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Evaluation of alternate furrow irrigation with different irrigation intervals on yield, water use efficiency, and economic return of green Cob Maize (*Zea mays*) production at WayuTuka and Diga Districts, Western Oromia

***Tadese A and Teklu L**
Department of Irrigation Enginnering,
Bako Agricultural Research Center, Ethiopia

Corresponding author: addisswem@gmail.com

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ABSTRACT

Aim: The main aim of this study was to investigate the effects of alternate furrow irrigation with different irrigation intervals on corn yield, irrigation water productivity, and economic return as compared with EFI (conventional method).

Materials and Methods: Normal irrigation interval was irrigation interval produced by CROPWAT model. The experimental plot size was 45m² (10m wide × 4.5m long). Each treatment included 7 furrows and 6 planting ridges (rows). Furrow spacing was 0.75 m. Space between plots been 1m and between replication 1.5 m. Space between rows 0.75m and 0.35cm between the plants was used. The experimental plot was pre-irrigated one day before planting.

Results: Results indicated that highest green cob yield 10733/ha and 10822/ha at Diga and 10044/ha and 10200/ha were obtained from AFI with normal irrigation interval treatment during two consecutive seasons whereas, low number are collected from Farmer practice (FP) treatments. However, highest water productivity (WP) values (3.42kg/m^3, 3.45 kg/m^3,3.55kg/m^3 and 3.30kg/m^3) were observed from AFI with extended irrigation interval at both locations during consecutive growing seasons. Irrigation water saved at Wayu Tuka under AFI_{norm} and $AFI_{extended}$ treatments were approximately 50% and 60% respectively, as compared to the CFI treatment and 43.6 and 55.7% AFI_{norm} and $AFI_{extended}$ treatments respectively at Diga site. However, under $AFI_{extended}$ yield reduction was observed as compared with AFI_{norm}.

Conclusion: It was concluded that Alternate-furrow irrigation with normal irrigation interval can improve crop water productivity without the risk of yield reduction. Therefore, if low cost water is available and excess water delivery to the field does not require any additional expense, then the AFI normal irrigation interval treatment will essentially be the best choice under the study area conditions.

Keywords: Alternate furrow irrigation, irrigation interval, water productivity and green crop yield.

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Introduction

Irrigated agriculture is the main solution to produce crop to feed and achieve the different needs for an ever-increasing world population. However, a Growing competition for water from domestic and industrial sectors reduced its availability for irrigation. In this regards irrigation only based on crop water requirement is not an option especially in areas where water resource is limited. Much of an increase in the irrigated area had come because of the expansion of small-scale irrigation in the country.

The existing irrigation development in Ethiopia, as compared to the resources the country has, is negligible. Irrigation water management implies the application of suitable water to crops in right amount at the right time. Salient features of any improved method of irrigation is the controlled application of the required amount of water at desired time, which leads to minimization of range of variation of the moisture content in the root zone, thus reducing stress on the plants (Monteith, 1990 and Ulsido and Alemu, 2014). Many investigations have been conducted to gain experiences in irrigation of crops to maximize performance, efficiencies and profitability. However, investigation in water saving irrigation still is continued (sleeper *et al.*, 2007).

Satisfying crop water requirements, although it maximizes production from the land unit, does not necessarily maximize the return per unit volume of water (Oweis *et al*., 2000 and Oweis *et al.,* 1998). The target crop maize is the one of the major crop in Ethiopia with is the top crop by the number of farming community engaged and next to teff it is the highest in area coverage in the country (Oweis *et al*., 20000. The study area is at Western Ethipia where crop production in wet season by rain fall and during dry season is unexpected without irrigation. Moreover, it is characterized by having highly variable initial and conditional probability of threshold limit of 30 mm per decade rainfall in the main rainy season (Oweis *et al.,* 1998). To improve crop production to feed the ever-increasing population under limiting water resource condition, strategies that conserve moisture in the soil and efficient irrigation techniques should be identified and practiced. Different works have been done on irrigation water management for maize in different part of the world that revealed that yield and water productivity of maize enhanced through different irrigation water management methods like conventional furrow, alternate furrow and water conservation methods like application of straw and plastic mulching (Mebrahtu, 2017 and Penman 1948).

