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RESEARCH ARTICLE

OPTIMIZATION OF IRRIGATION SCHEDULING AND NITROGEN RATE OF MAIZE TO IMPROVE YIELD AND WATER USE EFFICIENCY UNDER IRRIGATED AGRICULTURE

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ABSTRACT

A rapid growing of Ethiopian population and rising living standards are increasing the demands for agricultural products especially on food crops. Under this higher pressure over the available water resources of the country are increasing in irrigated agriculture. Higher agricultural productivity means inputs and water should be applied more efficiently. Therefore, understanding water and nitrogen redistribution in the soil profile is important to improve water and nitrogen use efficiency for sustainable agriculture. The aim of the study was to determine the optimal irrigation scheduling and fertilizer rate for better water use efficiency under irrigated agriculture. The effects of irrigation interval on maize yield and other crop properties were also assessed. The experiment was carried in the randomized completed block design experimental design with a combination of five levels of irrigation treatments and three levels of fertilizer rate with three replications of the treatments. The result revealed that the plot received an optimal irrigation interval of 14 days in a combination of 25% more than the recommended fertilizer rate (292.24kg/ha) had significantly higher effects on above-ground biomass (18.25 t /ha) and on grain yield (4.8 t/ha) of irrigated maize in the study area. However, the maximum water use efficiency of 2.05 kg/m3was obtained at the irrigation interval of 14 days, and the highest level of fertilizer rate. Hence, the use of 14 days of optimal irrigation interval and 25% more fertilizer than the recommended rate is advisable because the grain yield and crop water use efficiency had been improved in the study area. This optimization approaches will be worthwhile in farms with low water availability and input management, high profitability, and high economic capacity,

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INTRODUCTION

The rapid population growth worldwide in general and in developing countries in particular forces to increase food production and expansion of agricultural lands. To feed the entire nation, the enhancement of agricultural land alone will not satisfy the food demand without intensification of modern agricultural crop production techniques. However, for the intensification of agriculture, one of the main limiting factors is the temporal and spatial variation of rainfall distribution and amount of rainfall which supplies the moisture content of the soil during the entire cropping season when irrigation is not available. Nearly 40% of food and agricultural commodities are produced through irrigated agriculture on about only 17% of agricultural land (Moser, Feil, Jampatong, & Stamp, 2006). In contrary to the water need for irrigation of agricultural land for enhancing crop production, there is an increasing demand for limited water resource for municipality, industries and for natural resource rehabilitation. Ethiopia's economic growth is heavily dependent on the growth of the agricultural sector. Despite the importance of agriculture to the national economy and the favorable resource, the agricultural capacity and technology are far from the attainment of self-sufficiency in food production for rapidly increasing population and in meeting raw materials for industry. The country could not able to meet its large food-deficit through rain-fed farming. One of the most important considerations in increasing and stabilizing agricultural production is through irrigation development. Considering this fact and the potential water sources of the country, irrigation is of paramount importance to meet the national goal of food security, poverty reduction through increased agricultural production and productivity. Moreover, small-scale irrigation practices have an advantage in that they fit very well into resource poor farmers' circumstances. Increasing yields in both rain-fed and irrigated agriculture and cropping intensity in irrigated areas through various methods and technologies are therefore the most viable options for achieving food security (Chen, Wang, & Yu, 2010). The agriculture sector is facing increasing challenges in the face of changing climate, rapid population growth, increasing salinity accumulation, land degradation, decreasing availability of land, and competition for scarce water resources (Dubois, 2011). One of the most important considerations in increasing and stabilizing agricultural production is through irrigation and drainage development, reclamation of degraded lands, and wise use of water resources (Mintesinot, Verplancke, Van Ranst, & Mitiku, 2004; Seckler, 1998).

