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Bread wheat (*Triticum aestivum* L.) variety trials: farmer preference, adaptation, and performance in irrigable areas of Eastern Ethiopia

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ABSTRACT

Wheat is one of the most crucial and strategic food crops for the majority of the Ethiopian population. One of the key factors contributing to agricultural productivity growth is the expansion of Agricultural irrigation practices. The government extensively imported wheat, especially from Russia and Ukraine, in an effort to ensure food security, but these imports could not fully address the challenge. During the 2021/22 dry season, experiments were conducted in the Babile, Deder, and Gola Oda districts of the eastern Hararghe zone to promote the adaptation of bread wheat varieties to irrigation-based practices in different agro-ecological conditions. The experiment followed a lattice design with a factorial arrangement and three replications. Each plot measured 22 m long and 19 m wide, and 25 bread wheat varieties were grown across the three sites. The results indicated that the soil in these areas can retain essential plant nutrients in sufficient quantities. However, irrigation water salinity is high in Babile and Gola Oda, with sulfate-sodium chloride faces and a high alkaline risk. This highlights the need to enhance the timely availability of plant-essential nutrients and water. The adaptation of wheat varieties to different soil fertility, health, and water quality conditions varied across the agro-ecological study areas. Based on the analysis of crop varieties from the three sites, the Ogolcho, Boru, and Kulkulu varieties were identified as high-yielding and more stable in Gola Oda, Deder, and Babile, respectively. These varieties are considered adaptable to a wide range of agro-ecological conditions. The three varieties - Ogolcho, Boru, and Kulkulu - were identified as ideal in terms of yielding ability, stability, tolerance to moisture stress, and better agronomic performance during the multi-location evaluation.

Keywords: Wheat varieties, adaptations, soil and water quality, farmer preference, wheat yield

INTRODUCTION

Wheat agriculture plays an important role in economic growth, enhancing food security, consequently reducing poverty (Shiferaw *et al.,* 2013; Anteneh *et al.,* 2020). However, in many communities the farmers practice subsistence agriculture, depending on rainfall to ensure agricultural production, resulting in poor yields. The climate change effects have caused unprecedented losses in agricultural production (Gebrechorkos *et al.,* 2019; Rettie *et al.,* 2022). Wheat (*Triticum aestivum* L.) had been widely produced only by rainfed agriculture in the highlands and mid-altitudes of Ethiopia (Gebrechorkos *et al.,* 2019). However, in such areas the use of irrigation has been used. In the Ethiopia, the annual wheat production is about 5.8 million tons (mean productivity of 3 tons ha^{-1}) (CSA, 2021), which is below the expected mean yield for the crop (reaching up to 5 ha^{-1}) (Zegeye *et al.,* 2020). Wheat accounts for about 17% of total grain production in Ethiopia, making it the third most important cereal crop after teff and maize (CSA, 2021). Ethiopia's prospect of wheat self-sufficiency can be realized because of two favorable and realistic scenarios: increasing wheat productivity in the rain-fed agro-ecologies and expanding production to the irrigable lowland areas, where landholding size averages are high compared to their highland counterparts (Senbet and Worku. 2023). In Ethiopia, irrigation land is the secondary contributor to food production, but now, increasing the productivity of existing smallholder farmers and expanding large-scale production using irrigation be a practical solution to reduce the country's wheat imports.

Considering the information provided, starting from 2020, the Ethiopian government has been actively promoting irrigation-based bread wheat cultivation and seed production in order to improve local wheat production in the lowland agro-ecologies of the country. Several sources have highlighted issues such as insufficient extension services, inadequate water quality, and suboptimal irrigation water management in farmlands (Mihoub and Mokhtarim, 2016; Gedifew, 2022). Eastern Hararghe zone in eastern Ethiopia possesses favorable conditions, including moderate temperatures and rainfall, making it relatively suitable for wheat production. However, the practice of wheat irrigation is not widely known or practiced in this region. Introducing irrigation-based practices in areas where they are unfamiliar can present numerous challenges and constraints, hindering their adoption and expansion among local communities. Consequently, several studies have identified irrigation water management as a significant issue. Improper irrigation scheduling and a lack of knowledge regarding the appropriate timing and quantity of water application have emerged as key factors contributing to soil salinity and low productivity in many irrigation practices across the country (Etissa *et al.,* 2014; Hundie, 2020, Kibebew *et al.,* 2001b). Compounding the problem further is the lack of consensus on the extent of irrigated land, as different sources provide conflicting information on the matter, making it difficult to ascertain the accuracy of available data.

Enhancing wheat production and productivity in Ethiopia is crucial for ensuring food security and improving the well-being of farmers (Senbet and Worku. 2023). The adoption of all recommended production technologies is seen as a key driver in achieving these goals. However, recent studies have primarily focused on evaluating various wheat varieties, often overlooking the importance of considering the associated production technologies alongside them (Aklilu *et al.,* 2022). It is essential to recognize that the successful implementation of appropriate production technologies is integral to maximizing the benefits of different wheat varieties and achieving sustainable agricultural outcomes. This is, therefore, to promote the adaptation of bread wheat varieties irrigation-based practices in different agro-ecology of the eastern Hararghe zone.

MATERIAL AND METHODS

Site description

The experiments were conducted during the dry season of 2021/22 at Babile, Deder, and Gola Oda districts (Figure 1). The Babile District is located between 08°75’Nand 42°25’Eat an altitude of 1400 m above sea level, with minimum and maximum mean temperatures of13.3 and 28.1°C, respectively. Dader District is located between 09°19’N and 41°27’Eat an altitude of 2150 m above sea level, minimum and maximum mean temperatures of 12.3 and 27.4°C, respectively. Gola Oda District is located between 08° 24’Nand 41° 29’Eatan altitude of 1050 m above sea level, minimum and maximum mean temperatures of 15.3 and 29.6°C.

