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Effect of Different Irrigation Schedules Intervals on Yield and Water Productivity of Wheat at Ketar Genat Irrigation Scheme

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ABSTRACT

This study conducted at Ketar Genat irrigation scheme to determine different irrigation interval on water use and yield of wheat. The treatments considered for the experiments were three irrigation intervals of crop water requirement (CWR+2day, CWR+3day and CWR-1day) with CWR as control. From the four treatments used the maximum irrigation water applied were at CWR-1day (365.75mm). The minimum Seasonal water applied were CWR+3day (277.17mm). The maximum grain yield was obtained at CWR-1day (5.37 t/ha) was not statically significant different CWR (5.23 t/ha) and CWR+2day (5.01 t/ha) at ($p<0.05$). The optimum water productively was obtained at CWR+2day (1.69 kg/m³) that not significant different with CWR+3day (1.61 kg/m³) but significant different with the other treatment. Maximum Seasonal depths of irrigation water saved were 70.48 and 50.65mm at CWR+3day and CWR+2day respectively. The maximum additional areas irrigated were 0.16 and 0.12 ha at CWR+3day and CWR+2day respectively. The maximum additional yield from water saved were 0.72 and 0.58 t/ha at CWR+3day and CWR+2day respectively. The maximum total yield that takes rank from 1to3 among treatment were 5.59, 5.23 and 5.17 t/ha at CWR+2day, CWR and CWR+3day respectively. Therefore, it recommended using CWR+2day irrigation interval at Ketar Genat irrigation scheme for wheat producer.

Keyword: Biomass; Crop Water Requirement (CWR); Day; Irrigation-Intervals; Irrigation-Schedules; Plant Height; Scheme; Spike Length; Treatment; Wheat; Water-Productively and Yield.

1.0. Introduction

Wheat is the most important food security crop at the global level with a production of 750 million tons (MT) on about 220 million hectares (Mha) in 2017. Africa produces more than 25 million tons of wheat on 10 Mha. Sub-Sahara Africa (SSA) produced a total of 7.5 MT on a total area of 2.9 Mha accounting for 40 and 1.4 per cent of the wheat production in Africa and at global levels, respectively (Tadesse *et al.*, 2019). The most important wheat producing countries in Sub-Sahara Africa (SSA) are Ethiopia, South Africa, Sudan, Kenya, Tanzania, Nigeria, Zimbabwe and Zambia in descending order. Ethiopia accounts for the largest production (0.5 Mha) area followed by South Africa (1.7 Mha) (Tadesse *et al.*, 2019). About 1.8 million hectares (ha) of land areas are covered by wheat production with an estimated annual production of 50 million quintals at an average productivity of 28 quintals/ ha, which has been improving constantly over the past 25 years but remains lower than the world average of 33 quintals/ha (Anteneh and Asrat, 2020).

It has been reviewed that wheat is the most important staple crop and widely cultivating in most highlands of the northern, central and south-eastern parts of the country (Gete *et al*., 2025). Under rainfed though the country has an estimated 3.8 million hectares of irrigable land. Although the potential benefits of irrigation are great, the actual achievement in many irrigable areas of the country is substantially less than its potential that is only almost 5% of the irrigable land is currently irrigated and less than 3% of households having access to irrigation. The national irrigated lowland wheat research and development program identified that the national wheat productivity could be progressed from 30 quintals to 50 quintals per hectare concluding that the irrigated wheat production is a very promising farming system. Thus, it has been reviewed that the confidence of small-hold farmers and commercial farmers in the irrigated wheat production needs to be increased with the increased roles of researchers in the development of irrigated wheat technologies (Muchie, 2022)

The average of wheat production, area coverage and its productivity have shown increasing rate in country. This makes Ethiopia as one of the largest wheat producers in sub-Saharan African countries. Even if wheat shows an increasing trend in production and productivity domestically, still Ethiopian wheat yield is relatively small by global standards. One of main reason is production was dependent on rain (Anteneh and Asrat, 2020; Effa et al., 2025). Despite increasing wheat production trend in the country, the demand for it has been continuously increasing, and still falls short of satisfying the annual need of the country. The demand for wheat is growing at an average rate of 9% annually, while the local production is growing only at a rate of 7.8%. The increasing population size, changing food preference, low wheat production yield due to climate change and its related negative consequences are factors attributing to the demand and supply gap. To develop the wheat sector at the required level, Ethiopia has a number of irrigable rivers which are suitable for large-scale production. Therefore, designing appropriate policy which motivates large-scale farming industries for wheat production and expanding irrigable land are the benchmark to bring satisfactory productivity of wheat which make Ethiopia a competitor to other African wheat-producing countries (Anteneh and Asrat, 2020). Therefore, to minimize the imbalance between supply and demand for wheat, the government is heavily expanding irrigated wheat cultivation throughout the country as this enables to yield more harvest compared to the rainy fed cultivation (Effa et al., 2025).

The irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation. Proper irrigation scheduling is essential for the efficient use of water, energy and other production inputs (Khan et al., 2007, Aziz et al., 2024) . In many developing countries like Ethiopia, water application intervals are mutually agreed upon and fixed among growers (Gebeyhu et al., 2024). However, this method does not consider how and when to apply which resulting to increasing salinity at some place and water shortage at other. Therefore, control the drawback of over irrigation, water logging and under irrigation, this study was conducted with the following objective.

1.1. Objective of research

1) To determine different irrigation interval on wheat yield.
2) To identify irrigation interval on water productivity of wheat at Ketar Genat irrigation scheme.
3) To recommend best yield gain and water saving irrigation interval for Ketar Genat irrigation scheme water use associations.

2.0. Materials and Methods

2.1. Description of the Study Area

This study was conducted at Arsi Zone, Tiyo worada of Ketar Genat Irrigation scheme. Ketar-Genet is located approximately 214 km from Addis Ababa, the capital of Ethiopia, and 39 km from Asella town. It is situated between latitudes 7050’30”N and 70 51’0”N and longitudes 3901’0’’E and 390 2’0’’E (Gemeda et al., 2024).

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2.2. Experimental design and treatments

The crop used was wheat and the experiment arranged in Randomized Complete Block Design (RCBD) with three replications. The treatments considered for the experiments were three irrigation intervals (CWR+2day, CWR+3day and CWR-1day) with CWR irrigation interval as control. The experiment was conducted on plot size of 5 m x 5 m (25 m^2) totally 12 number of such plot. The spacing between the blocks and plots kept as 1 m and 0.75m respectively.

2.3. Data collection

2.3.1. Soil Data

For soil texture, organic matter, pH and EC, disturbed soil samples were used and undisturbed soil for bulk density, moisture content at field capacity (FC) and permanent wilting point (PWP). Undisturbed soil samples were collected by core sampler and disturbed by auger from four depths 0-25cm, 25-50cm, 50-75 cm and 75-100cm at three points diagonally of the experimental sites and were taken to laboratory for analysis. The soil bulk density of soil was analysed after oven drying the samples for 24 hours at 105°C and weighed for calculating dry density as given by Michael, (2008)

$$\rho_b = \frac{M_s}{V_t} \qquad (1)$$

Where: ρ_b = soil bulk density (gm/cm^3) M_s=mass of dry soil (gm) and V_t=total volume of soil in the core sampler (cm^3)

Soil pH was determined by using water suspension with soil to water ratio 1:2.5 by PH meter. EC were determined by method of water suspension with soil to water ratio 1:2.5 by electro conductivity meter. The soil moisture content at field capacity (FC) and permanent wilting point (PWP) were determined after soil samples were saturated for one day (24 hrs) using the pressure plate apparatus. Field capacity was determined by exerting a pressure of 0.33 bars and permanent wilting point were determined by exerting a pressure of 15 bars. The TAW calculated as stated Allen *et al*., (1998)

$$TAW = \frac{(FC - PWP)}{100} * BD * D \qquad (2)$$

Where: *TAW* = total available water (mm)

FC = field capacity (% by weight)

PWP = permanent wilting point (% by weight)

D = depth of root zone (mm)

BD = specific density of soil

The RAW were computed from the expression:

RAW = TAW * MAD (3)

2.3.2. Climatic data

The minimum and maximum temperature, relative humidity, wind speed and daily sunshine hour 30 years of the study area were collected from National Meteorological Agency to determine mean daily reference evapotranspiration (ETo).

2.3.3. Crop Water Requirement and Irrigation Water Requirement

CROPWAT version-8 were used to calculate the reference evapotranspiration (ET_o) of the study area.

$$ET_c = ET_o \times K_c \quad (4)$$

Where: ET_c = crop evapotranspiration (mm/day)

ET_o = reference crop evapotranspiration (mm/day)

K_c = crop coefficient

Total irrigation water requirement for the crop were calculated using net-irrigation requirement of the crop, irrigated areas and irrigation efficiency. Irrigation interval was calculated as;

$$I = \frac{d_{net}}{ET_c} \quad (5)$$

Where, I = irrigation interval (days)

D_{net}=net-depth of irrigation (mm)

ET_c=daily crop evapotranspiration (mm/day)

The moisture deficit (d) in the effective root-zone is found out by determining contents at the field capacity and bulk densities of each layer of the soil (Mishra and Ahmed, 1990).

$$d = \sum_{i=1}^{n} \frac{(FC_i - PWP_i)}{100} * \gamma_i * D_i * P \quad (6)$$

Where: FC_i= field capacity of the irrigation water layer on oven dry weight basis (%)