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The development of irrigation and agricultural water management holds significant potential to improve productivity and reduce vulnerability to climactic volatility in any country (Heydari, 2014). Although Ethiopia has abundant rainfall and water resources, its agricultural system does not yet fully benefit from the technologies of agricultural water management. Irrigation implies the application of suitable water to crops in sufficient amount at the suitable time (Molden *et al*., 2010). 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. Irrigation scheduling is the process of determining when to irrigate and how much irrigation water to apply (Ahmad, Wajid, Ahmad, Cheema, & Judge, 2019; Filintas *et al*., 2007; Guo, Gao, Tang, Liu, & Chu, 2015). The depth of irrigation water which can be given during one irrigation application is however limited. The maximum depth which can be given has to be determined and may be influenced by the soil type and the root zone depth. Thus, just after planting or sowing, the crop needs smaller and more frequent water applications than when it is fully developed. Hence, there is limited information on the water use efficiency, frequency and amount of water in production of irrigated maize. The objectives of this study is to evaluate the responses of crops to frequency and amount of irrigation with optimal rate of fertilizer application and also water use efficiency of irrigated maize production on vertisol of Pawe district, Metekel zone of Benishangul regional state.

MATERIALS AND METHODS

Experimental Site: The study was conducted in Pawe woreda of Metekel zone of Benishangul Regional State, North-West of Ethiopia. It is covering an area of 64,300.00 hectares. The topography of Pawe woreda mainly (74%) represents plain and having varying altitudes from 1000 - 1200 m a.s.l., latitude $11^0$10'00" to$11^0$30'00"and longitude $36^0$20’00" to $36^0$31'00". The mean annual rainfall of the area ranges from 1200-1500mm.

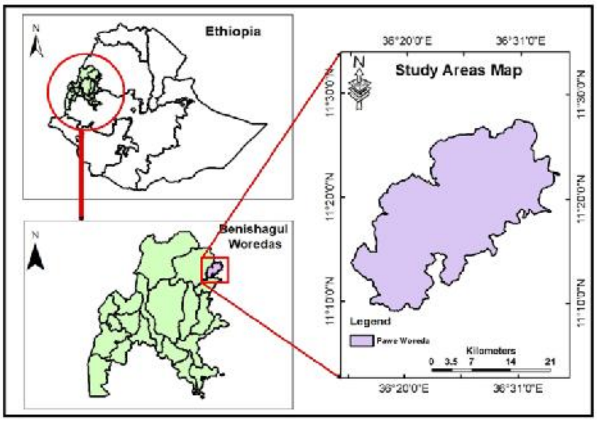


Figure 1. Location of the experimentation area

The area is fully characterized by Kolla (humid lowland) with annual minimum and maximum the temperature of 32°C and 42°C respectively (Metekel Zone, Department of Agriculture). The area contains many potential water resources, including Abat Beles, Gilgel Beles, and their tributaries, which include the following. Some of the potential irrigable water resources identified or found in the Pawe special district and its localities include: Abat Beles, Gilgel Beles, Chankur, Keteb, JigidaSilasse, Wagisho, Gite, BurjiWounz, MambukWounz, Anzobuka, Mugissa, Nur, GebeyaWounz, Bar,Chumbe, GeshoWounz, and Galessa. Not only these, but there are others that could be identified for their irrigation potentials.

Climatic Data: The daily mean maximum and minimum temperatures are 32.6 and 16.4°C, respectively. The monthly mean maximum temperature is between 34.9 °C during May and 33.7°C during December. The mean annual rainfall the in area was about 1570.4 mm and about 82 % of the rainfall occurs from June to September. The summary of the climatic variables as obtained from agro-meteorological observatory during the last 32 years in given in Table 1.

Reference evapotranspiration (ETo): The reference evapotranspiration ETo was calculated by FAO Penman-Monteith method, using decision support software CROPWAT8 developed by FAO, based on (Allen, Pereira, Raes, & Smith, 1998) and adopted the Penman-Monteith method as global standard to estimate ETo from meteorological data. The Penman-Monteith equation integrated into the CROPWAT program is expressed by the following equation.

$$ET_0 = \frac{0.408\ \Delta (Rn - G) + \gamma \frac{900}{T + 273} U2(es - ea)}{\Delta + \gamma(1 + 0.34u2)}$$ *Equation 1:*

