Original Research Article

Adaptation and Promotion of Improved Beard Wheat (*Triticum aestivum L.*) Varieties Under Irrigation in North West Amhara, Ethiopia

ABSTRACT

Twenty-two bread wheat varieties eight of them were heat tolerant and fourteen bread wheat varieties released under rain feed were evaluated in two sets for adaptation and promotion of the best-adapted varieties (2020-2021) cropping season under irrigation at Metema and Belesa districts. The objective of this experiment was to identify and promote the best adapted, high yielder, and heat tolerance bread wheat varieties for different agro ecology irrigated production areas of the region. The experiments were conducted one year for a variety adaptation trial and a second year for demonstration of the best adapted, high yielding, and heat tolerance varieties from the two sets in the selected farmers filed under irrigation. The analysis of variance in both sets of experiments indicated that there was a highly significant difference (p<0.01) among the varieties for for most of the studied traits. The average mean of days to maturity for both sets was 92 days ranging from 80-96 days for heat tolerance & 83-97 days for released under rain feed. Early maturity was observed on the variety Ardi & kingbird (80 & 84 days) and late maturity was observed on the variety Werer-2 & Lemu (96 & 97 days) heat tolerance & rain feed respectively. The mean grain yield was 5670 kg ha-1in heat tolerance & 3954 kg ha-1 released under rain feed. The grain yield was ranged from 5167 kg ha-1 (Amibara-2) to 6212 kg ha-1, 6195 kg ha-1 (Werer-2 & Fentale-2) and 2814 kg ha-1, 2820 kg ha-1 (Kingbird & Hidasie) to 6094 kg ha-1, 5220 kg ha-1 (Ogolcho & Adet-1) heat tolerance & released under rain feed prospectively. Three best adapted & high yielder varieties from both trails were selected and promoted to participatory evaluation and promotion on different farmer’s fields. Grain yield showed a positive and highly significant correlation (P<0.01) with biological yield and thousand seed weight. There was also a highly significant (0<0.01) correlation (r=0.55, r=0.59, r=0.79 & r=0.46) between plant height with thousand seed weight, spike length, and biological yield and spikelets per spike. Days to maturity show a high and positive correlation (r=0.88) with the grain filling period. Therefore these traits could be used as indirect selection traits for grain yield according to the significance correlation suggestion. Farmers were also invited and evaluated the varieties based on their selection criteria during maturity time in both districts. Therefore, based on the analysis and farmers' preference, Fentale-2 was recommended for production with its full production packages under irrigation in the lowland areas of Gondar and other similar agro-ecologies.

Keywords: Bread wheat, Grain yield, Irrigation, Heat tolerance, Adaptation

1. INTRODUCTION

Wheat is the most important and is ranked second in its total production next to rice in the world. Its global production increased from 763.49 million metric tons in 2019/2020 and 775.82 million metric tons in the 2020/2021 production season with an increase of 18.63 million metric tons or growth at an average annual rate of 2.40% from last year [1]. It shares 14% of the total calorie intake in Ethiopia which makes it the second most important food behind maize and ahead of teff and 'Enset' and ranks third after teff and maize in area coverage and second after maize in its total production. It also ranks third in its productivity (30.46 quintals per hectare) after maize and rice [2].

Ethiopia is the second-largest wheat-growing area in SSA next to South Africa covering an area of more than 1.67 million hectares with a productivity of 27.36 quintals/hectares [3]. Wheat is the important staple crop in Ethiopia and ranked 4th in area and production of total grain crops which has increased production mainly by smallholder farmers using a rain-fed-based production system [3]. It is an important staple food in the diets of many Ethiopians, providing an estimated 12% of the daily per capita caloric intake for the country's over 90 million population [4].

The potential lowland areas of Ethiopia especially the irrigated agroecology is not yet utilized as much as possible for improved wheat varieties and other main food crops to contribute their share to the national production, food security, and economic growth with existing resources. Over the last decade, the continual wheat research and technology generation, demonstration, and popularization in some lowland irrigated areas were very promising that showed the production potential for wheat. The progress in irrigated wheat varieties release and related development works can justify the possibility of utilizing the existing resources and opportunities [5].

The efficient way to attain the goal of improved variety dissemination in a short time could be the participation of end-users in wheat crops technology generation, adaptation, and adoption tasks which helps to achieve the required impact and improve the livelihoods of people. It is estimated that the average productivity of wheat is increased from 28 quintals/ha to 50 quintals/ha in rain-fed and irrigation farming systems respectively predicting that wheat self-sufficiency can be achieved while cultivating the crop using irrigation[6] which agrees with the approval that irrigation agriculture improves agricultural productivity [7].

