10.97 t ha<sup>-1</sup> grain yield. Moreover, the maximum water use efficiency (2.7 kg m<sup>-3</sup>) in Ribb and 1.4 kg m<sup>-3</sup> in Koga achieved at 50% ETc. The net irrigation water requirement found to be 447mm for Ribb and 562mm for Koga throughout the growing season. Therefore, 100% ETc and 21 days irrigation interval is recommended for Koga and similar agro ecology. For Ribb and similar agro ecology, 75% ETc and 21 days irrigation interval is recommended.

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