Where: ET_0 is reference evapotranspiration (mm day^{-1}), T, G and Rn are daily mean temperature °C at 2 m height, soil heat flux density (MJ m^{-2} day^{-1}) and net radiation value at crop surface (MJ m^{-2} day^{-1}) respectively. Also, u2, $e_s e_a$, (es–ea), D and c represent wind speed at 2 m height (m s^{-1}), saturated vapour pressure at the given temperature (kPa), actual vapour pressure (kPa), saturation vapour pressure deficit (kPa), slope of the saturation vapour pressure curve (Pa/°C) and psychometric constant (kPa/°C), respectively (Allen *et al*., 1998). According to (Djaman, Irmak, Rathje, Martin, & Eisenhauer, 2013) being a significant part of the hydrological cycle, the ETo will have its important impacts on ecosystem models, water uses by agriculture, humidity/aridity conditions, and runoff due to precipitation estimation. The ETo was calculated using the FAO Penman-Monteith method which is one of the most precise equations and the CROPWAT8 model is based on this equation.

Soil data and characteristics: The soils of Pawe area are broadly categorized as vertisols which account for 40-45% of the area; Nitosols which account for about 25-30%; and intermediate soils of a blackish brown color, which accounts for 25-30%. The soil texture is mainly sandy clay loam. As a result the sandy types of the soil under the study areas influences permeability (Brady, Weil, & Weil, 2008) and soil moisture which was course textured having high permeability and less soil moisture especially for Pawe woreda as indicated under table 2 below. Therefore, it is recommended to use short irrigation water application interval to satisfy the crop water requirements for those selected major crops under the experimental sites.

Crop data and characteristics: Crop data for Maize crop characteristics used as input parameters are mainly length of the growth cycle, crop factors, rooting depth, critical depilation factor; the yield response factor for each growth stages specified in table 1 below.

Table 1. Summary of long term (1987 – 2018) climatic condition of Pawe

Month	RF (mm)	T (ºC)		RH (%)	WS (m/s)	SH (hrs.)	ETo (mm/day)
		Min	Max				
Jan	0.8	11.8	34.2	38.3	39.9	9.7	3.78
Feb	0.6	14.5	36.2	40.3	53.6	9.9	4.58
Mar	7.2	17.9	37.6	44.7	65.5	8.7	5.24
Apr	28.1	19.5	37.4	48.1	75.9	8.9	5.60
May	100.2	19.4	34.9	58.3	78.5	8.0	5.27
Jun	279.3	18.1	30.1	66.6	78.7	6.5	4.31
Jul	352.4	17.8	27.8	71.7	58.7	4.6	3.57
Aug	395.5	17.6	27.7	71.1	51.1	4.8	3.55
Sep	256	17.3	29.1	67.2	46.7	6.1	3.81
Oct	132.6	16.8	30.5	62.5	29.7	7.3	3.87
Nov	17.1	14.1	32.4	46.9	27.7	9.3	3.85
Dec	0.6	12.2	33.7	40.2	41.4	9.8	3.84
Mean	1570.4	16.4	32.6	54.7	53.9	7.7	4.27

Best fit Distribution				
Months	Actual	Rain season (20%)	Mid (50%)	Dry season (80%)
	Rainfall	Jun-Sept	Oct-Jan	Jan-Apr.
Jan.	0.8	1.2	0	0
Feb.	0.6	11.1	0	0
Mar.	7.2	26.9	0	0
Apr.	28.1	45.9	19.8	4.5
May	100.2	142	91.2	40.4
Jun.	279.3	351.1	272.5	206.7
Jul.	352.4	417.2	354.6	298.6
Aug.	395.5	474.4	384.4	309.1
Sep.	256	292.3	248.8	205.3
Oct.	132.6	197.4	125.4	79.7
Nov.	17.1	28	9.2	1.8
Dec.	0.6	2	0.7	0
Sum	1570.4	1989.5	1506.6	1146.1