Nowadays, irrigation farming is identified as an important catalyst for increased agricultural growth in Africa [8], and expanding the countries' irrigation potential can improve agricultural productivity and extend annual growing seasons reducing poverty, food insecurity, and import dependency with an individual and the collective action by governments, the private sector, and communities in rural and urban areas [9].

It has been also confirmed that bread wheat cultivation under irrigation has a positive impact on the crop's yield [7] directing the possibility of improving the current national rain-fed wheat productivity (2.8 ton/ha which is lower than the world average of 33 quintals/ha) by using improved irrigation wheat cultivation techniques that the government of Ethiopia has embarked on its goal to achieve wheat self-sufficiency within 3-5 years by expanding production in the irrigable lowland areas and increasing productivity in the rain-fed agro-ecologies of Ethiopia [10]. During the 2020/2021 cropping season, project-based irrigated wheat production has been successfully carried out in 12 woredas of Amhara regional state (on almost 5,000 hectares of farming land) and 21 woredas (on almost 300, 000 hectares of farming land) of Oromia regional state[11].

The wheat research system of Ethiopia has been working to generate yield enhancement of improved varieties along with their full production packages to assist wheat-producing farmers of the country. Ethiopian Institute of agricultural research in collaboration with its strategic partners has long been striving to change the production system of wheat by developing its production technologies suitable for the irrigated lowland areas of the country in sequence with cotton and soybean by showing that the irrigated wheat in Ethiopia is the untapped resource.

Werer agricultural research center of the Ethiopian agricultural research center is the coordinating center for lowland irrigated wheat research and with the effort of the research teams working on the center's irrigated wheat research program and other collaborative staff of the institute seven bread wheat and one durum wheat lowland irrigated varieties have been released & it has been shown that improved packages of high-yielding, heat, and stress-tolerant wheat varieties could yield up to 6.5 tons per hectare in hot lowland irrigated areas of Ethiopia. Therefore, the objective of this study was to identify and demonstrate the best adapted and heat tolerance bread wheat varieties for different agro ecology irrigated production areas of the region.

2. MATERIALS AND METHODS

2.1 Description of the study area

The field experiments were conducted in the lowland of West Gondar at Metema and Belesa for two consecutive years (2020-2021), one year for adaptation and the second year for demonstration irrigation seasons, and in the mid-land of Central Gondar at Belesa for one year (2022) irrigation season. The first area is located with a latitude of 12° 38' N and a longitude of 36° 41' E at an altitude of 760 masl. The second area is located with a latitude of 13° 12' N and a longitude of 38° 8' E at an altitude of 1500 masl (NMSABB, 2022). The weather data **(**temperature, relative humidity, sunshine hours per day, and ultra-violate index) of both locations were collected from National Meteorology Station Agency Bahir Dar Branch as shown in Table 1.

Table 1. Weather conditions of Metema and Belesa by month

Months	Metema						Belesa					
	Max T° (°C)	Min T° (°C)	Mean T° (°C)	RH (%)	Sun hours per day	UV-index	Max T° (°C)	Min T° (°C)	Mean T° (°C)	RH (%)	Sun hours per day	UV-index
Jan	39.1	31.7	35.3	39.4	12.0	6	28	14	21	37.5	10	6
Feb	39.5	31.3	35.8	32.3	12.0	6	30	16	23	30.7	10	6
Mar	43.3	36.7	40.4	33.1	11.9	6	30	17	24	31.5	10	6
Apr	43.0	30.0	40.0	34.7	11.8	6	30	18	24	33.0	10	6
May	40.4	31.8	36.7	55.4	11.7	6	28	18	23	52.7	10	6
Jun	39.2	27.3	32.9	70.5	11.2	5	25	16	21	67.0	10	5
Jul	30.6	23.2	26.3	84.4	10.8	4	22	14	18	80.2	8	4
Aug	29.0	22.9	26.0	88.4	10.7	5	22	14	18	84.0	8	4
Sep	29.7	24.6	27.3	82.7	11.1	5	24	14	19	78.6	10	5
Nov	33.0	26.3	30.5	73.6	11.5	5	26	14	20	70.0	10	5
Oct	37.5	31.4	33.6	62.4	11.8	5	27	14	21	59.3	10	5
Dec	38.1	29.4	35.3	49.9	11.9	5	27	13	20	47.4	10	6

Source: NMSABB (National Meteorology Station Agency Bahir Dar Branch) report in 2022.

