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Effect of Irrigation Water Level and N-fertilizer Rate on Yield and Water Productivity of Wheat Under Furrow Irrigation at Tibila Irrigation Scheme, Arsi Ethiopia

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ABSTRACT

The response of wheat yield to different levels of irrigation and varying amounts of nitrogen fertilizer was investigated from 2020-2022 GC at Tibila irrigation scheme. Three levels of irrigation (70, 85, and 100% ETc) and three nitrogen rates (46, 69, and 92 kg/ha) were arranged in two factorial combination in Randomized Complete Block Design with three replications. Recently released bread wheat variety king-bird was used as test crop. The experimental field was divided into 27 plots with plot size of 4m x 6m dimension to accommodate five furrows with spacing of 60cm and having 6m length. From the result, it is found that, irrigation and nitrogen levels both had a considerable impact on wheat grain yield. The analysis of variance result revealed that the maximum grain yield (5.88 tha^{-1}) of wheat was recorded at 92 kg/ha nitrogen rate and 100% ETc irrigation level. The minimum grain yield (3.98 tha^{-1}) was obtained from 46 kg/ha nitrogen and 70% ETc irrigation treatment. Similarly, the study revealed that other yield components like plant height, spike length, number of seed per spike, productive tiller number and above ground biomass of wheat increased with the increasing rates of nitrogen fertilizer and irrigation water level. Here, increasing the application rate of nitrogen fertilizer from (46-92) kgh^{-1} and water level from 70% ETc to full irrigation maximize yields of wheat. On the other hand, reducing water level from 100 to 85% ETc and N-fertilizer rate from 92 to 69 kg/ha was not reduce the yield significantly, rather it have water saving and economic advantage. Moreover the partial budget analysis revealed that an application of 85% ETc and 69 kg/ha nitrogen fertilizer is the best treatment to obtain an optimum yield and maximum benefit cost ratio in the study area. Therefore, application of 85% ETc irrigation and 69 kg/ha nitrogen is recommended for optimum returns of irrigation and nitrogen fertilization of wheat in the area.

Keywords: Yield; Water level; Nitrogen rate; Wheat.

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the leading cereals in the world. It belongs to the family Gramineae and it is the world's most widely cultivated cereal crop which ranks first followed by rice. It is preferable than rice for its higher seed protein content. It ranks first both in acreage and production among the grain crops of the world (FAO, 2008). Likewise, wheat is one of the strategic crops in Ethiopia, because of its role for food security, import substitution and supply of raw material for agro-processing industry.

Ethiopia is the third largest wheat producing country in Africa (EIAR, 2020). This crop is one of the major cereal crops produced by 4.6 million smallholder farmers on 1.8 million hectares of land with an estimated annual production of 5.0 million tons at an average productivity of 2.8 t/ha which has been consistently increasing for the last 25 years in the country, but much lower than the world average 3.3 t/ha (EIAR, 2020). This is due to shortage of irrigation water, in sufficient farm resources, improper use of fertilizers and due to salinity and water logging.

Nitrogen (N) and water are the most common limiting factors in agricultural systems throughout the world. Similarly, wheat crop need sufficient available water and N to achieve optimum yield and adequate grain-protein content (IAEA, 2000). Wajid et al. (2002) reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages.

According to (IAEA, 2000), lower economical benefits for farmer often arise from the use of sub-optimal rate of N-fertilize. On the other hand, excessive irrigation and N-fertilizer use may result in environmental problem such as nitrate contamination of groundwater and emission of N_2O and NO. Thus; without judicious use of irrigation water and applied N-fertilize the yield potential of wheat crop cannot be obtained satisfactorily.

Nitrogen fertilizer and irrigation are two major factors influencing wheat yield and NO_3--N accumulation but these can be controlled by the grower (Ottman and Pope, 2000; Yin et al., 2007). Irrigation effectively increases crop yield although water-use efficiency (WUE) decreases as the irrigation rate increases (Al-Kaisi et al., 2003). Excessive N application could lead to soil acidification as well as worsen the soil environment thus, ultimately has a negative impact on crop growth and yield (Guo et al., 2010; Schroder et al., 2011).

Previous studies indicated that reducing N application rates to a reasonable level in maize and wheat planting caused no loss of yield and even small increases (Zhang et al., 2015). Zhao et al. (2014) found that the application of lower N rates sustained high yields compared with higher N rates. Yield reductions in crops with high N fertilization are primarily caused by physiological disorders associated with excessive uptake of N and soil degradation (Qiao et al., 2012). Although, optimum N rates are affected by many factors, studies have shown that a moderate reduction in N inputs does not lead to a decrease in crop yield (Luo Z. et al., 2018) but, conversely, improved N use efficiency (Zhang et al., 2015a).Excessive N fertilization has caused low N use efficiencies and serious environmental problems (Cui et al., 2016; Zhu et al., 2016). In general, increased soil water content enhances crop yield response to N fertilization, especially when optimum water-N rates are applied (Norwood, 2000).

The demand for wheat in Ethiopia is growing faster than for any other food crop, particularly in urban areas. The gap between demand and supply is widening because of rapidly increasing population and changing preferences towards wheat-based food items (EIAR, 2020). Cognizant to the aforementioned facts, the Government of Ethiopia (GoE) has already identified key priority intervention areas to increase productivity of small-scale farmers and expand large-scale commercial production of wheat. The top priorities identified include: development of small- and large-scale irrigation schemes, financing effectual supply of agricultural inputs, improving agricultural production methods using mechanization, post-harvest loss reduction and natural resources management (EIAR, 2020).