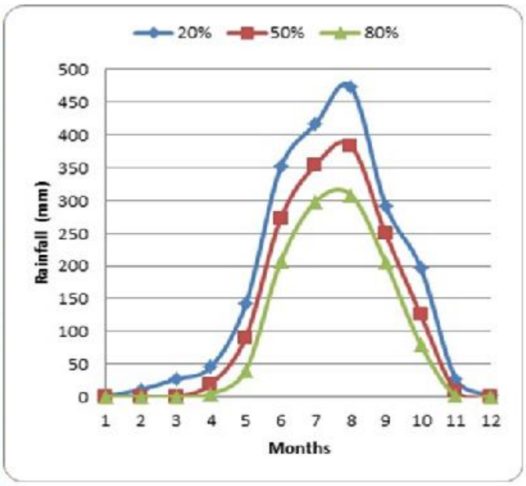


Figure 2. Probability of seasonal rain fall of Pawe

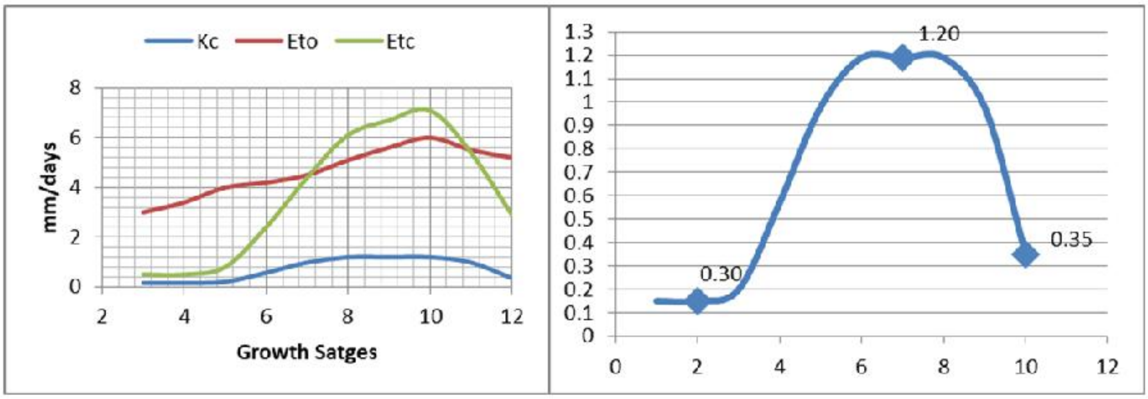
Table 2. Laboratory soil test report from DZARCof the study area

Depth of Profile	Texture %				pH, H2O 1:2.5	EC, 1:2.5 mS/cm	BD g/cm^3	FC (%)	PWP (%)	AW (mm/m)
	Sand (%)	Silt (%)	Clay (%)	Class						
0-15 cm	22	10	68	C	6.93	0.20	1.28	45.61	27.66	229.01
15-30 cm	14	18	68	C	6.53	0.13	1.12	36.80	25.11	131.09
30-60 cm	18	14	68	C	6.74	0.15	1.41	39.04	26.37	178.85
60-90 cm	24	12	64	C	6.88	0.12	1.39	39.90	26.94	179.63
90-120 cm	22	12	66	C	7.06	0.11	1.36	44.18	27.39	228.29

Table 3. Kc values, critical depletion and yield response factors for Maize

Kc and Yield Factors	Scientific name	Growing stages (day)			
		Initial season	Development	Mid-season	Late- season
Kc values	Zea mays L.	0.3	1.15	1.20	0.35
Critical depletion fraction.	Zea mays L.	55	55	55	0.8
Yield response fraction	Zea mays L.	0.4	0..4	1.3	0.5

Source: *FAO-56 (1998).*



Graph 1. Relationship of Reference Evapotranspiration (ETo), crop coefficient (Kc) and Crop water demand (ETc) (left) and average crop coefficient (right) with respect to growth stage

Table 4.The specific trial treatment combination

No	Treatment No.	Irrigation Interval	Urea (gm/plot)
1	T1	21days	R1 (R-25%)=215.21
2	T2	17 days	R1 (R-25%)=215.21
3	T3	14 days	R1 (R-25%)=215.21
4	T4	11 days	R1 (R-25%)=215.21
5	T5	7 days	R1 (R-25%)=215.21
6	T6	21 days	R2 (R)=286.95
7	T7	17 days	R2 (R)=286.95
8	T8	14 days	R2 (R)=286.95
9	T9	11 days	R2 (R)=286.95
10	T10	7 days	R2 (R)=286.95
11	T11	21 days	R3 (R+25%)=358.69
12	T12	17 days	R3 (R+25%)=358.69
13	T13	14 days	R3 (R+25%)=358.69
14	T14	11 days	R3 (R+25%)=358.69
15	T15	7 days	R3 (R+25%)=358.69