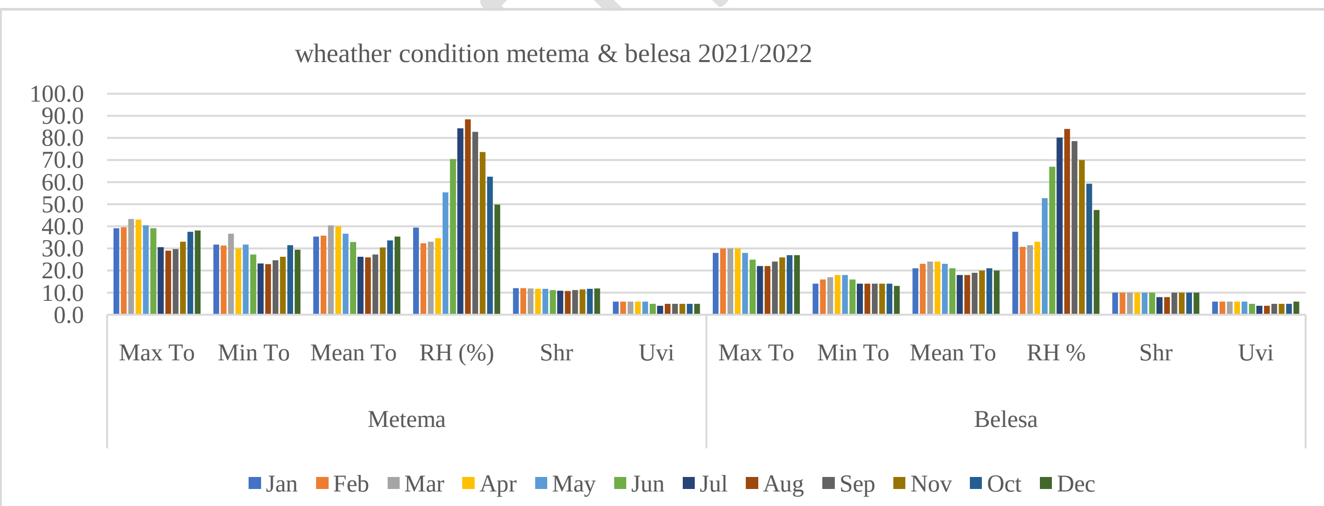

Fig 1. Graphical representation of weather conditions in 2020/2021 at Metema and Belesa districts

2.2 Plant Materials

Totally twenty-two bread wheat varieties of which eight heat tolerance/released under irrigation bread wheat varieties along with the standard checks (Fentale 1) and Fourteen bread wheat varieties which are released under rain feed conditions along with the standard checks (Kekeba) were evaluated in two separate sets based their history of released agroecology for yield and yield-related traits under irrigation in the Amhara region (Table 2). The experiment was laid out using a randomized complete block design (RBD) with three replications for both trials.

Table 2. List of bread wheat varieties released under irrigation/heat tolerance and released under rain feed conditions for variety adaptation trial under irrigation in the Amhara region.

No	Variety	Year of Release	Target Agro-Ecology	Released center	Released Under
1	Werer 2	2013	lowland	Werer	Irrigated
2	Fentale 1	2015	lowland	Werer	Irrigated
3	Fentale 2	2017	lowland	Werer	Irrigated
4	Amibara 1	2015	lowland	Werer	Irrigated
5	Amibara 2	2017	lowland	Werer	Irrigated
6	Luci	2013	lowland	Werer	Irrigated
7	Ardi	2019	lowland	Werer	Irrigated
8	Ga'ambo	2011	lowland	Werer	Irrigated
1	Ogolcho	2012	Midland	Kulumsa	Rain-fed
2	Hibist	2018	Mid/low	Srinka	Rain fed
3	Deka	2018	lowland	Kulumsa	Rain-fed
4	Netsanet	2020	Mid/high	Srinka	Rain fed
5	Sora	2013	Moisture deficit	Srinka	Rain fed
6	Hidasie	2012	Mid/high	Kulumsa	Rain fed
7	Kingbird	2015	Highland	Kulumsa	Rain-fed
8	Wane	2016	Mid/high	Kulumsa	Rain fed
9	Lemu	2016	High	Kulumsa	Rain fed
10	Alidoro	2007	High	Holeta	Rain fed
11	Kakaba	2010	Low/mid	Kulumsa	Rain fed
12	Dendea	2010	Mid/high	Kulumsa	Rain fed
13	Tay	2005	Mid/high	Adet	Rain fed
14	Adet 1	2020	Mid/high	Adet	Rain fed