Even though the government need to produce wheat crop by irrigation is high, there was no research work on fertilizer rate and irrigation water levels that gain high net return. To this end, efficient use of N-fertilizer requires comprehensive knowledge of the soil, the amount of water applied, timing and source and amount of N-fertilizer. Therefore; this study was aimed in finding out the optimized fertilizer rate and water level on wheat crop using furrow irrigation in Tibila irrigation scheme.

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted at Tibila Irrigation scheme of Arsi Zone, Oromia National Regional State, Ethiopia. The schemes is situated about 150 kilometers away to the east from the country's capital city, Addis Ababa and 95 kilometers away from Asella Town, the Arsi Zone capital. The sachem is bounded within $8^0$89293'N, 039^0 03129'E at an altitude of 1303m above sea level.

According to the meteorological data obtained from the nearest Awash Melkassa meteorological station, which is about 33 kilometers far from the study area, the annual mean rainfall distribution in the area ranges between 500mm to 900mm. The rainfall is mostly characterized by erratic and uneven distribution. The area has a bimodal rainfall pattern, with the small rains occurring from February to April and the main rainfall season, which accounts for the largest total rainfall of the year occurs from July to September. The Mean monthly relative humidity varies from 32% to 49%. The potential evapo-transpiration is 1650 mm per annum and the monthly mean temperature ranges from (17-23)^{o}C.

2.2. Soil Sampling and Analysis

Representative composite soil samples were collected from 0– 30 cm soil depths for analysis of selected soil physico-chemical properties (Textural, FC, PWP, ECe, pH and Organic matter (OM)). Bulk density of the field was determined from undisturbed soil samples using core sampler having a dimensions of 5.0 cm diameter and 5.0 cm height (V=98.21 cm^3). The samples were oven dried for 24 hours at temperature of 105^{o}C to obtain dry soil sample. Hence, the bulk density (BD) was computed following Eq.(1),

$$\mathrm{BD} = \frac{\text{weight of dry soil (g)}}{\text{volume of core sampler}(cm^3)} \qquad (1)$$

2.3. Treatments and Experimental Design

The experiment was two factorial combinations arranged in Randomized Complete Block Design (RCBD) with three replications. The two factors were irrigation water level and different fertilizer rate. The irrigation water level were three (85% ETc, 70% ETc, and one control 100% ETc). Whereas, a recommended fertilizer, three N rates (46N, 69N, 92N) kgha^{-1}. Recently released bread wheat varieties king-bird was used as test crop. All the agronomic activities including weeding, cultivation, disease and insect pest control were carried out for all the experimental plots equally as per the recommendation. A total of nine treatments were accomplished with three replications. The experimental field was divided into 27 plots with plot size of 4 m x 6 m dimension (24 m^2) to accommodate six furrows with spacing of 60 cm and having 6m length, Consisting four ridges and five furrows for each plot. The blocks had a buffer zone of 1.2 m from water supplying canal and plots were separated by 1.5 m from each other to eliminate influence of lateral flow of water. Field canal was constructed for each block to irrigate the field. For each plot box shaped structures were constructed to dissipate the energy of water diverted to the plots.

Table 1. The treatment combination of the experiment

Treatments	Water level (ETc%)	N-rate (kgha^{-1})
T_1	100	46
T_2	100	69
T_3	100	92
T_4	85	46
T_5	85	69

T_6	85	92
T_7	70	46
T_8	70	69
T_9	70	92

2.4. Crop Water Requirements and Irrigation Water Management

2.4.1. Crop water requirement

Reference evapotranspiration, ETo was estimated using FAO Penman-Monteith equation from long term meteorological data collected from Awash Melkassa meteorological station with the help of CROPWAT 8.0 model. Seasonal crop water requirements, ETc was estimated by multiplying long term ETo value with the established Kc value (Eq. 2),

$$ET_C = ET_O \; x \; K_c \qquad (2)$$

Where: ETc is Crop evapotranspiration (mm/day); ETo is Reference crop evapotranspiration (mm/day) and Kc is Crop coefficient (fraction).

Due to differences in evapotranspiration during the various growth stages, Kc for a given crop varies over the growing period. The growing period can be divided into four distinct growth stages. Such as: initial, crop development, mid-season and late season. The growth period of wheat in the experimental site is 135-days and it was divided into four stages, viz, initial stage (25days), development stage (40 days), mid stage (47 days) and late stage (23 days). Accordingly, the Kc value for wheat crop under Tibila irrigation scheme climatic condition were 1.00 throughout the growing period.

2.4.2. Irrigation water management

Soil moisture level in all plots was brought to field capacity for each treatment in the last irrigation during the common irrigation time. Soil water availability in the experiment was tested from routine measurements of soil moisture content by the gravimetric method. The wet soil samples was weighed and placed in an oven dry at a temperature of 105°c and dried for 24 hours. The gravimetric water content was converted to equivalent depth (D) from Eq.(3),

$$\mathrm{D} = \frac{W_w - W_d}{W_d} \; x \; BD \; x \; drz \qquad (3)$$

Where: D is the depth of available soil moisture (mm); Ww is wet soil weight (gm); Wd is dry soil weight (gm); BD is the soil dry bulk density (gm cm^{-3}) and drz is the sampling depth within the crop root depth (mm).