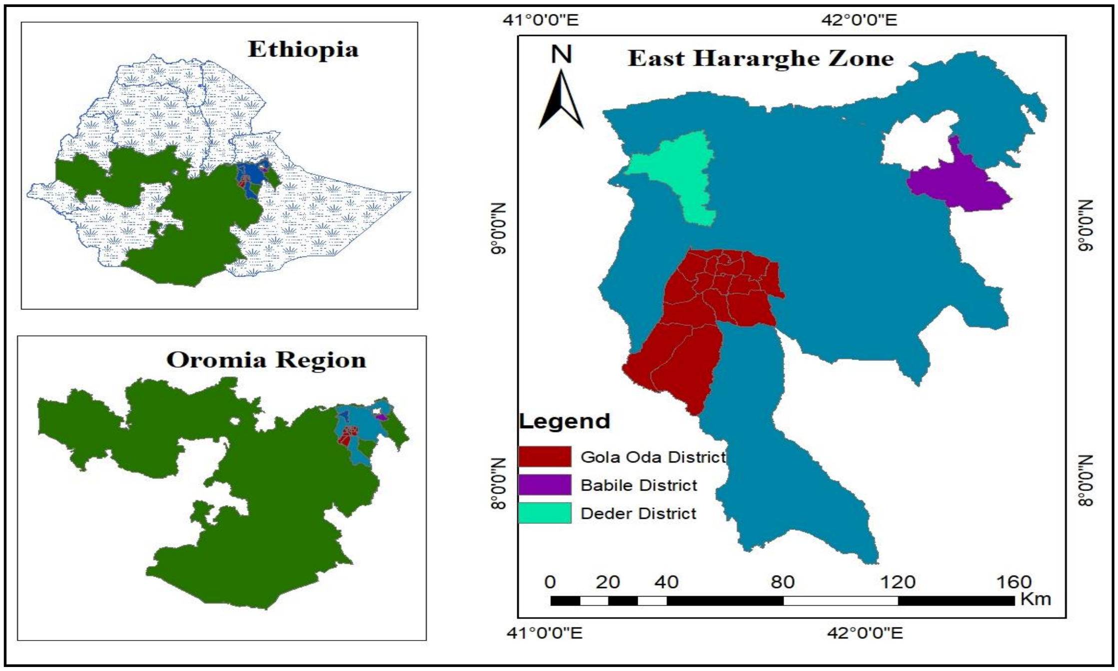

Fig. 1. Location of the study areas

Rainfall distribution of study areas:

The 40-year historical data of annual rainfall are shown in Figure 2, collected from the Ethiopian Meteorological Agency (EMSA, 2022). The distribution of rainfall in the study areas varied across the years (Abdisa *et al.* 2021). Based on the agro-ecology of the eastern Hararghe zone, we selected three sites: Deder (highland), Babile (midland), and Gola Oda (lowland). Agricultural rain performance was inadequate and ill-timed, with the spring ending two weeks earlier than usual and the summer starting a month later with uneven and erratic showers. Water stress is particularly acute in low-land areas, where most of the wheat yield is impacted due to poor irrigation management and other problems (Ameer *et al.,* 2009)

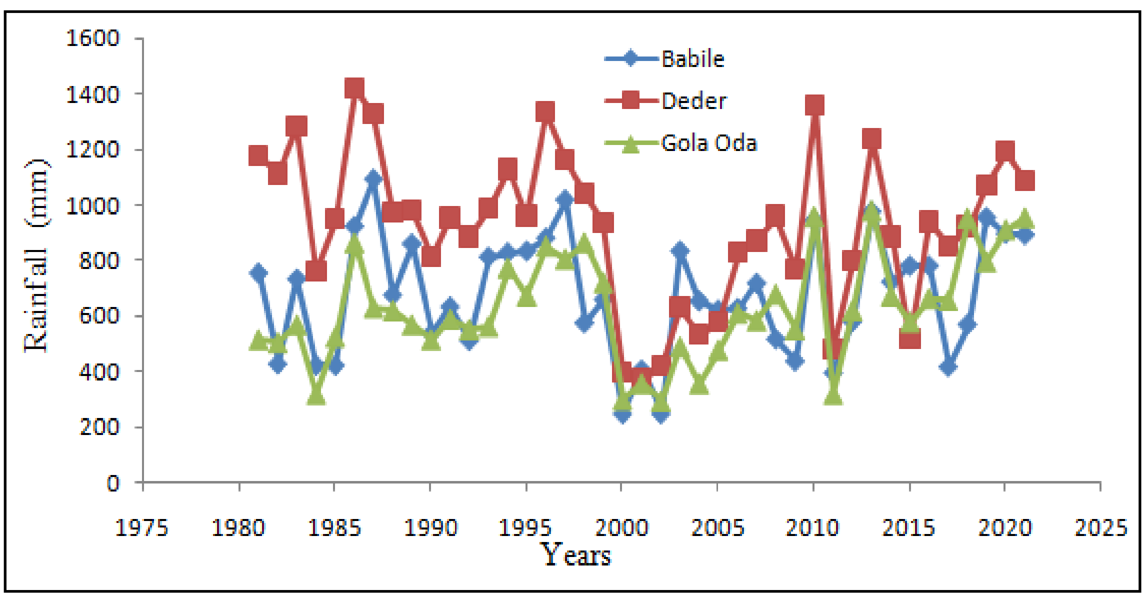

Fig. 2. Rainfall distribution of study areas (1981-2022).

History of wheat varieties

For research adaptation, these wheat varieties were collected from various agroecological zones across Ethiopia. Specifically developed to align with the unique conditions of diverse agroecological zones and seasonal variations, these bread wheat varieties ensure optimal adaptation and productivity. They were released under irrigation and rainfed seasons in different productivity over different years at various research centers (Table. 1).

Table 1. List of the history of bread wheat varieties released under different agro-ecology and seasons

TRT	Wheat variety	Place of released	Under irrigation/ rain fed released	Yield gained t ha^{-1}	
				Research Field	Farmers Field
V1	Abay	Kulumsa	Rain-fed	5.5	----
V2	Balcha	Kulumsa	Rain-fed	4.0-5.0	3.5-4.0
V3	Boru	Kulumsa	Rain-fed	5.2-7.0	4.9-5.3
V4	Dursa	Kulumsa	Rain-fed	5.1-6.2	4.2-6.1
V5	Deka	Kulumsa	Rain-fed	3.0-3.5	---
V6	Kakaba	Kulumsa	Rain-fed	3.3-5.2	2.5-4.7
V7	Kingbird	Kulumsa	Rain-fed	4.0-5.0	4.0-4.5
V8	Ogolcho	Kulumsa	Rain-fed	2.8-4.0	2.2-3.5
V9	Paven-76	Kulumsa	Rain-fed	4.0-4.5	3.5-4.0
V10	Shaki	Kulumsa	Rain-fed	5.0-7.0	4.5-5.5
V11	Shorima	Kulumsa	Rain-fed	2.9-7.1	2.3-4.3
V12	Wane	Kulumsa	Rain-fed	5.0-6.0	4.0-5.0
V13	Dendea	Kulumsa	Rain-fed	3.5-5.5	2.5-5.0
V14	Hawi	Kulumsa	Rain-fed	2.0-4.0	2.2-4.1
V15	Jaalanne	Haramaya	Rain-fed	4.5	2.7-3.2
V16	Kulkulu	Haramaya	Rain-fed	2.5-4.4	3.5-4.3
V17	Amibara	Werer	Irrigation	5.0-5.1	4.0-4.5
V18	Amibara-2	Werer	Irrigation	4.5-5.5	4.0-4.5
V19	Ardi	Werer	Irrigation	3.5-4.0	3.0-3.5
V20	Fentale	Werer	Irrigation	5.0-5.7	4.0-4.5
V21	Fentale-2	Werer	Irrigation	5.0-6.0	4.0-4.5
V22	Gaambo	Werer	Irrigation	3.5-5.7	4.5
V23	Gaambo-2	Werer	Irrigation	4.5-5.4	4.0-4.5
V24	Lucy	Werer	Irrigation	3.5-4.0	3.0
V25	Werer-2	Werer	Irrigation	3.5-4.0	3.0

Experimental design and growth conditions

The experiment was laid out in a lattice with three replications, consisting of the cultivation of 25 varieties of bread wheat (Table 1) in three different sites (Deder, Babile, and Gola Oda). Each plot had 22-m-long and 19-m-wide. The seeds were sown 22-11-2022 at a rate of 150 $kgha^{-1}$(36 $gplot^{-1}$). At planting and in the heading stage, 100 kg ha^{-1} (36 g $plot^{-1}$) of urea were applied. Every plot has roughly the same growing conditions. The growth stages of the plant and the harvest date spanned a total of 115 days. i.e., sowing, tillering, jointing, booting, anthesis, physiological maturity, and harvesting date, were registered accordingly. Comprehensive assessments for all parameters were conducted over a period of 115 dates.