Application of irrigation water through conventional furrow method that irrigate all the neighbouring furrow in two consecutive irrigation time leads to maximize yield under different crops including maize. However, productivity of irrigation water is maximized through deficit irrigation practice using different techniques like alternate furrow method by irrigating only one of the neighbouring two furrows during the consecutive irrigation time. For example, (SeidDebaeke and Aboudrare, 2004) reported that maximum maize yield was obtained under conventional furrow irrigation with irrigation water application of 100% crop water requirement than the alternate and fixed furrow irrigation method. The same research revealed that with comparable yield penalty, alternate furrow irrigation method maximized water use efficiency of maize. According to (Nasri *et al.,* 2010) that reported alternate partial root-zone irrigation improves water use efficiency of okra plant than the conventional furrow condition under different soil moisture depletion levels. Based on their findings, they concluded that alternate furrow irrigation as a way to save water and maize production relies heavily on repeated irrigation.

Alternate furrow irrigation (AFI) is considered to be one of the most effective tools to minimize water application and irrigation costs and produce a higher crop yield. The AFI method is a way to save irrigation water, improve irrigation efficiency, and increase corn yield (Shayannejad and Moharreri, 2009; Nasri et al., 2010; Rafiee and Shakarami, 2010; Kashiani et al., 2011). Using Alternate furrow irrigation with appropriate irrigation interval can save irrigation water without yield reduction. Little works were done on irrigation interval of Alternate furrow irrigation. Sepaskhah and Khajehabdollahi (2005) found that corn grain yield of AFI at 7-d intervals was lower than every-furrow irrigation (EFI) at 10-d intervals. In addition, Li et al. (2007) found that alternate partial root-zone and fixed partial root-zone irrigation techniques led to a higher reduction of transpiration than photosynthesis and thus increased corn leaf water use efficiency (WUE). Beside this, Abdel-Maksoud et al. (2002) found that AFI at 14-d intervals seemed to not significantly decrease yield, whereas yield increased under AFI at 7-d intervals as compared with the EFI method. Therefore, in an effort to improving water productivity through Alternate furrow irrigation with appropriate irrigation interval is an interest of the study done on maize crop.

The objective of this research study was to investigate the effects of alternate furrow irrigation with different irrigation intervals on corn yield, irrigation water productivity, and economic return as compared with EFI (conventional method).

Materials and Methods

Description of the study area: This experiment was conducted in Dida and Wayu Tuka Districts of western Oromia. The study sites are Lelisa Dimtu from Diga District and Xaxo from Wayu Tuka. Diga and Wayu Tuka districts were located at 338 and 325km from Addis Ababa, respectively. The districts has three agro ecologies Dega, weyna and Kola.

Treatments and experimental design: Irrigation treatments were: 1, Farmer practice (FP); 2, Conventional irrigation method (EFI), every furrow was irrigated at CROPWAT irrigation interval; 3, Alternate furrow irrigation at

CROPWAT irrigation interval (AFI_{norm}); 4, Alternate furrow irrigation at Reduced CROPWAT irrigation interval ($AFI_{reduced}$); and 5, Alternate furrow irrigation at extended CROPWAT irrigation interval ($AFI_{extended}$The adopted treatments were assessed with randomized complete block design (RCBD) with three replicates. The experimental plot size was 45m^2 (10m wide × 4.5m long). Each treatment included 7 furrows and 6 planting ridges (rows). Furrow spacing was 0.75 m. Space between plots been 1m and between replication 1.5 m. Space between rows 0.75m and 0.35cm between the plants was used. The experimental plot was pre-irrigated one day before planting. Before the commencement of treatment, two to three common light irrigations was supplied to all plots at two to three days interval to ensure better plant establishment.