The soil moisture depleted between irrigation was obtained from Eq.(4),

$$\mathrm{IRn} = (\mathrm{FC} - D) \qquad (4)$$

Where: IRn is the net irrigation requirement (mm) and FC is the soil moisture content at field capacity (mm).

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2.4.2.1. Irrigation scheduling and management

Total available water (TAW) was computed from the moisture content of field capacity and permanent wilting point using equation Eq.(5),

$$\mathrm{TAW} = (\mathrm{FC} - PWP)\ x\ BD\ x\ Dz \qquad (5)$$

Where: TAW is the total available water in the root zone (mm), FC and PWP are moisture content at field capacity and permanent wilting point (%) on weight basis respectively and Dz is the root zone depth of wheat at times of each irrigation. For maximum crop production, irrigation schedule was fixed based on p-value. The P-value so called depletion fraction for winter wheat used in this study was TAW (p = 0.55) according to (Allen et al.1998).

Hence, RAW was computed from the Eq.(6),

$$\mathrm{RAW} = \mathrm{TAW} \times \mathrm{p} \qquad (6)$$

Where: RAW is the readily available water or net irrigation depth, IRn (mm), p is allowable permissible soil moisture depletion fraction and TAW is total available water in the root depth (mm). Hence, the IRn of irrigation was computed from Eq.(7),

$$\mathrm{IR}_n = \mathrm{TAW} * \mathrm{P} \qquad (7)$$

Where: IRn is the net irrigation requirement (mm) and p is depletion fraction.

Irrigation interval, f was estimated using the following Eq.(8),

$$f = \frac{IRn}{ETc} \qquad (8)$$

Where: f is irrigation interval (day) and ETc is mean daily crop water requirement (mm day^{-1}).

Whenever there is rainfall between irrigation, the IRn could be obtained from the Eq.(9),

$$\mathrm{IRn} = \mathrm{ETc} - \mathrm{P_{eff}} \qquad (9)$$

Where: P_{eff} is effective rainfall (mm).

The effective rainfall, P_{eff} was estimated using the method given by (Allen *et al.*, 1998) as,

$$\mathrm{P_{eff}} = 0.6 \times \mathrm{P} - \frac{10}{30/31} \quad \text{for month} \leq \frac{70}{30/31}\ \text{mm} \qquad (10)$$

$$P_{eff} = 0.8 \times P - \frac{24}{30/31} \quad for\ month > \frac{70}{30/31}\ mm \qquad (11)$$

Where: P is daily rainfall (mm)

2.4.2.2. Field application efficiency and gross irrigation water requirement

Field irrigation application efficiency (Ea) is the ratio of water directly available in crop root zone to water received at the field inlet. Furrow irrigation could reach a field application efficiency of 70% when it is properly designed, constructed and managed. The average ranges vary from 50 to 70%. However, a more common value is 60% (FAO, 2002). For this particular experiment, irrigation efficiency was taken as 60%, which is common for surface irrigation method in furrow irrigation. Based on the net irrigation depth and irrigation application efficiency, the gross irrigation water requirement was calculated based on Eq.(12),

$$IR_g = \frac{IR_n}{E_a} \qquad (12)$$

Where: IR_g the gross irrigation requirement (mm) and E_a is the field application efficiency (%).

2.4.2.3. Setting and discharge measurement of parshall flume

Irrigation water applied to each experimental plot was measured by 3-inch Parshall flume (PF) made from metal sheet and installed 10 m away from the nearest plot along main canal. The entrance section was set 4 cm above the canal bed to avoid submergence flow. Only one measurement was required to determine flow rate of free flow condition. This is the height of water from gauge of PF written on two-third surface wall of the entrance section. The calculated gross irrigation was finally applied to each experimental plots based on the treatments proportion. Volume of water applied for every treatment was determined from plot area and depth of gross irrigation requirement.

Time required to irrigate each treatment was calculated from the ratio of volume of applied water to the discharge-head relation of 3-inch PF. Since discharge level might vary at field condition, time required was calculated from 5 to 15 cm head levels. The time required to deliver the desired depth of water into each furrow was calculated using Eq.(13),

$$t = \frac{A \text{ x dgross}}{Q} \qquad (13)$$

Where: dg - gross depth of water applied (mm), t - application time (sec), A - plot Area (m^2) and Q - flow rate (l/s).

2.5. Data Collection

All agronomic data were collected from net plot through marginalizing the boarder effect

Plant height (cm): The height wheat was measured from the soil surface to the tip of a spike from 10 randomly tagged plants in the net plot area at physiological maturity.

Number of productive tillers: The number tillers were counted from square box of (1 x 1) m^2 selected randomly per net plot at physiological maturity and converted to m^2.

Number of kernels per spike: The number of kernels per spike were recorded as an average of 10 randomly taken spikes from the net plot area.

Thousand kernel weight: This were also determined based on the weight of 1000 kernels sampled from the grain yield of each net plot and weighed with electronic sensitive balance.

Above-ground dry biomass yield: The wheat biomass was determined through weighting plants harvested from the net plot area.

Grain yield: This was also taken by harvesting and threshing the grain yield from net plot area. The yield were adjusted to 12.5% moisture content and expressed as yield in tone ha^{-1}.