2.3 Experimental Design and Procedures

Both sets of the adaptation experiment were conducted in a randomized complete block (RCBD) design with three replications at the Metema irrigation research site. A total plot size of 10.5m^2 (2.8m*3.75m), consisting of eight rows per plot, and a net plot size of 4.5m^2 (1.2m*3.75m), with six harvestable rows was used. Distance of 2m, 0.5m, and 0.2m was used between replications, plots, and rows respectively. 0.4m was used for the furrow to water. A seed rate of 125kg/ha was used and sown by hand drilling at a 20cm row interval. A fertilizer rate of 100/200kg/ha of NPS and UREA was applied. The application system of fertilizer was all NPS and half urea was applied at planting and the rest of urea was applied at the full tillering stage of the crop growth.

All appropriate agronomic practices such as weeding, watering, and protection management practices were done as the crop required. The irrigation was applied at 7-10 days intervals using the furrow method. Irrigation was provided using a river stagnant water resource to provide the essential moisture for normal crop growth. Therefore, the amount of irrigation water to irrigate each experimental plot was applied using generator and pump irrigation, which was installed in the experimental site and the amount of water was measured using a soil squeezed method to test soil moisture manually and visual soil texture observation.

2.4 Data Collection

Phenological and growth traits

Days to heading (days): The number of days was recorded from the date of emergency to the stage when the spikes of 50% of the plants are fully visible (exerted). **Grain filling period (days):** The grain filling period in days was computed by subtracting the number of days to heading from the number of days to maturity. **Days to physiological maturity (days):** It was calculated as the number of days from emergence to 95% maturity that is the number of days to maturity minus the number of days to emergence.

Yield and yield component traits

Plant height (cm): The average height of ten plants randomly taken from each plot at physiological maturity and measured from the ground to the tip of the panicle excluding the awns. **Biological yields (kg/ha):** It was recorded by weighing the total above-ground yield harvested from the four central rows of each experimental plot at the time of harvest. **Thousand kernels weight (gm):** The weight of one thousand randomly taken kernels from each experimental plot. **Grain yield (kg/ha):** The grain yield per plot was measured in grams using a sensitive balance after the moisture of the seed is adjusted to 12.5%. The total dry weight of grains harvested from the four rows was taken as grain yield per plot and expressed as a ton per hectare for analysis. **Kernels per spike:** The number of kernels per spike was counted from ten randomly taken plants and the average was worked out**.** **Spikelet per spike:** The number of spikelets per spike was counted from ten representative spikes per plant and the average was worked out. **Spike length (cm):** The average spike lengths of ten plants on the main Culm from the base of the spike to the top of the last spikelet excluding awns.

2.5 Promoted Technologies

Technologies introduced and transferred to the farmers and expertise were different bread wheat varieties, the optimum rate of fertilizers, planting methods, and irrigation frequency.

Fertilizer rate: Optimum fertilizer rate for bread wheat production under irrigation was identified in the district but applied Adet Agricultural Research Center (AARC) recommended that 200kg/ha Urea were applied. NPS was applied at planting time and the UREA was applied half at planting and the remaining after 45 days of planting. All agronomic practices like tillage (2-3 times), weeding (1-2 times), and disease and pest management were applied based on recommendation.

Irrigation Interval: Irrigation frequency was applied every 4-5 days for the first 3 weeks of establishment, and after that irrigate every 7-10 days intervals for the Belesa district and 5-7 days intervals for the Metema district.

Variety: The varieties that were demonstrated in the districts were Adet-1, Ogolcho, Kekeba, Worer-2, Fentale-2, and Ardi. The respective researchers selected these varieties on participatory variety selection trials based on productivity, disease reaction, and maturity date.

Planting method and seed rate: The crop was planted on a raw planting method with 20cm row spacing. 125kg/ha seed rate was applied.

Some participant farmers: Eight host farmers were selected based on their interest and probability of success and failures of irrigation wheat technology adoption. These host farmers were selected together with the district office of agriculture.

2.6 Statistical Analysis

Analysis of variance (ANOVA) was computed to test the presence of significant differences among the genotypes for studied traits. The data were collected for each quantitative trait and would be subject to analysis of variance using R-studio version 4.2.2. Fishers protected least significant difference (LSD) at 1% and 5% level of significance will be used for mean comparisons, whenever the Analysis of Variance (ANOVA) result showed a difference among genotypes for traits. In the demonstrations, the collected data were analyzed by simple descriptive statistics like mean, minimum, maximum, and percentage, and also Partial budget analysis, a sensitivity analysis was done.