PWP_i=actual moisture content of the water layer on oven dry weight basis (%)

γ_i =apparent specific gravity of the soil of irrigation layer

D_i=depth of the irrigation layer (mm)

P= depletion fraction (%)

n= number of layers in the root zone

2.3.4. Discharge measurements at field

The flow of water into the experimental flow were measured using 3" (3 inch) size parshall flume to be installed at its entrance. Discharge measurement was taken at two-third of length of converging section. Then the flow depth observed on the flume were converted to the corresponding discharge using equation (7) for 3" size parshall flume. Then the total volume of water applied (V_a) were calculated using equation (8) as stated (James, 1988) and the total depth of applied water were calculated based on the representative plot.

$$Q = C_f (KH)^{n_f} \quad (7)$$

$$Q = 0.1771 H^{1.550} \quad (8)$$

$$V_a = Q * \Delta t \quad (9)$$

Where: Q= discharge through the flume (l/s)

C_f= discharge coefficient from rated tables

K = unit constant (K= 3.28 for H in m)

n_f =flow exponent from the tables

V_a = total volume of water applied (m^3)

Δt =flow time to the field

2.3.5 Yield and yield Component

Wheat yield and yield components data were collected from one-meter square area of each plot. Data on the following yield components like: Number of tillers per plant; Number of grains per spike; Grain weight per spike and Grain yield in kg/ ha were collected.

2.4 Water productivity

The water utilization by crop is generally described in terms of water use efficiency (kg/ha, kg/m3 or q/ha) (Michael, 1997). Water use efficiency (WUE) and irrigation water use efficiency (IWUE) were determined by dividing the yield to seasonal ET and total seasonal irrigation water (IW) applied (Tanner and Sinclair, 1983).

$$WUE = \frac{Y_a}{ET_c} \quad (10)$$

Where: WUE = water use efficiency (kg/m^3)

Y_a = is actual yield (kg/m^2)

ET_c = seasonal crop evapotranspiration (m^3/m^2)

$$IWUE = \frac{Y_a}{IW} \quad (11)$$

Where, IWUE- irrigation water use efficiency (kg/m^3)

Ya - actual yield (kg/m^2)

IW - irrigation water applied (m^3/m^2)

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2.5 Statistical Analysis

The collected data were statistically analyzed using statistix version 8.0 software. Mean comparisons was executed using least significant difference (LSD) at 5% probability level when treatments show significant difference to compare difference among treatments mean

3.0. Result and Discussion

3.1. Physico-Chemical Properties of Soil

Table 1 below shows the physico-chemical property of the study area. From this average soil pH,EC and OM values were 5.52, 0.17 EC mmhos/cm and 3.48%. Soil texture class of study area was clay loam. According to Classes of salinity and EC (1 dS/m = 1 mmhos/cm; as adapted from Rhoades (2012), soil which has electrical conductivity 0<2 mmhos.cm is non-saline soil.

Table 1. Soil Physico-Chemical properties

Soil parameters	Schemes soil characters
Texture	CL
pH	6.52
EC mmhos/cm at 25^0c	0.17
% C	2.02
OM (%)	3.48
Bulk density (g/cm^3)	1.80
FC (% Vol)	31
PWP (%Vol)	13
TAW (mm/m)	324

CL=Clay loam C= Caly

3.2. Depth of irrigation water applied

The maximum irrigation water applied was at treatment of CWR-1day (365.75mm). The minimum Seasonal water applied were CWR+3day (277.17mm). The result agrees with the finding of Aziz et al., (2024) as extending irrigation interval save more water. Irrigation schedule can to save water by low reduction of crop yield (Ahmed *et al.*, 2021).

Table 2. Depth of irrigation water applied

Treatment	Seasonal irrigation water applied (mm)	Seasonal irrigation water applied per hectare (m^3/ha)
CWR-1day	365.75	3657.50
CWR	347.65	3476.50
CWR+2day	297.00	2970.00
CWR+3day	277.17	2771.67

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CWR= Crop water requirement

3.3. Yield and water productivity

From table 3 plant height at all treatment were not significant different at ($p<0.05$). The maximum number of tiller was at treatment of CWR-1day (8.50) and minimum at CWR (8.44). The maximum number of seed per spikes was at CWR (53.57) that significant different with CWR+2day and CWR+3day but not significant different with CWR-1day. The maximum grain yield was obtained at CWR-1day (5.37 t/ha) was not statically significant different CWR (5.23 t/ha) and CWR+2day (5.01 t/ha) at ($p<0.05$) however, significant different with CWR+3day. The minimum yield was obtained at CWR+3day. The optimum water productively was obtained at CWR+2day (1.69 kgm^{-3}) that not significant different with CWR+3day (1.61 kgm-3) but the optimum water productivity was significant different with the other treatment. The result concedes with the finding of Gedifew (2022) increasing interval at some extent, increase water productivity and slightly decrease yield.