Table 1. Treatment set-up

Treatment Code	Treatment combination
FP	Farmer practice
EFI	Convectional furrow irrigation (CROPWAT irrigation interval)
AFI_{norm}	Alternate furrow irrigation (CROPWAT irrigation interval)
$AFI_{reduced}$	Alternate furrow irrigation (Reduced CROPWAT irrigation interval)
$AFI_{extended}$	Alternate furrow irrigation (Extended CROPWAT irrigation interval)

Agronomic practices: Agronomic practices maize seeds (BH-546) were planted during 2018/19 and 2019/20 growing seasons at the rate of 25kgha^{-1}. Two seeds were planted per hole with a plant spacing of 0.35m. All plots were irrigated immediately after planting (planting irrigation). Recommended fertilizer of 100kg/ha NPS and half of 200kg/ha UREA was applied prior to the second pre-treatment irrigation. Thinning was carried out after the second pre-treatment irrigation and the remains half UREA was applied after 35 days of planting. All other agricultural operations, including pesticide and hand weeding, were applied uniformly and simultaneously for all treatments. Experimental treatments were implemented after the second pre-treatment irrigation in both seasons.

Crop water requirement and Irrigation Schedule

The estimate of the water requirement and irrigation scheduling of crops under this study was based on the atmospheric conditions of the environment by using a model. A computer program called "CROPWAT version 8.0" was used to determine reference evapotranspiration, crop water requirements, and irrigation schedule by utilizing metrological data as an input. For estimation of water irrigation requirements, climatic, crop and soil data have been utilized as an input. This calculation has been done by using the FAO Penman-Monteith method (Aallen 1998). In this experiment, the reference evapotranspiration (ETo) and crop water requirement (ETc) were estimated from long term climatic data collected from Ethiopia Metrological Agency.

Irrigation water was conveyed to the experimental plots through Parshall Flume having appropriate opening diameter of three inch (3") and a length of 2 m. The amount of water for each application was added through Parshall Flumeby recording time of water flow through furrows. Time is then recorded with a stopwatch to estimate the amount of water applied to each plot. Furrows subjected to irrigation were close-ended; then, water cannot exceed the edge of the plot because all were closed-ended. The water in the channel was controlled to maintain a constant head to provide an adequate inflow rate during irrigation events with a close ended.

Data Collection

Climatic data: Before the start of the experiment, secondary data such as climatic data of 30 years on rainfall (R.F.) min and max temperature, relative humidity (RH), wind speed (WS) and sunshine hours (SH) were collected from the National meteorological agency. Irrigation efficiency for furrow irrigation, root depth of maize crop, maize crop growth stages and their respective length of period data were also collected from previous records and FAO guidelines.

Soil Physical Properties: Four soil profiles were randomly made in the experimental site to measure soil physical properties. Soil texture was determined using the volumetric method at 0-5, 5-10, 10-15 and 15-20cm depths of the soil profiles. Bulk density was determined by the core method (Blake and Hartage 1986) for each sampling depth. Soil water content was determined from soil samples taken at the same locations using the gravimetric method. The soil basic infiltration rate was determined in the field using double-ring infiltrometer method in two separate sites in the experimental area as described by (Bouwer, 1986).

Table 2. Soil physical characteristics of the experimental sites

Sampling Depth	WayuTuka (LegaXaxo)			Diga (LelisaDimtu)		
	Bulk density	Average bulk density g/cm^3	Soil texture	Bulk density	Average bulk density g/cm3	Soil texture
0-5cm	1.32	1.34	clay	1.18	1.31	Sandy clay
5-10cm	1.34			1.29		
10-15cm	1.36			1.38		
15-20 cm	1.37			1.4		
FC (%)	61.72			52.6		
PWP (%)	50.18			34.87		

Yield and Yield Components: Yield (green cob) data, were collected from each plot size of 10 *4.5m and extrapolated to a hectare basis. Green Cobs of maize were categorized as small, medium and large based on the size of cobs and data were collected in number and weight basis from each plot at both locations. Stand count data was also collected from all plots at maturity stage.

Water Productivity: Water productivity (WP) Water productivity was determined by dividing grain yield by total applied irrigation water and was expressed as follows (Ali et al., 2007):

$$WP = GY/Wa \qquad 1$$

where GY was grain yield (kg ha^{-1}) and Wa was irrigation applied water (m3 ha^{-1}).

Data Analysis: The collected data was subjected to analysis of variance (ANOVA) and least significant difference (LSD) was used to separate means at $p<0.05$ probability levels of significance.