3. RESULTS AND DISCUSSIONS

The analysis of variance (ANOVA) showed that there was a highly significant ($p<0.01$) difference among the varieties of most of the studied traits. The significant difference among the bread wheat varieties for the traits indicates the presence of genetic variation among the varieties which is important for easily selection of varieties for improving both yield and quality traits. Similarly, [12] reported that there is considerable genetic variability existing for quantitative and qualitative traits in bread wheat varieties.

Day to heading and days to maturity: days to heading were found to be highly significant ($p\leq0.01$) among the tested verities for both trial sets. The mean of the heading days was found to be 57.83 days. Among the tested verities, the earliest heading days were observed on varieties Ardi and Deka (43.67 &

49.67 days), and the earliest maturity days were recorded from Ardi (80 days) and Kingbird (84 days) to heat tolerance and rain feed respectively. These varieties were registered relatively earlier dates of heading and maturity as compared to the other varieties. This indicates these varieties are early maturing genotypes in which they mature 90 days after sowing. The variations influence directly grain yield which means the shortest days to maturity are forced to yield penalty and Vis versa. This help to plan our breeding program by grouping varieties that are early and late maturing. [12] reported that the physiological maturity of the wheat crop was delayed in the early sowing date but it depended upon the prevailing weather conditions and genetic composition of the variety.

Late days to heading were recorded from variety Luci (70.67 days) and Lemu (64 days) the latest days to maturity were recorded from variety Lucy (98.67 days) and Lemu (97.33 days) for heat tolerance & rain feed respectively. According to the report made by [13], changes in mean temperatures can shorten the time to maturity of a crop, thus reducing yield. This is due to the reason that rising temperatures will decrease the length of the grain-filling period of wheat and other small grains [14]. Increases in temperature above 25 to 35oC during grain filling of wheat will shorten the grain filling period and reduce wheat yields [15]. When these temperature increases are extrapolated to the global scale a 5.4% decrease in wheat yield per 1 C^{o} increase in temperature is expected [16].

Table 3. The mean values of all phenological yield and yield-related traits of heat tolerance bread wheat varieties

Varieties	DSH	GFP	DSM	PH	SPL	SPS	KPS	BY	GY	TSW
Werer 2	61.00	35.33	96.33	80.46	8.88	13.79	45.00	13841.00	6212.80	35.14
Fentale 1	59.67	35.00	94.67	85.75	10.13	15.88	49.63	13548.00	5436.80	36.40
Fentale 2	53.67	37.00	90.67	89.63	10.00	15.67	40.17	14151.00	6195.10	42.59
Amibara 1	58.67	34.67	93.33	90.67	10.21	15.63	49.46	14024.00	5610.30	35.89
Amibara 2	56.33	34.33	90.67	85.46	10.04	15.38	47.96	12048.00	5167.50	37.92
Luci	70.67	28.00	98.67	89.92	9.79	15.92	46.04	14603.00	5667.60	36.11
Ardi	43.67	36.33	80.00	82.55	9.04	13.34	38.59	10032.00	5526.70	42.09
Gambo	59.00	36.33	95.33	88.84	10.75	16.79	49.21	12937.00	5549.60	41.97
Mean	57.83	34.63	92.46	86.66	9.86	15.29	45.78	13147.82	5670.81	38.51
CV	2.43	8.04	3.48	4.37	6.02	4.54	4.36	10.26	6.88	2.81
LSD	2.46	4.88	5.64	6.63	1.04	1.22	3.49	2363.40	683.56	1.88
Sig	***	ns	***	*	*	**	***	**	**	***

Plant height, spike length, and sparklets per spike and kernels per spike: The tested heat tolerance bread wheat varieties were significantly differed (P<0.05) in their plant height and spike length and highly significant variation observed (p<0.01) for rain feed varieties. However, the tested varieties of both sets were highly significant (P<0.01) spikelet per spike and number of kernels per spike. Gambo (10.75 cm), Fentale-1 (10.13 cm), Amibara-1 (10.11), Ogolcho (11.17), Alidoro (11.79), and Adet-1 (10.08) bread wheat varieties registered higher spike length, plant height and number of spikelet per spike while Ardi, Werer-2, Deka, Kingbird, Wane varieties produced lower plant height (82.55, 80.46, 79.42, 79, 77.42cm), spike length (9.04, 8.88, 9.58, 9.25, 8.29 cm), number of spikelets per spikes (13.34, 13.79, 14.04, 15.63, 14.63) and number of kernels per spike (38.59, 45.00,) in the order of heat tolerance and rain feed respectively. From rain feed varieties Alidoro and Dendea had the highest plant height 95.4 cm followed by the vaiety Ogolcho & Netsanet (93.4 cm and 88.8 cm respectively. This result might be attributed to the suitable temperatures beside other environmental conditions that encouraged the growth and early development of plants. The results are in harmony with those obtained by [17] who stated that sowing earlier seemed to be more favorable for producing the tallest plants compare to later sowing dates.