Table 3. Yield and yield component of wheat.

Treatment	PH (cm)	NT	SL	S/S	BM (t ha-1)	GY (t ha-1)	WP (kgm-3)
CWR-1day	87.07^{a}	8.50^{a}	6.75^{a}	50.45^{ab}	18.00^{a}	5.37^{a}	1.47^{c}
CWR	87.64^{a}	8.44^{a}	6.74^{a}	53.57^{a}	17.70^{a}	5.23^{a}	1.50^{bc}
CWR+2day	86.38^{a}	8.14^{ab}	6.19^{ab}	45.67^{bc}	18.10^{a}	5.01^{ab}	1.69^{a}
CWR+3day	83.90^{a}	7.78b	6.02^{b}	42.93^{c}	17.70^{a}	4.45^{c}	1.61^{ab}
S.Em±	1.82	0.23	0.25	2.31	0.70	0.18	0.06
CV	2.58	3.40	4.70	5.79	4.79	4.35	4.66
LSD (5 %)	4.20	0.53	0.57	5.32	0.16	0.41	0.13

CWR= Crop water requirement, PH (cm)=Plant height, NT = number of tillers SL=Spike length S/S= Number of seed per spikes and BY=Biomass yield and GY=Grain yield WP= Water productivity

3.4. Relative yield reduction and additional area irrigated by saved water

From table 4, the maximum seasonal depths of irrigation water saved were 50.65 and 70.48mm at CWR+2day and CWR+3day respectively. The additional area irrigated by CWR+2day and CWR+3day were 0.12 and 0.16 ha respectively. From additional area irrigated 0.58 and 0.72 t/ha of yield obtained at irrigation interval of CWR+2day and CWR+3day respectively. The total yield that takes rank from 1-3 among treatment were 5.59, 5.23 and 5.17 tone at CWR+2day, CWR and CWR+3day respectively. The result agreed with finding of Asnake et al., (2022) using the same water depth can irrigate different irrigation commend area and obtain different yield by using different irrigation water saving method.

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Table 4. Relative yield reduction and additional area irrigated by saved water

treatment	Yield (t/ha)	Seasonal irrigation water applied (mm)	Seasonal depth of irrigation water saved (mm)	Additional area irrigated (ha)	additional yield obtained (t/ha)	Total yield with Additional area irrigated (t/ha)
CWR-1day	5.37	365.75	71.75	0.16	0.88	6.25
CWR	5.23	347.65	89.85	0.21	1.07	6.30
CWR+2day	5.01	297.00	140.50	0.32	1.61	6.62
CWR+3day	4.45	277.17	160.33	0.37	1.63	6.08

CWR= Crop water requirement

4.0. Conclusion

In Ethiopia, irrigation wheat production is one of the initiatives plans to solve shortage of food security problems. For this proper irrigation, scheduling is essential for the efficient use of water to increase yield. This study conducted at Ketar Genat irrigation scheme to determine different irrigation schedules on water use and yield of wheat using three treatments of irrigation intervals (CWR+2day, CWR+3day and CWR-1day) with CWR as control. Among treatment, maximum irrigation water applied was at CWR-1day (365.75mm). The minimum seasonal water applied were CWR+3day (277.17mm). The maximum grain yield was obtained at CWR-1day (5.37 t/ha) was not statically significant different with CWR (5.23 t/ha) and CWR+2day (5.01 t/ha) at ($p<0.05$). The optimum water productively was obtained at CWR+2day (1.69 kg/m^3). Maximum seasonal depths of irrigation water saved were 70.48 and 50.65mm at CWR+3day and CWR+2day respectively. The maximum additional areas irrigated were 0.16 and 0.12 ha at CWR+3day and CWR+2day respectively. The maximum additional yield from water saved were 0.72 and 0.58 t/ha at CWR+3day and CWR+2day respectively. But maximum total yield were 5.59 t/ha was obtained at CWR+2day.

5.0. Recommendation

Based on the study results, maximum grain yield was obtained at irrigation of CWR-1day and CWR+2day. The optimum water productively was obtained at irrigation interval of CWR+2day. Therefore, it was recommended to use CWR+2day irrigation interval to obtain maximum wheat yield water productivity at Ketar Genat irrigation scheme and similar agrology schemes.

Declarations

Source of Funding

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Competing Interests Statement

The authors have not declared any conflict of interest.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in the literature review, analysis, and manuscript writing equally.

Informed Consent

Not applicable for this study.

Availability of data and material

Supplementary information is available from the authors upon request.

Institutional Review Board Statement

Not applicable for this study.

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