Water Sampling and Preparation

Water samples were taken from different sampling sites along the river and other water bodies from the zones temporally and spatially from the three research sites. The Water samples were collected by mixing several portions (sub-samples) taken at five-minute intervals in order to obtain representative samples using a grab method. Acid washed polyethylene bottles (2 liters) were used to collect irrigation water samples for all the sample sites. The samples were transported to the laboratory (in and near the zones) in ice boxes containing water from the same source to maintain the temperature of the samples close to that of the in-situ temperature and analyzed for their chemical composition immediately.

Generally, the collection and handling of irrigation water samples were done in accordance with the procedure outlined by USDA Hand book No. 60 (Richards, 1954) and the US Salinity Laboratory Staff, (1954). Each of the water sampling points was registered using GPS. Important soil salinity parameters pH and ECe were measured at field using mobile soil testing kits. Soil samples were collected for laboratory analysis from fields that are suspected of salinity from the interpretation of field test results.

Disturbed and core samples soil samples were collected at a depth of 0-30 cm from representative sites. One composite sample was prepared for one wheat field selected for the selected kebeles. Disturbed samples were air dried, crashed and sieved through a 2 mm sieve. Sub-samples were ground to pass a 0.5 mm sieve for nitrogen and organic carbon analysis.

Soil Physical and Chemical Analyses:

Soil pH and electrical conductivity of soil saturated paste extract (ECse) were measured in the field using mobile soil testing kits (STH, USA). Based on the interpretation of these field tests, soil samples with saline characteristics were collected for laboratory analysis.

The soil samples were collected at a depth of 0-30 cm from representative sites. One composite sample was prepared for one wheat field selected. Samples were air-dried, crashed, and sieved through a 2 mm sieve. Sub-samples were ground to pass a 0.5-mm sieve for nitrogen and organic carbon analysis.

Soil texture was determined by the hydrometer method (Boyoucos, 1962; Ranst *et al.,* 1999). The bulk density of the soil was determined by the core sampling method (Blake, 1965), and soil water-holding at field capacity (FC) and permanent wilting point (PWP) was determined at -33.3 and -1500 kPa, respectively (Reeve and Carter, 1991) using sandbox apparatus. The available water-holding capacity of the soils was calculated as a difference between the water content at FC and PWP. Soil pHs in H2O were measured in 1:2.5 soil-water suspensions. ECse was determined using a conductivity meter. The cation exchange capacity (CEC (meq/100g soil)) was obtained by ammonium acetate saturation method. The exchangeable bases Na^+ and K^+(cmol (+)/Kg soil) were determined by flame photometandCa^{2+} and Mg^{2+}(cmol(+)/Kg soil) by ASS (Rowell, 1994). The exchange sodium percent (ESP) and sodium adsorption ratio (SAR) were calculated according to Equations 1 and 2, respectively.

$$\mathrm{ESP} = \frac{Na}{Ca + Mg + K + Na} * 100 \qquad (1)$$

$$SAR = \frac{\left(Na^{+}\right)}{\left(Ca^{2+} + Mg^{2+}\right)^{0.5}} \qquad (2)$$

The pH,Ece (µS/cm), ES, and SAR values were used for classification of soil salinity status of the farm land.

Crop Data Collection and Analysis:

The Crop data was collected from the middle rows in order to avoid border effect. Data regarding different components of growth yield and yield components like effective tiller, none effective tiller, plant height, spikelet number, spikelet length, biomass, yield moisture, thousand kernel weight, and days of maturity were recorded. While conducting field research, farmers evaluated different bread wheat varieties based on their own selection criteria by simply observing plant physiology. The farmers' selection process and the research results (agronomic rank and farmer rank) were subsequently compared and discussed.

Statistical analysis:

All data collected were organized using the Excel computer software (Microsoft Excel, 2016). The data were subjected to analysis of variance by F-test ($p \le 0.05$), and the means were compared using least significant difference (LSD) test ($p \le 0.05$). Analyzes were performed using the SAS computer package version 8.2 (SAS Institute, 2001).

RESULTS

Soils characterization in the study sites:

The soils of the experimental sites were classifieds low and slightly medium in organic carbon, the result found in range of (1.04–1.12) and total nitrogen contents (0.06-0.15) (Table 2). The cation exchange capacity of the soils was within the range of 22.8-26.7 cmolc kg^{-1}. As a result, the soil can retain essential plant nutrients in sufficient quantity. Overall, the soil requires environmentally friendly integrated soil fertility management to enhance the timely availability of plant-essential nutrients and water.

Table 2. Soil physicochemical properties analysis of the study areas

Study area	Study area	pH	EC (µS/cm)	% C	% OM	%N	Av.P (mg/Kg soil)	CEC (meq/100g soil)	Ca (cmol(+) /Kg soil)	Mg (cmol(+)/ Kg soil)	K(cmol(+)/Kg soil)	Na (cmol(+) /Kg soil)	$CaCO_3$	ESP
Deder	Deder	7.90	2.59	0.61	1.04	0.06	16.65	26.40	8.10	8.04	2.55	0.36	15.0	1.36
Babile	Babile	7.16	2.60	0.65	1.11	0.09	21.55	22.80	8.30	6.96	3.73	0.59	19.9	2.59
Gola Oda	Gola Oda	7.94	2.15	2.06	1.12	0.15	22.01	26.70	8.21	7.15	3.45	0.45	19.7	1.69

The means of electrical conductivity of soil saturated paste extract (ECse = 2.15-2.60 dSm^{-1}) was high; therefore, the soilsof the experimental areas were classified as saline (>2 dSm^{-1}) (SSDS, 2017). Consequently, it could interfere with the growth of most crops. Nonetheless, this soil contained a high calcium carbonate concentration ($CaCO_3$ = 15.02-19.65%) (Table 2**).**

The means of soils pH were high (7.16-7.94) (Table 3) and classified as slightly alkaline, at which the availability of several plant nutrients (phosphorous, boron, cobalt, copper, iron, manganese, and zinc) could be deficient and are expected to be limiting crop productivity. This implies that the soil pH is not a growth-limiting factor, but it is a good indicator of essential nutrient availability and beneficial microbial activities in the soil.

Table 3. Average BD, FC, PWP and TAW of the experimental site

Study area	FC	PWP	(FC-PWP) BD*dz (mm)	BD (gm/cm3)	% Sand	% Clay	% Silt	Textural class
Deder	20.5	12.1	279.72	1.11	70	17	13	Sandy loam
Babile	26.9	17.2	325.92	1.12	62	26	12	Sandy clay loam
Gola Oda	25.3	14.3	372.9	1.13	55.5	21	23.5	Sandy clay loam

TAW =(FC-PWP) *dz*BD where soil sample (dz) is taken from depth of 30cm

Due to high organic matter contents increased compaction level and can be considered as suitable for crop root growth. The soil moisture content at field capacity (FC) and permanent wilting point (PWP) also showed variation across the sites.