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2.6. Water Productivity

Water productivity is simply the ratio of the water beneficially used and the quantity of water delivered. This parameter was calculated by dividing wheat harvested from net plot yield in kilogram to unit volume of water in cubic-meter or hectare-meter (Araya *et al*., 2011). The water productivity (WP) also known as the total water use efficiency (Kg m^{-3}) and Irrigation Water Use Efficiency (IWUE, Kg m^{-3}) was calculated based on Eq.(14),

$$WP = \frac{Ya}{Twu} \qquad (14)$$

Where: WP - Water productivity (kg/m^3), Ya - Actual yield (kg/ha), Twu – Total water used (m^3/ha).

2.6.1. Yield response factor

Yield response factor (Ky) is one of the important parameters that indicate whether moisture stress due to deficit irrigation is advantageous or not in terms of enhancing water productivity. The crop yield response to water relates relative yield decrease to relative evapotranspiration of irrigation deficit level. The effect of water stress on yield was quantified by calculating the yield response factor (Ky) (Doorenbos & Kassam, 1979):

$$(1 - \frac{Y_a}{Y_m}) = \text{ky}(1 - \frac{ET_a}{ET_m}) \qquad (15)$$

Where: Ym is maximum yield (kg/ha) from the plot without water stress during the growing season and Ya is actual yields (kg/ha); ETm (mm) and ETa (mm) are the maximum and actual evapotranspiration and Ky is a yield response factor representing the effect of a reduction in ET on yield losses.

2.6.2. Economic analysis

It is a way of calculating the total costs that vary and the net benefits of each treatment (CIMMYT, 1988). Economic water productivity analysis were begin by considering the general relationship between the crop water use and crop yield per hectare of land at different irrigation application levels using the partial budget analysis. In this study the costs that varied among treatments were cost of water and labor for watering during experimental season.

The net income was calculated by subtracting total variable cost production from total return (Kuboja and Temu, 2013) and is computed as Eq.(16),

$$NI = TR - TVC \qquad (16)$$

Where: NI -Net income;

TR -Total income from sales;

TVC -Total variable cost spent during production.

The marginal return rate in measures the increase of the net income, which is generated by each additional unit of expenses and is computed as Eq.(17),

$$MRR = \frac{\Delta NI}{\Delta VC} \qquad (17)$$

Where: MRR-Marginal rate of return (%).

ΔNI – change in net income;

ΔVC – change in variable cost.

2.7. Statistical analysis

The collected data were statistically analyzed using statistical analysis system (SAS) version 9.0 statistical package using procedure of general linear model (SAS, 2002) for the variance analysis. Mean comparisons was executed using least significant difference (LSD) at 5% probability level when treatments show significant difference to compare difference among treatments mean. Simple correlation analysis was also used to see the association of wheat yield component, yield and water productivity.

3. Results and Discussions

3.1. Soil Analysis

3.1.1. Analysis of selected soil physical properties

The laboratory results of soil physical properties of the experimental site were presented in (Table 2) below. The average result of the soil physical properties from the experimental site showed that, the composition of sand, silt and clay percentage were 41%, 39% and 20% respectively. Thus, according to USDA soil textural classification, the soil in which the trial conducted is classified as Loam soil.

Other soil physical properties like Bulk, PWP, FC and TAW had also determined by the following standard procedure in the soil laboratory. Hence, the average bulk density of the experimental soil is found to be 1.44 g/cm^3 and Field capacity (FC), Permanent wilting point (PWP) and total available water (TAW) of the soil were 27.8%, 13.7%, and 140mm/m respectively (Table 2).

Table 2. Results of selected soil physical properties

Depth (cm)	Bulk density (g/cc)	FC (%)	PWP (%)	TAW	Texture			
		(V/V)	(V/V)	(mm/m)	% Sand	% Silt	% Clay	Class
0 – 30	1.44	27.8	13.7	140.00	41.00	39.00	20.00	Loam

3.1.2. Analysis of selected soil chemical properties

From table 3, the pH of the experimental site through the analyzed soil profile was found to be in recommended range with average value of 8.43. In the same fashion the laboratory result gives 1.02% organic matter and 0.051% total nitrogen of the soil. An average electrical conductivity of an experimental soil is also 0.25 ds/m.

Table 3. Results of selected chemical properties of soil

Depth (cm)	pH	Total organic matter (% OM)	Total Nitrogen (% TN)	ECe (ds/m)
0 – 30	8.43	1.02	0.051	0.25

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3.2. Irrigation water applied to wheat throughout the growth stages

From Table 4, water saved from treatment of 100% ETc, 80% ETc and 70% ETc were 0, 112.5 mm and 168.7 mm of total net volume of irrigation water applied respectively. Total rainfall record in the growing season was 19.7 mm and this was deducted from gross irrigation requirement during irrigation.