A minimum temperature above (20 0C) caused a decrease in spikelet fertility, grains per spike, and grain size [15]. Therefore, the wheat production period in the lowland area of the Amhara region will be from November to February with a minimum temperature of 13.9-20 ^{0}C has highly coincided with the standard given by [15] which approved that 20 ^{0}C is comfortable for filling spikelets and florets to produce largely sized grains. But exposure shows to >30 ^{o}C temperatures for only 2 to 3 dates before anthesis can create small unfertilized kernels with symptoms of parthenocarpy, small shrunken kernels with notching and chalking of kernels [18].

Biological yield: there was a high significance (p<0.01) among the tested varieties for biological yield in heat tolerance bread wheat varieties while non-significant variation from rain feed varieties. The mean value of biological yield for heat-tolerance tested wheat varieties is 13147.82kg/ha. The highest biological yield was recorded from variety Luci (14603 kg/ha) followed by Fentale-2 and Amibara-1 (14151 &14024 kg/ha) respectively. While the lowest biological yield is obtained from the variety Ardi (10032 kg/ha) followed by Amibara-2 and Gambo (12048 & 12937) respectively. This result indicated/confirmed that heat tolerance bread wheat varieties were more favorable, productive, and high-yielding varieties in the lowland areas of both in biological and grain yield as compared to rain feed varieties.

Grain yield (kg/ha): There was a highly significant difference (p≤0.001) among the tested varieties in both sets in grain yield (Tables 3 & 4). Grain yield was taken after the harvest of wheat genotypes and measured at the standard moisture content (12.5) of wheat. The mean grain yield heat tolerance varieties were 5670.81kg ha-1 & 3953kg ha-1 in rain feed. In heat tolerance varieties the highest grain yield was observed from variety Werer-2 (6212.80kg/ha) followed by varieties Fentale-2 (6195.10), Luci (5667.60 kg ha-1), and Ogolcho (6093 kg ha-1) followed by variety Adet 1 and Wane (5220 and 4334 kg ha-1) in rain feed respectively. While the lowest grain yield was found to be variety Amibara-2 (5167.50kg ha-1) followed by varieties Fentale-1 (5436.80), Ardi, (5526.70kg ha-1) in heat tolerance varieties and kingbird (2814 kg ha-1) followed by varieties Hidasie and Alidoro (2820 and 3125 kg ha-1) in rain feed respectively (Table 3 & 4), this may be due to their lowest number of plant height, spikelet length, number of spikes per spike and number of normal kernels per spike. While the reasons for getting the highest mean grain yields from these varieties are due to their highest effective tiller production, plant height, spikelet length, number of spikes per spike, number of normal kernels per spike, and thousand kernels weight. This result coincides with the result reported by [14], in which yield attributes of cereal crops consists of the number of panicles per unit area, the number of spikelets (florets) per panicle, the percent (ripened) spikelet, and the thousand grain weight. Among all the yield attributes of wheat, panicle number per m^2 is highly correlated with grain yield and it is the most important factor that causes variation in grain yield [19]. They have also shown earlier times of heading and maturity periods. This confirmed the result of [20] that found early heading genotypes could perform better compared to latter heading cultivars where heat stress or high temperature occurred after anthesis due to the reason that early heading cultivars have a longer post-heading period enabled them to have greater grain filling period and completed their grain filling earlier when the air temperature is lower which is more favorable by escaping the most severe effects of heat stress compared to later heading genotypes.