Table 5.The specific trial field layout

Fertilizer Rate	Irrigation Treatments (Days of irrigation interval)				
R1	1	2	3	4	5
R2	6	7	8	9	10
R3	11	12	13	14	15

Determination of irrigation requirement and irrigation scheduling: Several approaches could be used to determine optimal irrigation regimes. In this study, an optimal irrigation schedule was worked out using CropWat for windows that permit to select the different irrigation scheduling criteria. The computation method used was irrigation to be given at fixed intervals per growth stage with a depth of irrigation that would refill the root zone to its field capacity. Irrigation Requirement (IR) computation of IR requires long-term rainfall data from study sites. The values obtained were used during the computation of CWR. Generally, IR can be estimated from the expression in equation 2.

$$CWR = \frac{E}{K} \quad \text{Equation 2.}$$

$$IR = CWR - \text{ Effective rainfall} \quad \text{Equation 3.}$$

RFef (mm) = 0.6 * RF (mm) – 10 for RF< 70 mm Equation 4.

RFef (mm) = 0.8 * RF (mm) – 24for RF >70 mm Equation 5

Where; CWR is crop water requirement in mm, Kc is crop coefficient; IR is irrigation requirement in mm, and RF_{ef} effective rainfall in mm. RF is actual monthly rainfall and the equations represent combined effect of dependable rainfall (80% probability of exceedance) and estimated losses due to Runoff (RO) and Deep Percolation (DP). The p-value was assumed 0.55 as given in Allen *et al*. (1998) for cereal crops and TAW is computed from the soil moisture content at field capacity (FC) and permanent wilting point (PWP) using the following expression: Considering the daily CWR, TAW, Dz, and p, the irrigation interval was computed from the expression equation 5. The optimal irrigation schedule was worked out using CROPWAT 8.0 for windows and assumed the irrigation regime applied at 100 % readily available soil moisture. The RAW is the amount of water that crops can extract from the root zone without experiencing any water stress. The RAW was computed from the expression in equation 6.

$$TAW = \frac{(F \ -P \ )}{1} * BD * Dz \quad \text{Equation 6.}$$

$$RAW = p * RAW \quad \text{Equation 7.}$$

Where; FC and PWP in % on weight basis, BD is the bulk density of the soil in gm cm^{-3}, and Dz is the maximum effective root zone depth in mm. RAW in mm, p is soil water depletion fraction for no stress in fraction and TAW is the total available soil water of the root zone in mm per root depth.

$$\text{Interval (Days)} = \frac{R}{C} \quad \text{Equation 8.}$$

$$IRg = \frac{I \ * C}{E} \quad \text{Equation 9.}$$

Where; RAW in mm and CWR in mm day^{-1}, IRgis gross irrigation requirement in mm, interval in days and Ea is the Irrigation water application efficiency as fraction. Field application efficiency in this study was assumed as 60%.

Layouts and Experimental Design: The trial was carried out in completely randomized plot design, compromising fifteen treatments with three replicates. Each plot was 5m long and 4m wide, with an area of $20m^2$. The following treatments were used (Table 4): t in this area for the continuous two years having the experimental treatments of RCBD with three replications. The following treatments were used (Table 4/5): R1 (R-25%) recommended fertilizer minus 25% combined with (to 21days of irrigation interval; (2) 17 days of irrigation interval; (3) 14 days of irrigation interval; (4) 11days of irrigation interval; (5) to 7 days of irrigation interval. R2 (R) recommended fertilizer combined with (1) 21days of irrigation interval; (2) 17 days of irrigation interval; (3)14 days of irrigation interval; (4) 11days of irrigation interval; (5) 7 days of irrigation interval. R3 (R+25%) recommended fertilizer plus 25% is combined with (1) 21days of irrigation interval; (2) 17 days of irrigation interval; (3) 14 days of irrigation interval; (4) 11days of irrigation interval; (5) 7 days of irrigation interval. Irrigation schedule, when to irrigate, and how much water to apply per irrigation, is one of the most important tools for the best management of irrigated agriculture.