Water quality in the study sites

The results indicated that the pH of irrigation water samples from the three sites (Deder, Babile, and Gola Oda) was considered to be within the normal range (7.29-7.59) (Table 4). The chemical analysis of irrigation water shows a range of total dissolved salts (350-420) and electrical conductivity (791-825). According to Ayers and Westcot, 1985; FAO, 1999 and USLS, 1954 the irrigation water salinity is high, with a high alkaline risk. The irrigation system, management, depth of irrigation, and when and how to irrigate affect soil and crop yields in terms of quantity and quality. For this reason, comparing the effect of irrigation on soil salinity is important to preserve our resources in the ground against the degradation mainly caused by salinization.

Since irrigation water has sulfate or sodium chloride facies, the sodium, CaCO3 (Table 4), and chloride variations follow exactly the changes in the EC, therefore confirmed our results on the salinity of the soil.

Table 4. Water quality analysis of the study areas

Study area	pH	EC (µS/cm)	TDS (Mg/L)	Zn (Mg/L)	Ca (Mg/L)	Mg (Mg/L)	Na (Mg/L)	TSS (Mg/L)	SAR
Deder	7.29	791	500	0.043	2.80	2.46	9.82	350	9.87
Babile	7.59	823	700	0.086	3.98	2.49	9.91	420	11.02
Gola Oda	7.31	805	654	0.075	3.25	2.50	9.87	400	10.01

Wheat bread varieties adaptation and development during the three sites studied:
In the present study at the eastern Hararghe lowland area by the initiative of Haramaya University, the crop growth and yield components of wheat bread varieties were analyzed (Tables 5 to 7).
Some of the varieties released from the research station and farmer field sites are now more than good enough (Tables 5, 6, and 7). The tested wheat bread varieties significantly differed in their effective tiller, none effective tiller, plant height, spikelet number, spikelet length, biomass, yield moisture, thousand kernel weight, and days of maturity (Tables 5 to 7). However, some of the tested wheat bread varieties were statistically similar. For instance, biomass, yield moisture, and thousand kernel weight in the Gola Oda (Table 5), spikelet number and thousand kernel weight in the Deder (Table 6), and spikelet length and thousand kernel weight in Babile were statistically similar (Table 7).

Table 5. Agronomic traits performance of bread wheat varieties adaptation at Gola Oda District area

Variety	ET (per plot)	NET (per plot)	PH (cm)	SKN (No.)	SKL (cm)	BMY (kg)	SNP	MCS	TKW (gm)	DM (Day)	YLY (t ha^{-1})
Abay	4.55^{bac}	0.45^{edc}	36.50^{gf}	14.20^{bac}	3.00^{bdac}	1.00^{b}	38.50^{a}	9.85^{ebdagcf}	42.80^{ba}	88.50^{fe}	3.98^{bac}
Balcha	5.25^{ba}	0.40^{ed}	37.85^{egf}	14.35^{bac}	3.11^{bac}	1.50^{ba}	30.20^{bac}	10.55^{ebac}	42.15^{ba}	100.00^{a}	4.06^{bac}
Boru	4.55^{bac}	0.65^{bedc}	43.15^{bdac}	14.4^{5bac}	3.36^{a}	1.50^{ba}	28.50^{bac}	10.80^{ebac}	43.55ba	94.50^{d}	4.60^{bac}
Dursa	3.95^{bac}	0.70^{bedc}	38.80^{edgcf}	14.20^{bac}	3.12^{bac}	1.50^{ba}	33.50^{bac}	11.30^{ba}	46.60a	87.00^{hg}	4.54^{bac}
Deka	3.45^{c}	0.55^{bedc}	37.50^{egf}	13.70^{bac}	2.72^{ebdc}	1.00^{b}	35.60^{bac}	8.85^{egf}	40.35^{ba}	97.00^{bdac}	3.46^{dc}
Kakaba	3.60^{bc}	1.05^{ba}	43.05^{bdac}	14.50^{bac}	2.80^{ebdac}	1.50^{ba}	33.20^{bac}	8.30^{gf}	45.55ba	97.50^{bdac}	3.88^{bc}
Kingbird	3.40^{c}	0.60^{bedc}	40.65^{ebdacf}	14.75^{ba}	2.96^{ebdac}	1.50^{ba}	33.10bac	10.50^{ebac}	38.85^{ba}	99.50^{ba}	3.79^{bc}
Ogolcho	4.25^{bac}	1.30^{a}	44.10^{ba}	13.30^{bac}	3.10^{bac}	1.50^{ba}	36.80^{ba}	11.60a	45.85ba	99.50^{ba}	5.38^{a}
Paven-76	3.70^{bc}	0.70^{bedc}	43.55^{bac}	14.25^{bac}	2.42^{edf}	1.00^{b}	29.60^{bac}	10.30^{ebac}	43.00^{ba}	95.50^{dc}	4.15^{bac}
Shaki	4.05^{bac}	0.55^{bedc}	38.15^{edgf}	13.20^{bac}	2.79^{ebdac}	1.00^{b}	30.40^{bac}	10.55^{0ebac}	45.50ba	88.50^{fe}	4.48^{bac}
Shorima	5.45^{a}	1.05^{ba}	43.25^{bdac}	12.15^{c}	3.02^{bdac}	1.00^{b}	31.50^{bac}	11.05^{bac}	38.75^{ba}	99.50^{ba}	4.51^{bac}
Wane	4.65^{bac}	0.40^{ed}	36.85^{gf}	14.20^{bac}	2.35^{ef}	1.00^{b}	30.60^{bac}	9.50^{ebdgcf}	41.25^{ba}	84.50^{hg}	3.65^{bdc}
Dendea	4.30^{bac}	0.45^{edc}	44.95^{a}	14.25^{bac}	2.86^{ebdac}	1.25^{ba}	30.30^{bac}	10.90^{bdac}	45.10ba	100.00^{a}	4.08^{bac}
Hawi	4.95^{bac}	0.95^{bac}	43.85^{bac}	15.25^{a}	3.33^{ba}	1.75^{ba}	6.80^{ba}	10.80^{ebac}	42.90^{ba}	99.50^{ba}	3.88^{bc}
Jaalanne	4.75^{bac}	0.75^{bdc}	44.50^{ba}	13.80^{bac}	2.76^{ebdac}	1.50^{ba}	35.50^{bac}	11.10ba	42.60^{ba}	99.50^{ba}	4.16^{bac}
Kulkulu	5.25^{ba}	0.30^{ed}	44.25^{ba}	14.65^{ba}	3.22^{bac}	1.50^{ba}	38.50^{a}	9.85^{ebdagcf}	45.50ba	96.5^{dc}	4.68^{bac}
Amibara	4.55^{bac}	0.75^{bdc}	41.45^{ebdacf}	13.75^{bac}	2.77^{ebdac}	1.25^{ba}	30.10^{bac}	10.85^{bdac}	36.85 ^{b}	97.00^{bdac}	4.66^{bac}
Amibara-2	3.60^{bc}	0.55^{bedc}	43.60^{bac}	12.80^{bc}	2.60^{edc}	1.25^{ba}	29.80^{bac}	9.10^{edgcf}	42.15^{ba}	84.50^{hg}	4.14^{bac}
Ardi	3.75^{bc}	0.55^{bedc}	34.40^{g}	13.10^{bac}	1.83^{f}	1.25^{a}	25.20^{c}	7.30^{g}	45.30ba	74.50^{i}	2.33^{d}
Fentale	4.75^{bac}	0.20^{e}	42.10^{ebdac}	14.05^{bac}	3.04^{bdac}	1.00^{b}	32.00^{bac}	9.00^{edgf}	44.15ba	88.00^{feg}	4.37^{bac}
Fentale-2	4.50^{bac}	0.60^{bedc}	40.20^{ebdacf}	14.60^{ba}	2.80^{ebdac}	1.50^{ba}	30.60^{bac}	10.30^{ebac}	42.95^{ba}	85.00^{hg}	4.37^{bac}
Gaambo	4.20^{bac}	0.60^{bedc}	43.05^{bdac}	14.75^{ba}	2.97^{ebdac}	1.50^{ba}	30.10^{bac}	10.80^{ebac}	45.10ba	91.00^{e}	4.23^{bac}
Gaambo-2	5.00^{bac}	0.45^{edc}	39.75^{edcf}	13.05^{bac}	3.00^{bdac}	1.75^{ba}	26.40^{bc}	10.30^{ebac}	44.10ba	91.00^{e}	4.97^{ba}
Lucy	4.70^{bac}	0.70^{bedc}	43.70^{bac}	13.40^{bac}	2.99^{bdac}	2.00^{ba}	29.70^{bac}	10.20^{ebacf}	40.35^{ba}	98.50^{bac}	4.24^{bac}
Werer-2	5.00^{bac}	0.60^{bedc}	40.65^{ebdacf}	14.95^{ba}	2.41^{edf}	2.00^{ba}	32.70^{bac}	9.95^{ebacf}	38.25^{ba}	89.00^{fe}	4.85^{bac}
LSD	1.67	0.52	5.11	2.43	0.62	1.09	10.61	1.2	9.15		14.24
CV	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06		2.06
F test	**	**	**	**	**	**	**	**	**	**	**