Table 4. The mean values of all Phenological yield and yield-related traits of bread wheat varieties release under rain feed conditions

Varieties	DSH	GFP	DSM	PH	SPL	SPS	KPS	BY	GY	TSW
Ogolcho	57.00	35.00	92.00	93.42	11.17	16.25	50.25	12119	6093.70	42.69
Hibist	55.33	35.00	90.33	79.88	9.92	16.05	55.84	7270	3490.40	35.36
Deka	49.67	42.00	91.67	79.42	9.58	14.04	49.83	6929	4202.30	40.95
Netsanet	56.67	33.67	90.33	86.88	9.59	15.13	45.25	8095	3368.30	40.98
Sora	53.67	39.67	93.33	81.75	9.50	14.88	42.50	7444	3970.50	35.86
Hidasie	56.33	30.33	86.67	82.25	9.25	16.46	46.13	8683	2820.30	35.21
Kingbird	54.33	29.33	83.67	79.00	9.34	15.63	50.21	7230	2814.40	29.74
Wane	50.33	41.67	92.00	77.42	8.29	14.63	46.29	9214	4334.10	33.32
Lemu	64.00	33.33	97.33	84.54	9.96	15.67	42.91	10381	3822.40	37.91
Alidoro	57.67	34.33	92.00	95.92	11.79	17.63	49.17	10405	3125.50	37.71
Kekeba	54.33	37.33	91.67	84.05	9.67	15.59	45.337	9317	3807.50	35.18
Dendea	58.67	37.00	95.67	95.04	9.59	16.04	37.837	10802	4224.60	43.93
Adet 1	60.33	32.00	92.33	83.71	10.08	15.33	44.58	9349	5220.20	37.49
Mean	56.28	35.36	91.64	88.45	9.86	15.71	47.01	9108.28	3953.85	37.29
Cv	2.78	20.79	7.89	6.06	3.78	7.56	7.71	23.10	5.97	5.93
Lsd	2.62	12.34	12.14	8.69	0.63	1.99	6.08	3531.4	396.42	3.71
Sig	***	ns	**	***	***	ns	***	ns	***	***

Thousand seed weight: Thousand Kernels' weight showed a highly significant difference ($p \leq 0.001$) among the tested varieties. The mean thousand Kernels weight was 38.81gm and ranged from 35.14gm to 42.09gm (Table 3). The highest thousand Kernels weight was observed in variety Fentale-2 and Ardi (42.59 and 42.09gm) followed by the varieties Gambo, Amibara-2, Fentale-1, and Luci (41.97, 37.92, 36.40, and 36.11gm) respectively. While the lowest thousand Kernels weight was observed in varieties Amibara-1 and Werer-2 (35.89 and 35.14gm), respectively. According to the rain feed bread wheat varieties the highest thousand seed weight values were obtained from variety Dendea (43.9 g) and Ogolcho (42.7 g) while the lowest thousand seed weight were recorded from varieties Kingbird (29.7gm followed by variety Wane (33.3gm). Thousand seed weights increased early sowing date might be due to the suitable and longer environmental conditions for vegetative growth, which resulted in the active photosynthesis and maximum translocation of assimilates to the grains and thus had heaviest grains. These results are in agreement with those obtained by [21] who reported that under late sowing, a reduction in 1000-grain weight could be attributed to the reduction in grain filling period. Flour industrialists attach special importance to thousand seed weight since there is a significant positive correlation between this trait and flour yield [22].

Correlation of Traits

Correlation coefficients between the different pair of yield traits of the tested wheat varieties were calculated to find out the relationship among the various yield traits studied as presented in below, fig 2.

As shown in the above figure, grain yield shows a positive and highly significant correlation ($P<0.01$) with biological yield and thousand seed weight while it shows a non-significant ($p<0.05$) correlation with the date of heading, spike length, number of spikelet per spike and number of kernels per spike. Similarly, a thousand kernels weight showed a positive and highly significant correlation ($P<0.05$) with plant height, biological yield, days to maturity, mean grain yield, and spikelet per spike of the tested varieties. This result is in agreement with the result of Blanco et al. (2001) who found a significant positive correlation between thousand seed weight and grain yield ($p<0.05$) in four out of six populations of hexaploidy wheat. There was also a highly significant ($0<0.01$) correlation ($r=0.55$, $r=0.59$, $r=0.79$ & $r=0.46$) between plant height with thousand seed weight, spike length and biological yield and spikelet per spike which is also similar to the finding of [23]. However, mean grain yield was positively but non-significantly ($p<0.05$) correlated ($r= 0.23$) with spike length which is in contradiction with the result of [24] who reported as spike length was negatively correlated with grain yield ($r=- 0.13$). Therefore, these traits could be used as indirect selection traits for grain yield according to the significance correlation suggestion.