Optimal irrigation regime results in high irrigation water use efficiency that is necessary to conserve limited water resources. In this study, the optimal irrigation schedule is worked out using CropWat windows for computing the optimal irrigation scheduling for no yield reduction is the irrigation given at 100 % readily available soil moisture depletion to refill the soil to its field capacity.

Field management practices: Maize (Zea mays L.) was sown during January in the experimental sit. A row spacing of 0.75m and plant spacing of 0.30 m were used. Maize plots were fertilized with 46kg/ha, P as DAP and 23kg/ha, N as Urea at sowing and 23kg/ha, N was applied as Urea when maize plant reached knee height. Furrow irrigation method was used, and the amount of water applied was measured using 3 inch Parshall flume. Crop water requirement was calculated using the CROPWAT program based on the FAO Penman-Monteith method and based on the soil moisture depletion level irrigation scheduling was done as per the five soil moisture depletion levels and rate fertilizer application was also done based on three rate of fertilizer application. The soil water level was monitored by using the gravimetric soil moisture content determination method. All other agronomic practices were kept normal and uniform for all the treatments including pre-irrigation and irrigation after germination as establishment irrigations. In a crop production systems, water productivity (WP) is used to define the relationship between crops produced and the amount of water involved in crop production, expressed as crop production per unit volume of water (Molden *et al*., 2010). Water productivity (WP) in this study was determined by dividing the grain yield to the net amount of irrigation water used by the crop as indicated by the following equation (Heydari, 2014):

$$\mathrm{WUE} = \mathrm{GY}/\mathrm{I} \qquad \text{Equation 10.}$$

Where: WUE is water use efficiency (kg/m^3), GY is grain yield per unit area (kg/h) (De Feudis, D'Amato, Businelli, & Guiducci, 2019; Fang & Su, 2019)a), I is net water applied to produce the grain during the growing period (m^3/ha).

Data analysis: The two years over year yield and yield component data were subjected to the ANOVA test using SAS software to evaluate the overall variability and effects of yield and yield component parameters were considered as significant when $p< 0.05$. The Least Significant Difference (LSD) test was applied for statistically significant parameters to compare means among the treatments.

RESULTS AND DISCUSSIONS

Biomass yield: Different irrigation intervals had a significant influence ($p<0.05$) on maize biomass production. It has been observed that the increment of the irrigation interval of water application was significantly affected above-ground biomass of irrigated maize at the experimental areas. Maximum biomass yield of 19.20t/ha and 17.30t/ha were obtained in the first and second cropping season with increasing fertilizer rate by 25% than recommended, respectively. The above biomass harvested for the treatment T13, T14, and T8 were statistically the same during both growing seasons (Table 6). However, during the first year minimum above-ground biomass of 11.73t/ha was observed from the combination of wider irrigation interval and25 % lower fertilizer than recommended. Whereas in the second year minimum above-ground biomass of 10.53t/ha, 11.25t/ha & 11.95t/ha was harvested from treatment T1.T2, and T6 respectively. Generally, it has been observed that the mean above-ground biomass of the first year was 16.24t/ha and that of second year 14.64t/ha. The trend of biomass production shows decreasing with increasing the interval of irrigation events and increasing fertilizer rate to 25% more than the recommended. This is in agreement with former reports of (De Feudis *et al*., 2019) on maize. The over year combined mean analysis showed that there is high interaction of irrigation interval and fertilizer rate and the maximum above-ground biomass of 18.25t/ha (T13) though treatments T14, T8, T9, T10, and T15 were statistically the same during combined analysis's and the minimum biomass were 11.13t/ha for T1. The mean above-ground biomass was 15.44t/ha and that of second-year 14.64t/ha.(Badr, Tawfik, & Thalooth, 2005; Gheysari, Mirlatifi, Homaee, Asadi, & Hoogenboom, 2009) stated that nutrient uptake is closely linked to water soil status. It is expected that the decline in available soil moisture might decrease the diffusion rate of nutrients from soil matrix to roots. Evidence of decreased ion uptake due to water stress was attributed to the reduction in the above ground biomass of maize.