Table 6. Combined mean grain yield and other agronomic traits performance of irrigated bread wheat varieties adaptation at Deder District area

TRT	ET (per plot)	NET (per plot)	PH (cm)	SKN (No.)	SKL (cm)	BMY (kg)	SNP	MCS	TKW (gm)	DM (Day)	YLY (t ha^{-1})
Abay	4.80^{bac}	0.20^{ba}	67.00^{f}	12.45^{ba}	2.78^{bdc}	0.75^{dc}	27.80^{b}	8.70^{a}	42.20^{ba}	93.00^{ebdc}	3.20^{gf}
Balcha	4.45^{bdac}	0.15^{ba}	74.25^{ebdcf}	13.05^{ba}	2.83^{bac}	1.00^{bac}	29.80^{ba}	7.85^{a}	38.80^{ba}	92.50^{edc}	3.83^{ebdgcf}
Boru	4.25^{ebdac}	0.15^{ba}	84.65^{a}	14.45^{ba}	3.09^{ba}	1.00^{bac}	35.00^{ba}	8.05^{a}	36.59^{ba}	93.50^{ebdac}	5.01^{ba}
Dursa	3.50^{edf}	0.50^{a}	79.00^{ebdac}	14.45^{ba}	2.74^{bdc}	1.00^{bac}	35.10^{ba}	8.05^{a}	42.80^{ba}	93.50^{ebdac}	3.4^{ebdg}
Deka	3.55^{edf}	0.45^{ba}	78.25^{ebdac}	12.90^{ba}	2.55^{dc}	0.75^{dc}	30.10^{ba}	9.10^{a}	44.50^{ba}	93.00^{ebdc}	3.8^{ebdgcf}
Kakaba	4.40^{bdac}	0.45^{ba}	80.75^{ebdac}	14.05^{ba}	2.78^{bdc}	0.75^{dc}	31.20^{ba}	9.15^{a}	41.55^{ba}	93.50^{ebdac}	4.4^{bdac}
Kingbird	3.75^{ebdcf}	0.35^{ba}	80.00^{ebdac}	13.25^{ba}	2.49^{dc}	1.00^{bac}	31.50^{ba}	8.05^{a}	35.50^{ba}	94.00^{ebdac}	3.88^{ebdgcf}
Ogolcho	3.70^{ebdcf}	0.50^{a}	80.75^{ebdac}	14.65^{a}	3.30^{a}	1.00^{bac}	37.70^{a}	8.60^{a}	37.40^{ba}	94.50^{bdac}	3.82^{ebdgcf}
Paven-76	3.80^{ebdacf}	0.30^{ba}	83.75^{ba}	14.60^{a}	2.81^{bac}	1.25^{bac}	36.5^{ba}	7.55^{a}	36.25^{ba}	92.00^{ed}	4.00^{ebdacf}
Shaki	4.05^{bdac}	0.20^{ba}	72.50^{edf}	13.70^{ba}	2.89^{bac}	0.50^{d}	31.60^{ba}	7.50^{a}	40.20^{ba}	91.50^{e}	3.65^{ebdgc}
Shorima	4.95^{a}	0.10^{b}	76.50^{ebdacf}	14.10^{ba}	2.70^{bdc}	1.00^{bac}	27.80^{b}	7.50^{a}	39.15^{ba}	93.00^{ebdc}	3.86^{ebdgcf}
Wane	4.10^{ebdacf}	0.35^{ba}	75.50^{ebdacf}	12.20^{b}	2.37^{d}	1.5^{ba}	29.10^{ba}	8.60^{a}	40.90^{ba}	91.50^{e}	4.30^{ebdac}
Dendea	3.45^{edf}	0.45^{ba}	84.50^{a}	14.55^{a}	2.75^{bdc}	1.25^{bac}	34.90^{ba}	7.60^{a}	39.85^{ba}	95.50^{ba}	4.92^{bac}
Hawi	3.20^{ef}	0.20^{ba}	81.00^{bdac}	13.55^{ba}	2.75^{bdc}	1.25^{bac}	31.60^{ba}	8.05^{a}	40.00^{ba}	93.00^{ebdc}	4.21^{ebdagcf}
Jaalanne	3.45^{edf}	0.30^{ba}	77.00^{ebdacf}	13.75^{ba}	2.65^{bdc}	1.75^{a}	32.40^{ba}	7.50^{a}	41.05^{ba}	96.00^{a}	5.21^{a}
Kulkulu	3.95^{ebdacf}	0.25^{ba}	82.50^{bac}	14.00^{ba}	2.97^{bac}	1.25^{bac}	32.90^{ba}	7.85^{a}	44.70^{a}	94.00^{ebdac}	4.29^{ebdacf}
Amibara	3.00^{f}	0.15^{ba}	79.75^{ebdac}	13.55^{ba}	2.60^{dc}	1.00^{bac}	29.90^{ba}	7.50^{a}	33.75^{ba}	95.00^{bac}	3.013^{g}
Amibara-2	3.65^{edcf}	0.20^{ba}	77.00^{ebdacf}	14.00^{ba}	2.74^{bdc}	1.00^{bac}	29.00^{ba}	7.70^{a}	35.50^{ba}	91.50^{e}	4.48^{bdac}
Ardi	3.55^{edf}	0.20^{ba}	71.00^{ebdac}	12.75^{ba}	2.58^{dc}	1.00^{bac}	29.60^{ba}	7.65^{a}	41.65^{ba}	77.00^{f}	3.1^{ebg}
Fentale	4.85^{ba}	0.20^{ba}	76.50^{ef}	13.85^{ba}	2.75^{bdc}	0.50^{d}	31.50^{ba}	7.85^{a}	44.25^{ba}	94.50^{bdac}	4.370^{ebdac}
Fentale-2	3.65^{edcf}	0.15^{ba}	73.25^{edcf}	14.00^{ba}	2.70^{bdc}	0.75^{dc}	37.65^{a}	8.40^{a}	42.85^{ba}	92.00^{ed}	3.94^{ebdacf}
Gaambo	3.70^{ebdcf}	0.35^{ba}	78.75^{ebdac}	14.45^{ba}	3.29^{ba}	1.00^{bac}	31.10^{ba}	7.50^{a}	39.00^{ba}	95.00^{bac}	4.26^{ebdagcf}
Gaambo-2	3.90^{ebdacf}	0.30^{ba}	75.25^{ebdacf}	13.70^{ba}	2.80^{bac}	1.00^{bac}	31.50^{ba}	7.55^{a}	37.65^{ba}	95.00^{bac}	4.34^{ebdac}
Lucy	3.75^{ebdcf}	0.45^{ba}	80.50^{ebdac}	13.90^{ba}	2.78^{bdc}	1.00^{bac}	33.10^{ba}	7.50^{a}	32.65^{b}	93.00^{ebdc}	3.69^{edgcf}
Werer-2	3.90^{ebdacf}	0.15^{ba}	73.25^{ebdc}	12.20^{b}	2.54^{dc}	1.00^{bac}	30.30^{ba}	7.65^{a}	34.650^{ba}	95.00^{bac}	4.49^{bdac}
LSD	1.16	0.40	10	2.06	0.49	0.61	9.73	1.88	11.85	2.99	12.72
CV	2.06	2.06	2.06	2.32	2.06	2.06	2.06	2.06	2.06	2.06	2.06
F test	**	**	**	**	**	**	**	**	**	**	**