Table 4. Water applied per growth stage and water saved from each treatment (mm)

Treatment	Growth stage				IRg	Water saved
	Initial	Development	Mid	Late	(mm)	(mm)
100% ETc	151.5	138.5	202.5	70.1	562.6	-
80% ETc	121.2	110.8	162.0	56.1	450.1	112.5
70% ETc	106.1	92.9	141.8	49.1	393.8	168.7

3.3. Effect of different Irrigation water levels and N-fertilizer rate on yield and yield component of wheat

The effect of different Irrigation water levels and N-fertilizer rate on plant height, number of seed per spikes, spike length, tiller number, above ground biomass yield and grain yield of bread wheat King-bird varieties at Tibila irrigation scheme is indicated in Table 5. As indicated in the Table 5, there were mean yield and mean yield component differences between the treatments. Accordingly, wheat grown under T_3 (100% ETc of water and 92 kgha^{-1} N level) had the highest plant height, spike length, number of seed per spike, productive tiller number, above ground biomass yield and grain yields (Table 5). Whereas, wheat grown under T_6 (85% ETc of water and 92kgha^{-1}N) was recorded the highest thousand kernel weight (TKW) and also ranks as the 2nd higher yield among the treatment.

Moreover, the highest wheat biomass yield of 14.2 t ha^{-1} which is 32% higher over the smallest biomass yield were recorded on wheat grown under T_3 (100% ETc and 92 kgha^{-1} N) and shown significant variation ($P<0.05$) over T_4 (100% ETc and 92 kgha^{-1} N), T_5(85% ETc and 69 kgha^{-1} N) and T_7T (70% ETc and 46 kgha^{-1} N). The 2nd biomass yield 14 t ha^{-1} which gave 30% higher biomass yield over the smallest biomass among the treatment were recorded on T_6 (85% ETc and 92 kgha^{-1} N) and also shown significant variation ($P<0.05$) over $T_{4,}$ T_5 and T_7 (Table 5). Here, the reduction of irrigation water from 100% ETc to 70% ETc and N-rate from 92 to 46 kg ha^{-1} reduced the biomass production by 32%. Different researchers reported similar result on wheat production (Maqbool *et al*., 2015; Guo *et al.*, 2013; Tavakoli and Moghadam, 2012). The decreased above-ground biomass in reduced water level and N-rate treatments might be due to reduction in photosynthesis in which amount of water and chlorophyll is important. According to Guo *et al*., (2013) reduced water level affects photosynthesis capacity through reduction of chlorophyll content and damage of the reaction center of photosystem.

Similarly, different water levels and N-rates on wheat has shown a significant ($p<0.05$) influence on grain yield per hectare production (Table 5). The highest grain yield (5.88 tha^{-1}) were obtained when the bread wheat was grown under T_3 (100% ETc and 92 kgha^{-1}N) and has no significant differences over T_1 (70 ETc and 69 kgha^{-1}N), T_2 (100 ETc and 69 kgha^{-1}N), T_5 (85 ETc and 69 kgha^{-1}N), T_6 (85 ETc and 92 kgha^{-1}N), and T_9 (70 ETc and 92 kgha^{-1}N) treatments. This result is almost similar with finding by Xiaojun Shen (2020) who reported that the grain yield decreased with the decrease of the amount of irrigation under each nitrogen fertilizer treatments, and there was no significant difference when the irrigation amount exceeded 80% ETc of the irrigation requirement. Aydin et al. (2000) also reported that irrigation at 66% ASMD was the most effective in terms of grain yield in wheat. Similarly, Nuru Seid *et al*., (2021) reported as nitrogen fertilizer applied at rate of 138 kg ha^{-1} had 6.2 % less grain yield on bread wheat than fertilizer rate applied at 92 kg ha^{-1} clay soil of Mekidal district, Wollo.

On the other hand, the minimum grain yield (3.98 tha^{-1}) was observed at T_7 (70 ETc and 46 $kgha^{-1}$N) and this was significantly different over T_3 (100% ETc and 92kg N), T_5 (85 ETc and 69 $kgha^{-1}$N), T_6 (85ETc and 92 $kgha^{-1}$N) and T_9 (70ETc and 92$kgha^{-1}$N) (Table 5). Different studies conducted revealed as water level and N-rate affects grain yield production of irrigated wheat (Maqbool *et al*., 2015; Guo *et al.*, 2013; Tavakoli and Moghadam, 2012). In this study, reduction of irrigation water and N-rate from 100% ETC and 92 kg ha^{-1} N to 70% ETC and 46 $kgha^{-1}$N leads to reduction of grain yield by 28%.

Thus, better water and nutrient availability contribute for better plant growth and yield. Tavakoli and Moghadam (2012) concluded wheat output could be substantially and consistently increased in semi-arid climate zone when 66% of full irrigation with appropriate management practiced. Generally, though bread wheat grown under full irrigation (100% ETc water level) and maximum N-fertilizer rate had better yield advantage as compared to minimum water level and fertilizer rate and it were not significantly varied over the treatment T_1, T_2, T_5, T_6, and T_9. Here it can be observed that, reducing irrigation water level and N-fertilizer rate reduce the yield, but reduction to some extent will not reduce the yield significantly.