Results and Discussion

In order to characterize soils of the study site, soil physical and chemical parameters were measured in the field and laboratory. The laboratory results of the average chemical properties of the experimental site were presented (Table 3). The result of the soil analysis from the experimental site showed that the top soil surface had bulk densities were of 1.34gm/cm^3 and 1.31gm/cm^3 at Wayu Tuka (Xaxo) and Diga (Lelisa Dimtu) sites respectively. In general, the average soil bulk density (1.31gm/m^3) is below the critical threshold level (1.4g/cm^3) and was suitable for crop root growth. Average moisture content at field capacity of the experimental sites soils were 61.72% and 52.6% at Xao and Lelisa Dimtu sites respectively, and permanent wilting point the sites were 50.18% and 34.87% at Xaxo and Lelisa Dimtu respectively. Soil pH was found to be at slightly acidic value (5.7 averages of all treatments) at both sites for maize and other crops. Therefore, the soils of the study area are normal soils. The weighted average organic matter content of the soil was 5.3 and 5.6% at Xaxo and Lelisa Dimtu respectively.

Depth of applied water: The irrigation events and amount of applied water (Wa) for each treatment at Wayu Tuka district of Lega Xaxo site were shown (Table 4). The AFI_{Redu} (Altenat Furrow irrigation with reduced irrigation interval) treatment was more frequent (11 irrigation events) than CFI and AFI_{Norm} (eight irrigation events) for both seasons. The mean of the two seasons were amounted to 415mm (415m^3ha^{-1}), 346mm(346m^3ha^{-1}), 173mm(173m^3ha^{-1}), 135mm (135m3ha^{-1}) and 208mm (208m^3ha^{-1})for FP, CFI, AFI_{Norm}, AFI_{Extend} and AFI_{Redu}, respectively.

This indicated that the AFI_{Extend} and AFI_{Norm} alternate furrow irrigation treatments saved water by approximately 60% and 50% (two-season means), respectively, as compared to conventional CFI. Regardless of irrigation intervals, the lowest amount of applied water (Wa) under AFI_{Norm}, treatments as compared with CFI might be due to the great reduction of wetted surface in AFI_{Norm}; almost half of the soil surface was wetted in AFI_{Norm} as compared with CFI. This result supports the outcome obtained by (AwadAbd El-Halim, 2013), who found that AFI methods can supply water in a way that greatly reduces the amount of wetted surface, which leads to less evapotranspiration and less deep percolation.

The irrigation events and amount of applied water (Wa) for each treatment at Diga district of Lalisa Dimtu site were shown (Table 5). The AFI_{Redu}(Altenat Furrow irrigation with reduced irrigation interval) treatment was more frequent (11 irrigation events) than CFI and AFI_{Norm} (eight irrigation events) for both seasons. Based on the output of the CROPWAT 8 model, the optimum seasonal irrigation requirement in the area for maize was found to be mean of the two seasons were amounted to 471mm (471m^3ha^{-1}), 402mm

(402m³ha⁻¹), 229mm (229m³ha⁻¹), 178mm (178m3ha⁻¹) and 283mm (283m³ha⁻¹) for FP, CFI, AFI_{Norm}, AFI_{Extend} and AFI_{Redu}, respectively. This indicated that the AFI_{Extend} and AFI_{Norm} alternate furrow irrigation treatments saved water by approximately 55.7% and 43.6% (two-season means), respectively, as compared to conventional CFI. Amount of water saved under AFI_{Extend} and AFI_{Norm} at Lelisa Dimtu site was relatively low as compared to Lega Xaxo Site.