Table 7. Combined mean grain yield and other agronomic traits performance of irrigated bread wheat varieties adaptation at Babile District area

TRT	ET (per plot)	NET (per plot)	PH (cm)	SKN (No.)	SKL (cm)	BMY (kg)	SNP	MCS	TKW (gm)	DM (Day)	YLY (t ha^{-1})
Abay	4.65^{ebdagcf}	1.55^{a}	61.40^{edgf}	12.45^{bdac}	3.30^{a}	0.50^{de}	30.40^{bdac}	7.55^{c}	38.15^{a}	86.50^{egf}	3.21^{bdc}
Balcha	4.65^{ebdagcf}	0.30^{b}	61.36^{edgf}	11.60^{bdc}	3.13^{ba}	1.00^{be}	29.30^{bdac}	7.60^{bc}	45.85^{a}	86.50^{egf}	2.62^{bdc}
Boru	5.40^{bac}	0.90^{ba}	68.95^{ebdac}	14.30^{ba}	3.47^{a}	0.75^{dc}	28.20^{bdc}	7.60^{bc}	44.00^{a}	88.00^{egdf}	3.62^{bdc}
Dursa	5.65^{ba}	0.95^{ba}	62.25^{edaf}	12.95^{bac}	3.30^{a}	0.65^{de}	30.00^{bdac}	8.00^{bac}	39.15^{a}	85.00^{gf}	3.70^{bdc}
Deka	5.75^{a}	0.70^{b}	73.80^{ba3}	12.95^{bac}	3.12^{ba}	1.15^{b}	33.00^{bac}	8.15^{bac}	42.25^{a}	96.50^{bac}	4.35^{bdac}
Kakaba	4.95^{bdac}	0.80^{b}	74.85^{bac}	13.00^{ba}	3.14^{ba}	1.20^{ba}	28.30^{bdc}	7.55^{c}	45.35^{a}	95.50^{bac}	4.62^{bac}
Kingbird	4.75^{ebdacf}	0.45^{b}	67.95^{ebdacf}	12.85^{bdac}	3.06^{ba}	1.10^{b}	28.50^{bdac}	7.55^{c}	40.80^{a}	97.00^{ba}	4.62^{bac}
Ogolcho	5.00^{bdac}	0.40^{b}	70.35^{ebdac}	13.80^{ba}	3.48^{a}	1.10^{b}	31.50^{bdac}	8.30^{a}	43.2^{a}	92.50^{bac}	3.78^{bdac}
Paven-76	4.65^{ebdagcf}	0.60^{b}	60.10^{edgf}	13.20^{ba}	3.02^{ba}	1.00^{bc}	29.70^{bdac}	7.60^{bc}	39.10^{a}	88.00^{egdf}	2.64^{bdc}
Shaki	4.55^{ebdgcf}	0.65^{b}	60.85^{edgf}	10.45^{dc}	3.06^{ba}	1.00^{bc}	29.20^{bdac}	7.60^{bc}	42.65^{a}	84.5.00^{gf}	32.00^{bdc}
Shorima	4.30^{edgcf}	0.55^{b}	65.80^{bdacf}	12.15^{bdac}	3.14^{ba}	1.00^{bc}	30.40^{bdac}	7.55^{c}	38.00^{a}	95.50^{bac}	3.76^{bdc}
Wane	3.75^{egf}	0.55^{b}	56.05^{g}	10.35^{d}	2.04^{ba}	0.50^{de}	24.50^{d}	7.60^{bc}	37.80^{a}	93.00^{g}	2.37^{d}
Dendea	4.20^{edgf}	0.60^{b}	71.20^{bdac}	12.60^{bdac}	2.86^{ba}	1.50^{a}	35.40^{ba}	7.50^{c}	48.15^{a}	97.50^{ba}	4.74^{ba}
Hawi	4.85^{ebdac}	0.95^{ba}	68.95^{ebdac}	12.90^{bac}	3.06^{ba}	1.00^{bc}	35.80^{a}	7.75^{bac}	42.55^{a}	88.00^{egdf}	45.78^{bac}
Jaalanne	4.55^{ebdgcf}	0.50^{b}	76.50^{ba}	14.10^{ba}	3.05^{ba}	1.00^{bc}	34.50^{bac}	7.60^{bc}	39.80^{a}	98.00^{a}	4.10^{bdac}
Kulkulu	4.20^{edgf}	0.30^{b}	78.00^{a}	13.85^{ba}	3.40^{ba}	1.50^{a}	35.80^{a}	8.25^{ba}	43.25^{a}	91.50^{edc}	5.89^{a}
Amibara	4.05^{edgf}	0.80^{b}	66.95^{ebdacf}	13.50^{ba}	3.00^{ba}	1.00^{bc}	33.10^{bac}	8.00^{bac}	40.70^{a}	94.00^{bac}	3.75^{bdc}
Amibara-2	4.30^{edgf}	0.35^{b}	63.70^{edacf}	12.60^{bdac}	2.77^{ba}	1.00^{bc}	32.10^{bac}	7.60^{bc}	42.60^{a}	85.00^{gf}	4.20^{bdac}
Ardi	3.75^{egf}	0.80^{b}	57.65^{gf}	12.15^{bdac}	3.00^{ba}	0.40^{e}	27.30^{dc}	7.65^{bac}	38.05^{a}	73.00^{h}	2.76^{bdc}
Fentale	3.50^{g}	0.75^{b}	64.00^{edacf}	11.90^{bdac}	3.00^{ba}	1.50^{bc}	30.70^{bdac}	7.65^{bac}	42.20^{a}	86.50^{egf}	3.0^{bdc}
Fentale-2	3.65^{gf}	0.50^{b}	61.15^{edgf}	12.15^{bdac}	3.00^{ba}	1.50^{bc}	28.20^{bdc}	7.65^{bac}	45.50^{a}	83.00^{g}	4.59^{bac}
Gaambo	3.70^{gf}	0.65^{b}	65.90^{bdacf}	12.50^{bdac}	3.23^{a}	0.50^{de}	34.50^{bac}	7.70^{bac}	39.40^{a}	91.50^{edc}	3.19^{bdc}
Gaambo-2	3.70^{gf}	0.45^{b}	59.15^{gf}	13.30^{ba}	3.22^{a}	1.25^{ba}	31.00^{bdac}	7.70^{bac}	38.65^{a}	95.50^{bac}	4.13^{bdac}
Lucy	3.70^{gf}	0.75^{b}	68.80^{ebdacf}	12.65^{bdac}	3.14^{ba}	1.25^{ba}	32.40^{bac}	7.55^{c}	39.40^{a}	88.50^{edf}	4.70^{bdac}
Werer-2	3.70^{gf}	0.75^{b}	65.25^{edacf}	12.05^{bdac}	3.00^{ba}	1.00^{bc}	31.30^{bdac}	7.60^{bc}	45.90^{a}	86.00^{gf}	4.11^{bdac}
LSD	1.13	0.69	11.26	2.06	0.756	0.33	7.40	0.69	10.80	5.20	2.11
CV	2.06	2.06	2.06	2.32	2.06	2.06	2.06	2.06	2.06	2.06	2.06
F test	**	**	**	**	**	**	**	**	**	**	**