Table 5. Effects of water levels and N-fertilizer rates on grain yield and yield components for two cropping seasons (2020-2022 GC)

Treatments	W/Level ETC%	N-level $kgha^{-1}$	PH(cm)	NT	S/S	SL(cm)	BY (ton/h)	GY (t/h)	TKW
T_1	100	46	77.53^{bcd}	3.27^{ab}	48.93^{bc}	7.73^{abc}	12.3^{abc}	4.99^{bc}	35.23^{ab}
T_2	100	69	80.27^{abc}	3.53^{ab}	51.27^{bc}	7.93^{ab}	12.0^{abc}	5.23^{abc}	35.97^{ab}
T_3	100	92	83.87^{a}	4.13^{a}	57.77^{a}	9.03^{a}	14.2^{a}	5.88^{a}	37.13^{ab}
T_4	85	46	73.47^{de}	3.27^{ab}	46.87^{bc}	7.13^{cd}	11.0^{bc}	4.49^{c}	34.80^{b}
T_5	85	69	78.67^{abcd}	3.33^{ab}	51.25^{bc}	7.90^{ab}	10.3^{c}	5.22^{ab}	36.57^{ab}
T_6	85	92	82.27^{ab}	4.07^{ab}	51.00^{bc}	8.27^{ab}	14.0^{a}	5.58^{ab}	38.63^{a}
T_7	70	46	69.9^{e}	2.67^{b}	44.80^{c}	6.83^{d}	9.7^{c}	3.98^{c}	37.30^{ab}
T_8	70	69	76.07^{cd}	2.87^{ab}	44.80c	7.60bc	12.0^{abc}	4.70^{bc}	35.23^{ab}
T_9	70	92	81.20^{abc}	4.13^{a}	47.73^{bc}	8.10^{ab}	13.7^{ab}	5.29^{ab}	37.90^{ab}

CV	4.52	21.28	7.92	5.15	14.14	1.33	5.42
Mean	78.58	3.47	48.59	7.68	12.1	5.04	36.80
LSD (0.05)	6.15	1.28	6.67	0.68	0.29	0.74	3.45

S/S= Number of seed per spikes , NT = number of tillers and TKW = thousand kernel weight, PH(cm)=Plant height, SL=Spike length, BY=Biomass yield and GY=Grain yield

3.4. Effect of Irrigation Water Level and N-fertilizer rate on Water Use Efficiency

It can be observed from the result that, as treatments with lower yield due to less water application had higher water use efficiency. As shown in Table 6, water use efficiency (WUE) was significantly ($P<0.05$) affected due to irrigation level and fertilizer rate. The largest value of 1.34 kg m^{-3} was recorded by T_9, and also of the next was recorded by T_8 (1.19 kg m^{-3}) and T_6 (1.24 kg m^{-3}) respectively. Water productivity was less and not significantly varied from one another in T_1, T_2 and T_3 due to full irrigation (i.e. 100 % ETc) and in T_4 and T_7 due to less N-rate application. In this study, high irrigation water level records low water use efficiency and higher N-fertilizer rate and lower water level records higher water use efficiency. From Table 6, the highest value 1.34 kgm^{-3} of WUE was recorded at lower irrigation level and maximum N-rate application and the minimum value 0.89 kgm^{-3} was obtained under full irrigation and low N-rate application. Different studies conducted on wheat reveal reduction of irrigation water level affects water use efficiency of irrigated wheat (Pradhan *et al*., 2013). Shamsi *et al*., (2010) for instance reported that, water use efficiency of wheat varied from 0.66 to 1.34 kg/m^3 between different irrigation regimes. Hamid *et al*., (2012) on the other hand found that, irrigation of wheat below optimum level to some extent save about 22% of irrigation water with no significant loss in yield. There for the result obtained in this experiment is within the previous study range and was found reasonable.

Table 6. Effects of water levels and fertilizer rates on wheat water use efficiency

Treatments	**Water/L ETc%**	**N-level kgha-^{1}**	**GY(t/h)**	**Water Used (mm)**	**WUE (kg m^{-3})**
T_1	100	46	4.99^{abc}	562.6	0.89^{d}
T_2	100	69	5.23^{abc}	562.6	0.93^{cd}
T_3	100	92	5.88^{a}	562.6	1.1^{bcd}
T_4	85	46	4.49^{bc}	450.1	1.0^{bcd}
T_5	85	69	5.22^{abc}	450.1	1.16^{ab}
T_6	85	92	5.58^{ab}	450.1	1.24^{ab}
T_7	70	46	3.98^{c}	393.8	1.01^{abc}
T_8	70	69	4.70^{bc}	393.8	1.19^{ab}
T_9	70	92	5.29^{ab}	393.8	1.34^{a}

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CV	1.33	2.6
Mean	5.04	1.01
LSD (0.05)	0.74	0.32

3.5. Yield response factor

The result reveals that lower yield response factor was associated with higher water level and fertilizer rate treatments in which values of 100% ETc 92 kg of N, 85 % ETc 92 kg of N were 0.23 and 0.25 respectively. The result reveals the sensitivity of yield increased as water level decreases. According to FAO (2002), yield response factor of different crops and different stress condition varies from 0.20 for tolerant crops to 1.15 for sensitive crops. Reducing irrigation water during practicing deficit irrigation in wheat at flowering and grain filling resulted in a yield response factor of 0.39 and reduction of irrigation water amount during the entire growing season leads to yield response factor of 0.76 in wheat (FAO, 2002).

Crop yield and water use efficiency can be increased if sufficient amount of water is supplied and if sufficient amount of nutrient (especially nitrogen) is also added. The 85 % ETc water level and 69 kg N gives optimum yield and water production (Table 7).

As indicated in Table 7, the result shown that the minimum yield reduction 5.1% was in T_6 (85% ETc and 92 kgha^{-1} of N). But, it consumes large amount N-rate. T_5 (85% ETc & 69 kgha^{-1} of N) result in yield reduction of 12.9% correspondingly saves 112.5mm of water from the required amount of gross irrigation and about 27 kgh^{-1}of N from the maximum application in the trial. Accordingly, additional area irrigated with saved water and the saved amount of fertilizer can be used for other area. It clearly seen that the value of net yield generated was not influenced only by water applied but also with N-rate applied.