Table 3. Soil chemical properties characteristics of the experimental sites

Treatments	WayuTuka (Lega Xaxo)					Diga (Lelisa Dimtu)				
	pH(1:2.5)H_2O	OC (%)	OM (%)	TN %	Av.P (ppm)	pH(1:2.5)H_2O	OC (%)	OM (%)	TN %	Av.P (ppm)
FP	5.81	3.43	5.92	0.20	16.5	5.86	3.24	5.58	0.18	25.1
CFI	5.64	2.83	4.87	0.14	16.7	5.61	2.91	5.01	0.15	24.7
AFI_{Norm}	5.68	3.24	5.58	0.18	15.6	5.86	3.26	5.61	0.18	19.7
AFI_{Extend}	5.5	3.14	5.41	0.17	12.7	5.64	2.87	4.94	0.15	25.7
AFI_{Redu}	5.84	2.69	4.64	0.13	29.6	5.71	4.04	6.96	0.25	18.1

Table 4. Number of irrigation events and depth of applied water for each irrigation event under different irrigation treatments for both seasons at Wayu Tuka

	WayuTuka (LegaXaxo)									
	Depth of applied water (Wa) (mm)									
	Season 2018/19					Season 2019/20				
	FP	CFI	AFI_{Norm}	AFI_{Extend}	AFI_{Redu}	FP	CFI	AFI_{Norm}	AFI_{Extend}	AFI_{Redu}
1	37.1	30.9	15.4	18.7	11.8	38.9	32.4	16.2	19.6	12.3
2	44.8	37.3	18.6	21.7	9.8	46.9	39.2	19.6	22.7	10.2
3	51	42.5	21.3	21.95	12.7	53.6	44.6	22.3	23.0	13.3
4	51.9	43.3	21.7	22.2	15.5	54.6	45.5	22.7	23.3	16.2
5	52.7	43.9	21.9	25.3	18.7	55.3	46.1	23.0	26.5	19.6
6	53.2	44.3	22.2	22.2	21.3	55.8	46.5	23.3	23.3	22.3
7	53.3	44.4	22.2	-	21.7	55.9	46.6	23.3	-	22.7
8	60.6	50.5	25.3	-	21.9	63.6	53.0	26.5	-	23.0
9	-	-	-	-	22.2	-	-	-	-	23.3
10	-	-	-	-	22.2	-	-	-	-	23.3
11	-	-	-	-	25.3	-	-	-	-	26.5
Total	404.5	337	167	132	203	425	354	177	139	213
Mean of the two seasons	415	346	173	135	208					

Table 5. Number of irrigation events and depth of applied water for each irrigation event under different irrigation treatments for both seasons at Diga

	Diga (LelisaDimtu)									
	Depth of applied water (mm)									
	Season 2018/19					Season 2019/20				
	FP	CFI	AFI_{Norm}	AFI_{Extend}	AFI_{Redu}	FP	CFI	AFI_{Norm}	AFI_{Extend}	AFI_{Redu}
1	43.1	36.9	21.5	24.7	17.8	46.9	40.4	24.2	27.6	20.3
2	50.9	43.3	24.7	27.7	15.8	54.9	47.2	27.6	30.7	18.2
3	57	48.5	27.3	27.9	18.7	61.6	52.6	30.3	31.0	21.3
4	57.9	49.3	27.7	28.2	21.5	62.6	53.3	30.7	31.3	24.2
5	58.7	49.9	27.9	31.3	24.7	63.3	54.1	31.0	34.5	27.6
6	59.2	50.3	28.2	28.2	27.3	63.8	54.5	31.3	31.3	30.3
7	59.3	50.4	28.2		27.7	63.9	54.6	31.3		30.7
8	66.6	56.5	31.3		27.9	71.6	61.0	34.5		31.0
9					28.2					31.3
10					28.2					31.3
11					31.3					34.5
Total	453	385	217	168	269	489	418	241	187	300.8
Mean of the two seasons	471	402	229	178	283					

Amount of water applied under alternate furrow irrigation also agrees with the conclusion that says that alternate furrow irrigation is commonly applied as part of a deficit irrigation program because it does not require the application of more than 50–70% of the water used in a conventional furrow irrigation method (Webber et al, 2006).

Yield (Green Cobs) and Stand count: At maturity stage of the crop numbers of cobs were counted for all plots and categorized to three groups (small, medium and large) based on the size of cobs. Based this, Number of cobs categorized as small , medium and large size were collected from each plot was significantly affected by the irrigation treatments and had the same trend in both seasons (Table 6).