Grain yield: The result revealed that the irrigation interval and fertilizer rate significantly affected crop yield parameters (table 5 & 6). There is a significant difference ($p<0.05$) among the treatments of irrigation interval and fertilizer rate on yield and yield components of irrigated maize in the experimental area. During first season, the maximum grain yield (4.54 t/ha) and (4.50 t/ha) was recorded by the T13and T14treatmentwhereas the lowest number of grains yield was observed in the T1. Nitrogen rates significantly increased the grains of maize at different rates. Therefore, the highest yield increment was observed when the application rate of fertilizer increased by 25% with the combination of optimal irrigation interval of 14 days.

The minimum grain yield of 2.3 t/ha and 2.5 t/ha was recorded during the first and second year both at treatment one and also during the second year with 2.7 t/ha for T2 without any statistical significance. However, the over year analysis of the grain yield was maximum (4.8 t/ha) for treatment 15 (table 6) which used an optimal interval of irrigation events with a combination 25% more fertilizer than the recommended and the minimum (2.4 t/ha) for treatment one of irrigation water application of wider interval with the combination of minimum dosage of fertilizer rate this is supported by (Tefera & Mitku, 2017). There was a consistent result that shows, the higher grain yield was directly associated with the lower irrigation interval applied during treatments in both seasons and this result is supported by (Wang *et al*., 2010).Besides the former report by (Fang & Su, 2019; Farhad *et al*., 2018) also shows the minimum grain yield was obtained by applying water at the lowest frequency during higher water demand by the plant.

Water Use Efficiency (WUE): It has been reported by many scholars that managing maize irrigation at the field scale can be improved by quantifying the water balance and using advanced techniques for irrigation scheduling for more effective and economic use of limited water supplies. Irrigation interval and fertilizer rate had a significant ($p<0.05$) influence water use efficiency of irrigated maize during both years. Water use efficiency was higher 1.89 and 1.98kg/m^3 for T13 and T14 respectively in the first season with no statistical difference but in the second season maximum WUE of 2.20 kg/m^3 was obtained at T13 of which received an optimal irrigation interval and 25% more than the recommended fertilizer rate.

Table 6.Maize response to the irrigation interval & fertilizer rate under two successive year of field evaluation

No	Treatments	1st year			2nd year		
		BMY (t/ha)	GY (t/ha)	WUE (kg/m^3)	BMY (t/ha)	GY (t/ha)	WUE (kg/m^3)
1	T1	11.73^{e}	2.25^{h}	1.13^{h}	10.53^{f}	2.47^{e}	1.24^{g}
2	T2	15.86^{c}	2.49^{hg}	1.57^{ef}	1125^{f}	2.72^{e}	1.47^{efg}
3	T3	12.50^{de}	2.68^{hg}	1.34^{gh}	12.32^{def}	2.95^{de}	1.47^{efg}
4	T4	13.71^{d}	2.75^{fg}	1.45^{fg}	12.07^{ef}	3.03^{de}	1.50^{def}
5	T5	13.45^{d}	3.20^{def}	1.33^{gh}	14.03^{bcd}	3.52^{cd}	1.72^{cde}
6	T6	13.27^{de}	2.42^{hg}	1.22^{h}	11.95^{f}	2.66^{e}	1.35^{fg}
7	T7	17.95^{ab}	2.79^{fg}	1.65^{cdef}	16.16^{abc}	3.63^{cd}	1.81^{bcde}
8	T8	19.21^{a}	3.98^{b}	1.83^{abc}	17.12^{a}	4.37^{ab}	2.02^{abc}
9	T9	18.18^{ab}	3.68^{bc}	1.83^{abcd}	16.78^{ab}	4.05^{cd}	2.01^{abc}
10	T10	18.63^{a}	3.24^{cde}	1.64^{cdef}	16.38^{abc}	3.52^{cd}	1.82^{bcd}
11	T11	15.89^{c}	2.84^{efg}	1.62^{cdef}	14.30^{cde}	3.12^{de}	1.79^{bcde}
12	T12	17.04^{bc}	3.30^{cd}	1.76^{bcde}	16.16^{abc}	3.56^{cd}	1.78^{bcde}
13	T13	19.20^{a}	4.54^{a}	1.89^{a}	17.30^{a}	4.95^{a}	2.20^{a}
14	T14	19.03^{a}	4.50^{a}	1.98^{a}	17.28^{a}	4.50^{a}	2.07^{ab}
15	T15	17.95^{ab}	3.19^{def}	1.61^{edf}	15.34^{abc}	3.06^{de}	1.95^{abc}
Mean		16.24	3.19	1.59	14.64	3.51	1.75
R^2		0.92	0.91	0.86	0.84	0.85	0.74
$LSD_{0.05}$		1.54	0.45	0.21	2.33	0.69	0.34
CV (%)		5.79	8.44	8.03	9.51	11.67	11.65

N.B: BMY is above ground biomass yield, GY is a grain yield, and WUE is water use efficiency.