Table 7. Extent of saved water and yield reduction

Treatments	Water/L ETc%	N-level kgha-^{1}	GY(t/h)	Yield Reduction (%)	GIrr (mm)	Water saved (mm)
T_1	100	46	4.99	15.1	562.6	-
T_2	100	69	5.23	11.1	562.6	-
T_3	100	92	5.88	-	562.6	-
T_4	85	46	4.49	23.6	450.1	112.5
T_5	85	69	5.22	12.9	450.1	112.5
T_6	85	92	5.58	5.1	450.1	112.5
T_7	70	46	3.98	32.3	393.8	168.7
T_8	70	69	4.70	20.1	393.8	168.7
T_9	70	92	5.29	10.0	393.8	168.7

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3.6. Partial budget analysis

For partial budget analysis, the price of grain wheat in the area is taken during time of harvest was 45 Birr kg^{-1} and the price for water was 3.8 Birr m^{-3} (Jansen, 2007). From Table 8, the highest net benefit is 89,168 Ethiopian birr (ETB) with 2.06 benefit cost ratio (B/C) was obtained at 100 % ETc and 92 $kgha^{-1}$ of N treatment. Whereas, the minimum net benefit is 63,107 Ethiopian birr (ETB) with 2.39 benefit cost ratio (B/C) was obtained at 70 % ETc and 46 $kgha^{-1}$N treatments. Accordingly, an application of 85 % ETc and 69 kg/ha of N fertilizer rate gave the optimum net benefits and best benefit cost ratio (B/C) of 84,572ETB and 2.57 respectively.

Table 8. Partial budgeting and MRR analysis for economic wheat production

Treatments	Water/L ETc%	N-level $kgha^{-1}$	TC (ETB/ha)	UTY (kg/ha)	ATY (kg/ha)	GB (ETB/ha)	NB (ETB/ha)	B/C
T_1	100	46	34,918	4,990	4,491	112,275	77,357	2.22
T_2	100	69	38,327	5,230	4,707	117,675	79,348	2.07
T_3	100	92	43,132	5,880	5,292	132,300	89,168	2.06
T_4	85	46	30,680	4,490	4,041	101,025	70,345	2.29
T_5	85	69	32,878	5,220	4,698	117,450	84,572	2.57
T_6	85	92	39,100	5,580	5,022	125,550	86,450	2.21
T_7	70	46	26,443	3,980	3,582	89,550	63,107	2.39
T_8	70	69	30,400	4,700	4,230	105,750	76,753	2.52
T_9	70	92	36,870	5,290	4,761	119,025	82,155	2.23

TC= Total cost, UTY= Unadjusted total yield, ATY= Adjusted total yield, GB= Gross benefit, NB =Net benefit, and B/C= Benefit cost ratio.

4. Conclusion and Recommendation

The combination effect of nitrogen fertilizer rate and irrigation water levels on wheat yield and yield component were investigated at the experimental field from 2021-2022 GC. From the study result, irrigation and nitrogen levels had a substantial impact on wheat grain yield. Increasing the application rate of nitrogen fertilizer from 46 to92 kgh^{-1} and water level from 70 % ETc to full irrigation maximize yields of wheat. On the other hand, reducing water level from 100 to 85% ETc and N-fertilizer rate from 92 to69 kg/ha was not reduce the yield significantly; rather it saved water and economic advantage. The combination of 85 % ETc and 69 kg/ha of N fertilizer rate is the best treatment to obtain an optimum yield and maximum B/C ratio in the study area. Therefore it was recommended to farmer of Tibla irrigation scheme to use combination of 85 % ETc irrigation and 69 kg/ha nitrogen fertilizer rate to enhance production and productivity of wheat in the study area. It was also recommended that if similar experiment will be conducted on other irrigation scheme to identify the combination effects of water level and fertilizer rate.

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Competing Interests Statement

The authors declare no competing financial, professional, or personal interests.

Consent for publication

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

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References

Al-Kaisi MM, & Yin XH (2003). Effects of nitrogen rate, irrigation rate and plant population on corn yield and water use efficiency. Agron J., 95: 1475-1482

Allen, R.G., Pereira, L.S., Raes, D., & Smith, M. (1998). Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper, 56, FAO: Rome, Italy.

Araya, A., Stroosnijder, L., Girmayc, G. & Keesstra, S. (2011). Crop coefficient, yield response to water stress and water productivity of tef (Eragrostis tef Zucc.)'. Agricultural Water Management, 98(5): 775-783.

Aydin, M., M. Kalayci, & H. Ekiz (2000). Effect of irrigation applied depending on soil moisture on some wheat cultivars. Orta Anadolu'da hububat tarmnn sorunlar ve cozum yollar Sempozyumu, Konya, Turkey, Pages 8-11.

CIMMYT (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F.

Doorenbos, J., & Kassam, A.H. (1979). Yield response to water. FAO Irrig. Drain. Paper No.33. FAO, Rome, Italy.

EIAR (2020). Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa (Unpublished).

Fang QX, Yu Q, Wang EL, Chen YH, Zhang GL, Wang J, & Li LH. (2006). Soil nitrate accumulation, leaching and crop nitrogen use as influenced by fertilization and irrigation in an intensive wheat- maize double cropping system in the North China Plain. Plant Soil, 284: 335-350.