The highest number of cobs 483 per plot (107333 per hectare) and 487 per plot(108222 per hectare)were recorded from AFI $_{Norm}$ for both seasons respectively followed by AFI $_{Redu}$ at Lelisa Dimtu Site. Numbers of cobs recorded from AFI $_{Norm}$ were higher than for CFI with 9111 to 9333 numbers per hectare in both seasons. Beside this, statistical analysis showed that stand count of maize had not affected by the application of different irrigation systems with different irrigation intervals ($p<0.05$). The lowest number of cobs per plant 438 per plot (97333 per hectare) and 441 per plot (98000 per hectare) were recorded from FP for both seasons respectively at Lelisa Dimtu site. Numbers of cobs AFI_{Extend} were higher than CFI for in both seasons. When comparing CFI and AF_{norm}, the latter increased number of green cobs by approximately 667/ha and 889 in the first and second seasons respectively.

Statistical analysis also showed significance influence ($p<0.005$) due to the adoption of both different furrow irrigation methods as well as irrigation intervals on weight of cobs per plot (Table 7). Highest weight of cobs per plot were recorded from AFI_{Norm}130.2kg per plot (28933 kgha^{-1}) and 135.3kg per plot (30067kgha^{-1}) for both seasons respectively at Lelisa Dimtu Site respectively. However, the lowest weight of cobs 93kg per plot (20689kgha^{-1}) and 97 kg per plot (21578kgha^{-1}) were recorded from FP for both seasons respectively.

Highly significant ($p<0.005$) difference was observed on number cobs per plot due to different irrigation methods with different irrigation intervals during both the study season at Wayu Tuka (Xaxo site) (Table 8). The higher number of cobs per plot 452 (100444 per hectare) and459 (102000 per hectare) were obtained from AFI_{Norm} and statistically superior to other irrigation method during both season. The lower number of cobs per plot 439 (97556 per hectare) and 446 (99111 per hectare) wereobserved from FP treatment during both season respectively. Application of Alternate furrow irrigation with normal irrigation interval (irrigation interval produced by CROPWAT Model) for maize improved number of cobs than convectional furrow irrigation and other irrigation methods. Beside this, statistical analysis showed that stand count of maize had not affected by the application of different irrigation systems with different irrigation intervals ($p<0.05$). On the other hand, statistically insignificant difference was observed between AFI_{norm} and $AFI_{extended}$ regardingin number of cobs during both seasons (Table 8).

This implied at Xaxo Site, under AFI_{norm} and $AFI_{extended}$ treatments similar green cob yield was observed with less amount of water applied for $AFI_{extended}$ during both seasons. When comparing CFI and AF_{norm}, the latter increased number of green cobs by approximately 1555/ha in the first and second seasons. This result shows the same trend as Abd El-Halim **[15]** reported Shifting irrigation practice from conventional irrigation (CFI) to alternate furrow increased corn yield to 8.9% (0.5 ton/ha).

The analysis of means and both season data also revealed that different irrigation methods with different irrigation interval on maize had a highly significant ($p<0.05$) influence on weight of cobs per plot (Table 9). Moreover, weight of cobs (green cob) of maize was significantly ($p<0.05$) affected by different types irrigation methods with different irrigation interval at Lega Xaxo site for both seasons. Maximum weight of cobs per plot 126 (28044kgha^{-1}) and 129 (28711kgha^{-1}) were observed from AFI_{Norm} treatment during both season respectively. The maximum weight of cobs obtained from AFI_{Norm} was statistically superior to both treatments which followed Alternate furrow irrigation condition. Moreover, the minimum weight of cobs per plot 89 (19822 kgha-1) and 93 (20711kgha-1) were obtained from FP treatment were statistically inferior to other treatments during both seasons respectively.