Table 7. The over year combined analysis of maize to the irrigation interval & fertilizer rate

No	Treatments	Pooled analysis of consecutive years		
		BMY(t/ha)	GY(t/ha)	WUE(kg/m^3)
1	T1	11.13^{e}	2.36^{f}	1.18^{f}
2	T2	13.55^{cd}	2.61^{ef}	1.51^{de}
3	T3	12.41^{de}	2.82^{ef}	1.41^{ef}
4	T4	12.89^{de}	2.89^{de}	1.52^{de}
5	T5	14.05^{cd}	3.36^{cbd}	1.53^{de}
6	T6	12.61^{de}	2.54^{ef}	1.28^{f}
7	T7	16.65^{ab}	3.37^{bcd}	1.74^{cd}
8	T8	18.16^{a}	3.77^{b}	1.86^{abc}
9	T9	17.51^{a}	3.78^{b}	1.83^{abc}
10	T10	17.04^{a}	3.42^{bc}	1.82^{bc}
11	T11	15.10^{bc}	2.98^{cde}	1.71^{cd}
12	T12	16.60^{ab}	3.38^{bcd}	1.82^{bc}
13	T13	18.25^{a}	4.77^{a}	2.05^{a}
14	T14	18.17^{a}	4.73^{a}	2.03^{ab}
15	T15	17.48^{a}	3.47^{bc}	1.81^{bc}
Mean		15.44	3.35	1.67
R^2		0.73	0.75	0.67
$LSD_{0.05}$		1.85	0.51	0.22
CV (%)		10.42	13.33	11.65

N.B: BMY is above ground biomass yield, GY is a grain yield, and WUE is water use efficiency.

kg/m^3 was obtained at T13 of which received an optimal irrigation interval and 25% more than the recommended fertilizer rate. The minimum water-use efficiency was recorded at T1 (1.13 kg/m^3) and T6 (1.22 kg/m^3) during the first season without statistical difference between two treatments and T1 (1.24 kg/m^3) during the second season. The study revealed that the pooled mean of WUE of maize was maximum (2.05 kg/m^3) when the irrigation interval of 14 days and maximum fertilizer dose applied.

However, when the irrigation interval increased and combined with 25% less than the recommended fertilizer was applied, WUE was affected highly scoring only 1.18 kg/m^3. Generally higher water use efficiency was associated with shorter irrigation interval and more fertilizer than recommended to enhance water productivity. This is in agreement with former reports (Tefera & Mitku, 2017; Zwart, Bastiaanssen, de Fraiture, & Molden, 2010) on maize production. Hence water use efficiency was improved with the highest grain yield obtained due to treatments in which an irrigation interval (14 days) combined with 25% more fertilizer than recommended applied for the experimental area.

Conclusions and recommendation

The results of this study revealed that shorter irrigation interval with the integration of higher fertilizer rate improves the yield and water use efficiency of irrigated maize on vertisol conditions of the study area. The result obtained from this experimental study on yield and yield component and as well as WUE showed a significant influence among the treatments. The highest grain yield (4.77 t/ha) and water use efficiency (2.05 kg/m^3) was obtained from at optimal irrigation frequency or irrigation interval (14 days) with combinations of 25% more fertilizer rate application than the recommended one. Moreover, to enhance the water use efficiency in maize production without affecting the grain yield, maize can be irrigated at 14 days irrigation intervals in the study area. It is understood that managing with different irrigation interval sat different fertilizer levels has highly influenced the production and water use efficiency of maize. In addition, the use of frequent and wider irrigation interval is n't advisable because the grain yield and crop water use efficiency is highly influenced.

This study also revealed that the appropriate irrigation interval at each crop growth stage should be identified in the area for ease of work to the users.

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