Food and Agricultural Organization (2002a). Irrigation manual: planning, development, monitoring and evaluation of irrigated agriculture with farmer's participation. 2(7), Harare, Zimbabwe.

Food and Agriculture Organization (2002). Deficit irrigation practice. Water Reports Paper No.22, FAO, Italy.

Food and Agriculture Organization (2008). Production Year Book. Food and Agriculture Organization, Rome, 68.

Guo, J.H., Liu, X.J., Zhang, Y., Shen, J.L., Han, W.X., Zhang, W.F., et al. (2010). Significant acidification in major Chinese croplands. Science, 327: 1008-1010. doi: 10.1126/science.1182570.

Guo, R., Hao, W.P., Gong, D.Z., Zhong, X.L., & Gu, F.X. (2013). Effects of water stress on germination and growth of wheat, photosynthetic efficiency and accumulation of metabolites. In: Soriano, M. H. (ed). Soil processes and current trends in quality assessment, Chapter 13, InTech., Rijeka, Croatia.

Hamid, D.J., Karim, N.N., & Mohsen, A. (2012). Effect of deficit irrigation regimes on yield, yield components and some quality traits of three bread wheat cultivars (*Triticum aestivum* L.). Intl J Agri Crop Sci., 4(5): 234-237.

IAEA (2000). Optimizing Nitrogen fertilizer application to irrigated wheat. TECDOC-1164.

Jansen, H., Hangsdijk, H., Dagnachaw Legesse, Tenalem Ayenew, & Spliethoff, P.H. (2007). Land and Water Resources Assessment in Ethiopian Central Rift Valley. Project: Ecosystem for water, food and economic development in for Ethiopian Central rift valley, Wageninge, Alterra, Alterra Report 1587.

Karim, A.J.M.S., K. Egashira, & M.J. Abedin (1997). Interaction effects of irrigation and nitrogen fertilization on yield and water use of wheat grown in a clay terrace soil in Bangladesh. Bull. Inst. Tropical Agric., 20: 17-26.

Maqbool, M.M., Ali, A., Haq, T., Majeed, M.N., & Lee, D.J. (2015). Response of spring wheat (*Triticum aestivum* L.) to induced water stress at critical growth stages. Sarhad Journal of Agriculture, 31(1): 53-58.

Nuru Seid et al. (2021). Response of bread wheat (*Triticum aestivum* L.) varieties to nitrogen fertilizer rates Series A. Agronomy, Vol. LXIV, No. 2.

Ottman MJ, & Pope NV. (2000). Nitrogen fertilizer movement in the soil as influenced by nitrogen rate and timing in irrigated wheat. Soil Sci Soc Am J., 64: 1883-1892.

Pradhan, S., Chopra, U.K., Bandyopadhyay, K.K., Singh, R., Jain, A.K., & Chand, I. (2013). Effect of water and nitrogen management on water productivity and nitrogen use efficiency of wheat in a semi-arid environment. International Journal of Agriculture and Food Science Technology, 4(7): 727-732.

Qiao, J., Yang, L., Yan, T., Xue, F., & Zhao, D. (2012). Nitrogen fertilizer reduction in rice production for two consecutive years in the Taihu Lake area. Agric. Ecosyst. Environ., 146: 103-112. doi: 10.1016/j.agee.2011.10.014.

Schroder, J.L., Zhang, H.L., Girma, K., Raun, W.R., Penna, C.J., & Payton, M.E. (2011). Soil acidification from long-term use of nitrogen fertilizers on winter wheat. Soil Sci. Soc. Am. J., 75: 957-924.

Shamsi, K., Petrosyan, M., Noor-Mohammadi, G., & Haghparast, R. (2010). The role of water deficit stress and water use efficiency on bread wheat cultivars. Journal of Applied Biosciences, 35: 2325- 2331.

Tavakoli, A.R., & Moghadam, M.M. (2012). Optimization of deficit irrigation and nitrogen rates on bread irrigated wheat at northwest of Iran. Intl J. Agri. Crop Sci., 4.

Wajid, A., A. Hussain, M. Maqsood, A. Ahmad, & M. Awais. (2002). Influence of sowing date and irrigation levels on growth and grain yield of wheat. Pak. J. Agri. Sci., 39(1): 22-24.

Irish Interdisciplinary Journal of Science & Research (IIJSR)
Volume 7, Issue 3, Pages 01-16, July-September 2023

Xiaojun Shen, Guangshuai Wang, Ketema Tilahun Zeleke (2020). Crop Water Production Functions for Winter Wheat with Drip Fertigation in the North China Plain. School of Agricultural and Wine Sciences, Charles Sturt University, Wagga Wagga, NSW 2650, Australia.

Zhao, S., Qiu, S., Cao, C., Zheng, C., Zhou, W., & He, P. (2014). Responses of soil properties, microbial community and crop yields to various rates of nitrogen fertilization in a wheat–maize cropping system in north-central China. Agr. Ecosyst. Environ., 194: 29-37. doi: 10.1016/j.agee.2014.05.0 06.

Zhu, G., Peng, S., Huang, J., Cui, K., Nie, L., & Wang, F. (2016). Genetic improvements in rice yield and concomitant increases in radiation and nitrogen use efficiency in middle reaches of Yangtze river. Sci. Rep., 6: 210-249.