Farmers' perceptions and variety ranking:

In the areas under study, farmers evaluated improved bread wheat varieties based on their own selection criteria. This can be a time-consuming process, but it is worth the effort to ensure a profitable harvest. Based on these, Ogolcho, Gaambo-2, and Werer-2 (Gola Oda District), Jaalanne, Boru, and Dendea (Dader District), and Kulkulu, Dendea, and Kingbird (Babile District) were the best varieties selected in the respective sites. The selected varieties were then multiplied and distributed to other farmers in the area. The following Tables 8 and 9 describes farmers' selection criteria and their perceptions (feedback) toward the varieties.

Table 8: Wheat varieties irrigation-based production evaluation and ranking by farmer selection criteria relatively compare

Woredas	Varieties	Farmers rank	Rank
Gola Oda	Ogolcho	**1st**	High tillering capacity, medium seed per spike, medium disease tolerant, high plant height, early maturing, high yield, good uniformity
	Gaambo-2	**2nd**	Medium tillering capacity, medium seed per spike, medium disease tolerant, high plant height, early maturing, medium yield, good uniformity
	Werer 2	**3rd**	Low tillering capacity, medium seed per spike, Low disease tolerant, medium plant height, early maturing, relatively low yield, low uniformity
Dader	Jaalanne	**1st**	High tillering capacity, high seed per spike, medium disease tolerant, high plant height, early maturing, high yield, good uniformity
	Boru	**2nd**	High tillering capacity, medium seed per spike, medium disease tolerant, low plant height, early maturing, medium yield, good uniformity
	Dendea	**3rd**	Medium tillering capacity, low seed per spike, low disease tolerant, medium plant height, relatively late maturing, low yield, not uniformity
Babile	Kulkulu	**1st**	High tillering capacity, high seed per spike, medium disease tolerant, high plant height, early maturing, high yield, good uniformity
	Dendea	**2nd**	High tillering capacity, medium seed per spike, low disease tolerant, medium plant height, early maturing, medium yield, better uniformity
	Kingbird	**3rd**	Low tillering capacity, medium seed per spike, low disease tolerant, low plant height, late maturing, medium yield, not uniformity

In terms of agronomic and farmer scores, the Kulkulu and Dendea wheat varieties received high ratings of the rank, indicating their excellence according to the farmers' evaluations (Table 9).

The Kulkulu and Dendea wheat varieties have emerged as top performers based on their agronomic and farmer scores, which were rated at the highest level of rank. This indicates that these varieties have demonstrated exceptional qualities and characteristics that are highly valued by the farmers.

Agronomic scores typically reflect the performance of a variety in terms of important agronomic traits such as plant height, tillering ability, lodging resistance, uniformity, and maturity. These traits are crucial for successful wheat cultivation and can greatly impact overall productivity and ease of management. The high agronomic scores obtained by Kulkulu and Dendea indicate that they have exhibited desirable characteristics in these aspects, making them attractive choices for farmers (Table 9). `

In addition to agronomic scores, farmer scores consider subjective assessments based on the farmers' own preferences and experiences. This can include factors such as taste, cooking quality, market demand, and other subjective considerations that may influence the farmers' decision-making process. The fact that Kulkulu and Dendea received top ratings in the farmer scores indicates that they have met or exceeded the farmers' expectations in terms of these subjective criteria.