Water productivity (WP): Water productivity was significantly ($p<0.05$) influenced due to application of different irrigation method with different irrigation intervals at Diga (Lelisa Dimtu site) and Wayu Tuka (Xaxo site) for both seasons (Table 10). Results indicated that the water productivity of maize was higher under AFI_{norm} next to $AFI_{extended}$ treatment during both seasons as compared with conventional and other treatments. Maximum water productivity values were 3.42kg/m^3, 3.45 kg/m^3,3.55kg/m^3 and 3.30kg/m^3 observed from $AFI_{extended}$ and statistically superior to AFI_{norm} and other treatments for both seasons respectively. Statistically there was significant difference between Water productivity values of AFI_{norm} and $AFI_{extended}$ at both locations and seasons. However, there was no statistical difference between AFI_{norm} and $AFI_{reduced}$ on water productivity values for both location and seasons. This implies that more amount of water was applied under $AFI_{reduced}$ at both sites than AFI_{norm} produces similar water prodctity values. The minimum water Productivity values were 1.04kg/m^3, 1.05kg/m^3,1.03kg/m^3 and 1.05kg/m^3 s observed at both locations from FP respectively and this was statistically inferior to other treatments (Table 10).These results indicated that $AFI_{extended}$ and AFI_{norm} were appropriate to increase WP because they allow applying less irrigation water for maize production.

The high WP values for AFI could be due to the small amount of applied water for AFI as compared with the EFI treatment. Sepaskhah and Hosseini (2008) reported similar results. In addition, Nouri and Nasab (2011) concluded that the AFI system generally increases crop yield and WP. Clearly, WP depends on total applied water. This finding agrees with results obtained by Ibrahim and Emara (2010), who reported that an adverse relationship was found between the amount of applied irrigation water and WP.

Table.6. Average number of cobs (green cobs) under different irrigation treatments at Lelisa Dimtu during 2018/19 and 2019/20

Treatment	Diga (LelisaDimtu)									
	Season 2018/19					Season 2019/20				
	Stand count	Number of cobs per plot			Total number of cobs per ha	Stand count	Number of cobs per plot			Total number of cobs per ha
		small	Medium	Large			small	medium	Large	
FP	160.7a	65c	131.3c	241.7b	97333d	160.7a	65c	132.3c	243.7b	98000d
CFI	162.7a	65.7bc	132.7c	243.7b	98222d	162.7a	65.7c	133.7c	246.7b	98889d
AFI_{Norm}	164.7a	66.7a	146.3a	270a	107333a	164.7a	69.7a	148.3a	275a	108222a
AFI_{Extend}	163.7a	66.3ab	136b	248.7b	100222b	163.7a	67.3b	138b	250.7b	100889c
AFI_{Redu}	162.3a	66.0ab	137.3b	262.7a	103556b	162.3a	67.0b	137.3b	269.7a	104444b
CV	11.6	14.6	11.7	16.8	14.6	12.8	14.6	15.7	13.8	14.6
LSD	5.06	0.91	2.8	8	1867	5.06	1.5	2.8	8	1867

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Table 7. Average Weight cobs (green cobs) under different irrigation treatments at LelisaDimtu during 2018/19 and 2019/20

Treatment	**Diga (LelisaDimtu)**							
	Season 2018/19				Season 2019/20			
	Weight cobs per plot(kg)			Total Weight (kg/ha)	Weight cobs per plot (kg)			Total Weight (kg/ha)
	small	medium	large		small	medium	large	
FP	8.7b	12.1c	72.4c	20689d	3.1bc	17.3cd	76.7c	21578d
CFI	8.3b	17.5b	77.6b	22978c	2.7c	21.3bc	83.3b	23844c
AFI $_{Norm}$	6.0d	34.1a	90.1a	28933a	7.3a	33a	95a	30067a
AFI $_{Extend}$	7.4c	12.7c	80.6b	22378c	5.0abc	13.3d	86.1b	23200c
AFI $_{Redu}$	9.5a	21.8b	81.1b	24978b	6.0ab	26b	84.4b	25867b
CV	13.4	15.2	13.8	15.8	12.4	17.6	14.8	16.8
LSD	0.4	4.6	4.9	1422	2.9	5.9	5.9	1489

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Table 8. Average number of cobs (green cobs) under different irrigation treatments at Lega Xaxo during 2018/19 and 2019/20