Table 9. Wheat varieties irrigation-based production and ranking

Name of wheat variety	Gola Oda (t ha^{-1})	Deder (t ha^{-1})	Babile (t ha^{-1})	Average (t ha^{-1})	Agronomic rank	Farmer Score
Abay	3.98	3.02	3.21	3.40	34	3
Balcha	4.01	3.83	2.62	3.50	22	3
Boru	4.60	5.01	3.62	4.41	6	3
Dursa	4.54	3.43	3.70	3.89	17	4
Deka	3.46	3.81	4.35	3.88	18	5
Kakaba	3.88	4.42	4.62	4.31	8	5
Kingbird	3.79	3.87	4.62	4.09	12	5
Ogolcho	5.36	3.82	3.78	4.32	7	4
Paven-76	4.15	4.00	2.64	3.60	21	2
Shaki	4.48	3.65	3.20	3.78	20	3
Shorima	4.51	3.86	3.76	4.05	13	4
Wane	3.65	4.30	2.37	3.44	23	3
Dendea	4.08	4.92	4.74	4.58	2	5 **
Hawi	3.88	4.21	4.58	4.22	11	4
Jaalanne	4.17	5.21	4.10	4.49	3	5
Kulkulu	4.68	4.29	5.89	4.95	1	5 **
Amibara	4.66	3.01	3.75	3.81	19	4
Amibara-2	4.12	4.48	4.20	4.27	10	5
Ardi	2.31	3.12	2.76	2.73	25	2
Fentale	4.37	4.37	3.07	3.94	15	5
Fentale-2	4.37	3.94	4.59	4.30	9	5
Gaambo	4.22	4.26	3.19	3.89	16	3
Gaambo-2	4.97	4.34	4.13	448	5	4
Lucy	4.24	3.69	4.17	4.03	14	5
Werer-2	4.85	4.49	4.11	4.48	4	5

DISCUSSION

The soils at the experimental sites were coarse-textured, classified as sandy clay loam or clay loam. These soil types exhibit good infiltration rates and internal drainage, along with moderate water-holding and nutrient retention capacities (ISRIC, 2000; Hillel, 2004). The total available water (TAW), which represents the amount of water a crop can extract from its root zone, is influenced by variations in field capacity (FC), permanent wilting point (PWP), and root depth. This aligns with Allen et al. (1998), who described the typical soil water characteristics of sandy clay loam soils. The medium infiltration rate of sandy clay soil suggests that irrigation furrows can be designed to run efficiently across the length of the experimental field.

During the irrigation season, when water is plentiful for crop cultivation, the primary focus should be on enhancing the physical properties of the soil to make the most of this available water. A soil's water-holding capacity is a crucial characteristic that can significantly boost crop growth and yield. However, the need for amendments to soil and water quality indicates that underlying issues may be hindering crop performance despite good water retention. Surface and groundwater samples collected from three sites (Table 4) reveal that the quality of irrigation water directly affects soil health and the crops grown (Lessa *et al.,* 2023).

Salinity represents the most prevalent challenge, with approximately 10 million hectares of land being lost each year to this issue (Tanji, 1990). Moreover, it was slightly alkaline and slightly beyond the optimum range of pH values (6.3-7.5) for most crops (Landon, 2013). Consequently, effectively utilizing both agricultural land and irrigation water has become essential. Even when water quality falls within acceptable limits, it may still be subpar, and the long-term impact of inadequate irrigation practices can harm soil health and reduce crop yields. The quality criteria for irrigation of water are influenced by factors such as salinity, permeability, specific ion toxicity (especially sodium, measured by the sodium adsorption ratio or SAR), chloride, boron, and other components like nitrates, bicarbonates, and pH levels (Ayers and Westcot, 1985; Aboukila *et al.,* 2018; Tavares Filho *et al.,* 2022).

When evaluating bread wheat varieties, farmers typically consider yield potential, disease resistance, adaptability to local conditions, grain quality, and overall field performance (Bekele *et al.,* 2000; Belay *et al.,* 2006; Seiuf *et al.,* 2018).

The high scores achieved by the Kulkulu and Dendea varieties indicate their excellence in these critical areas (Table 9).

The superior yields from these irrigation-based wheat varieties can be attributed to their effective tiller production, plant height, spikelet length, number of spikes per spike, normal kernels per spike, and thousand kernel weights. This finding aligns with previous research by Chatterjee and Maiti (1985) and Zeleke *et al.* (2019), which highlighted that cereal crop yield attributes include the number of panicles per unit area, spikelet count per panicle, percentage of ripened spikelets, and thousand grain weight. Among these factors, the number of panicles per square meter is particularly correlated with grain yield and is a significant determinant of yield variation (Miller *et al.,* 1991; Thankur, 1993; Yigezu *et al.,* 2021). Kassa *et al.* (2003) and Alebachew (2012) also noted that grain yield and spike size are crucial criteria for farmers.

Farmers use criteria such as tillering capacity, seeds per spike, disease tolerance, plant height, early maturity, yield, seed quality, uniformity, and resilience against drought and environmental stresses to select the best varieties (Kassa *et al.,* 2002; Getachew and Jens, 2018; Vernooy *et al.,* 2022). This selection process is complex and requires careful consideration, urging farmers to consult with experts and conduct their own research to choose the most suitable varieties for their needs.

In Ethiopia, various bread wheat varieties have been adapted for off-season cultivation across diverse high, mid, and lowland areas, making it the second highest in productivity (Gebrie *et al.,* 2020). Although many improved varieties have been released, not all have been effectively disseminated (Shiferaw *et al.,* 2014). Successful farmer-led varietal selection has proven to be a sustainable and cost-effective approach to introducing improved crop varieties (Jabbar *et al.,* 1998; Kassa *et al.,* 2003; Vernooy *et al.,* 2022). This method empowers farmers to choose the varieties that best suit their local environments, enhancing yields and income while conserving the local ecosystem.

Such practices foster a sustainable agricultural cycle that benefits both farmers and the environment, helping to alleviate poverty and ensuring resilience against climate change and other threats. Ultimately, this leads to a secure and sustainable food system. The strong performance of the Kulkulu and Dendea wheat varieties suggests they have been well adopted in the research areas, making them promising options for farmers aiming to maximize their yields and success in wheat production.

The adoption of new approaches is closely linked to technology and problem-solving (Jabbar *et al.,* 1998; Chi & Yamada, 2002). According to Efa *et al.* (2023), the success of the current irrigated wheat initiative in Ethiopia has been supported by continuous access to agricultural inputs, financial assistance, tax exemptions for agricultural machinery, supportive policy frameworks, ongoing training for stakeholders, market access, and dedicated leadership.

CONCLUSIONS

Ethiopia faces significant challenges due to climate change, low agricultural productivity, and rapid population growth. The overall results from the experiments on various crop varieties showed promising performance under irrigation practices in the lowland regions of Ethiopia. The analysis of variance indicated that there was a highly significant difference in varieties, almost in all parameters measured in the three sites. Therefore, this study to enhance productivity through different wheat varieties' adaptation to new agro-ecologies is very important. This study examined the adaptation of wheat varieties to different soils and water conditions in contrasting sites in the eastern agro-ecological region of Ethiopia. Ogolcho, Boru, and Kulkulu varieties were considered high yielders Gola Oda, Deder, and Babile, respectively. Therefore, such varieties are adaptable to a wide range of agro-ecological conditions. Whereas the Kulkulu, Dandea, and Jalane varieties were selected as top farmers preferred crop varieties based on their selection criteria. In the eastern Ethiopian lowland area, the Kulkulu, Dandea, and Jalane varieties are recommended for production based on quantitative measurements of agronomic traits, such as grain yield and maturity date, as well as farmers' visual observations in the field. Farmers adopt varieties if they provide additional benefits to them such as better productivity, increased market value, and increased quality. These varieties have been developed with their full packages and are suitable for the region's rain-fed agricultural system. However, the currently widely grown varieties have been primarily developed for rain-fed agriculture. Therefore, further varietal development efforts should be undertaken to create new varieties specifically tailored for irrigated agriculture in the eastern Ethiopian lowland area.

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