Treatment	**WayuTuka (LegaXaxo)**									
	Season 2018/19					Season 2019/20				
	Stand count	Number of cobs per plot			Total number of cobs per ha	Stand count	Number of cobs per plot			Total number of cobs per ha
		small	Medium	large			small	medium	Large	
FP	160.7a	65.0c	132.3c	241.7c	97556c	165.7c	70.0c	138.3c	248.7c	99111c
CFI	161.3a	65.7bc	132.7c	243.3bc	98156c	166.3c	70.7bc	138.7c	250.3bc	99711c
AFI_{Norm}	164.7a	66.7a	136a	249.3a	100444a	169.7a	71.7a	142a	256.3a	102000a
AFI_{Exten}	1643.3a	66.3ab	135a	248a	99933a	1648.3ab	71.3ab	141a	255a	101489a
AFI_{Redu}	161.7a	66ab	133.7b	245b	98822b	166.7bc	71ab	139.7b	252b	100378b
CV	12.3	17.4	15.6	16	11.3	12.4	16.4	10.2	17.4	12.5
LSD	5.76	0.81	0.94	2.3	700	1.8	0.81	0.9	2.3	711

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Table 9. Average Weight cobs (green cobs) under different irrigation treatments at LegaXaxo during 2018/19 and 2019/20

WayuTuka (LegaXaxo)								
Season 2018/19					Season 2019/20			
Treatment	Weight cobs per plot			Total Weight (kg/ha)	Weight cobs per plot			Total Weight (kg/ha)
	small	medium	large		small	medium	large	
FP	8ab	13.2b	68d	19822d	8.8b	18.7c	65.7d	20711d
CFI	7.3ab	14.1b	78.3c	22156c	10.7ab	21bc	71.4c	22911c
AFI_{Norm}	7b	26.5a	92.7a	28044a	12.7a	31.2a	85.3a	28711a
AFI_{Exten}	7.4ab	14.53b	74.6c	21444c	10.7ab	21.1bc	68.5cd	22267c
AFI_{Redu}	9.5a	14.5b	84.4b	24089b	10.9ab	23.5b	78.1b	24978b
CV	13.6	14	12	10.7	15.4	13.5	10.5	12.3
LSD	2.2	3.9	4.9	1600	2.9	4.8	4.7	1200

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Table 10. Water Productivity of maize crop at Diga and Wayu Tuka sites of both seasons

Treatment	**Diga**		**WayuTuka**	
	Season 2018/19	Season 2019/20	Season 2018/19	Season 2019/20
	WP	WP	WP	WP
FP	1.04d	1.05d	1.03d	1.05d
CFI	1.60c	1.62c	1.69c	1.67c
AFI_{Norm}	2.84b	2.85b	2.46b	2.56b
AFI_{Exten}	3.42a	3.45a	3.55a	3.30a
AFI_{Redu}	2.30b	2.32b	2.09b	2.12b
LSD	0.6	0.6	0.6	0.5
CV	12.4	10.7	14.4	11.4

Note: FP; Farmer Practice, CFI; Convectional Furrow Irrigation, AFI_{Norm}; Alternate Furrow irrigation with normal irrigation Interval, AFI_{Exten}; Alternate furrow irrigation with extended irrigation interval, AFI_{Redu}; Alternate furrow irrigation with reduced irrigation interval, CV; Coefficient of Variance and LSD; least significant difference.

Conclusions

The effort of this study was to determine the effect of Alternate furrow irrigation with different irrigation interval on maize green cob production by comparing with farmer practice and convectional furrow irrigation. Beside this, maximum number of green cobs and green cob weight were obtained by applying Alternate furrow irrigation with normal irrigation interval throughout the growing season at both locations and during 2018/19 and 2019/20 growing seasons. Crop water productivity (WP) was highest for Alternate furrow irrigation with extended irrigation interval when comparing with Alternate furrow irrigation with normal irrigation interval and other treatments at both study area. Higher water productivity can be obtained by stressing maize crop by extending irrigation interval under alternate furrow irrigation. However, extending irrigation interval under Alternate furrow irrigation showed yield reduction when comparing with applying Alternate furrow irrigation with normal irrigation interval.

Alternate-furrow irrigation with appropriate normal irrigation interval (irrigation interval produced by CROPWAT software) can be used as an efficient method for maize n production during dry season when production depends heavily on irrigation. It could be concluded that Alternate-furrow irrigation with normal irrigation interval can improve crop water productivity without the risk of yield reduction. Generally in all parameters alternative furrow system with full irrigation application has shown the good mean results in contrasts to other treatments under normal irrigation water quality.

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