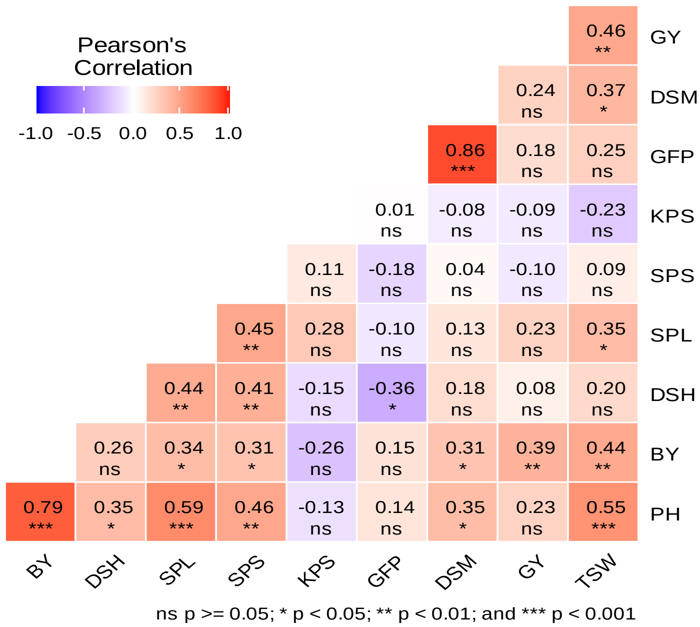

Fig 2. The correlation of traits among the tested bread wheat varieties under irrigation

4. Promoted Technologies

4.1 Awareness creation activities

Farmers Research Extension Group (FREG): Two FREGs were established in Metema and Belesa Districts. The FREG members have evaluated the technology based on their crop selection criteria.

Training: On-farm practical training was given to participant farmers and stakeholders about wheat production under irrigation.

Table 5. Number of training participants

District	FREG			District expert			Kebele expert			Researcher			Total
	M	F	T	M	F	T	M	F	T	M	F	T	
Belesa	27	3	30	2	0	2	4	3	7	4	0	4	43

This evaluation aimed were conducted at each district with the collaborations of WOA and Gondar Agricultural Research Center. The field day was organized at the maturity stage of the crop. During the field day, stakeholders were involved like farmers, governmental officials, and different experts and they discussed the opportunities and challenges of wheat production and marketing under irrigation.

Table 6. Field day event participants

District	Farmers			District expertise			Kebele expertise			ARARI			Researchers			Total
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	

Belesa	52	7	59	0	0	0	4	3	7	5	0	5	8	0	8	79
Metema	25	5	30	2	0	2	3	2	5	0	0	0	4	0	4	41

Note; M = male, F = female, and T = total

Technology Evaluation

Technology evaluation is a very important task to increase farmers' research participation level that is used to generate appropriate and easily disseminated technology in the area. FREG members (52 male and 8 female) did technology evaluation by setting their selection criteria. The criteria were spick length, maturity date, plant height, head size, and tillering. The FREG members have been ranked for each selection criterion.

Table 7. Rank of selection criteria

Selection criteria	Rank	**Weight**
Spick length	1	5
Plant height	5	1
Head size	3	3
Tillering capacity	4	2
Maturity date	2	4

After setting the rank of each criterion the FREG members gave, a score for the treatment based on each selection criteria from one up to 5 scores and weighted the criteria to select the best technology. Based on the above-listed selection criteria FREG members have selected Fentale-2, Kekeba, and Ogolcho varieties as the first, second, and third selected varieties in Belesa district.

Table 8. Weighted rank of the technology at Belesa district

Variety	Selection criteria					Total score	Rank
	Spick length	Plant height	Head Size	Tillering capacity	Maturity date		
Adet-1	1*5=5	2*1=2	1*3=3	1*2=2	1*4=4	16	5
Ogolcho	1*5=5	1*1=2	1*3=3	1*2=2	1*4=4	16	5
Kekeba	2*5=10	2*2=4	2*3=6	1*2=2	2*4=8	30	2
Ardi	1*5=5	2*2=4	1*3=3	2*2=4	3*4=12	28	3
Fentale-2	3*5=15	3*2=6	3*3=9	3*2=6	3*4=12	48	1
Worer	1*5=5	1*2=2	1*3=3	3*2=6	1*4=4	20	4

Grain Yield

Yield is the major parameter to evaluate the varieties of both technology generation programs and technology promotion. The collected yield data from each demonstrated plot were presented in the following table.

Table 9. Bread wheat mean grain yield ton/ha, 2021

Variety	Mean grain yield kg/ha		
	Metema	Belesa	Mean
Ogolcho	2150.3	2915.6	2532.5
Kekeba	3012.9	3405.55	3208.4
Adet-1	2487.8	3106.7	2796.5
Aridi	2450.3	3019.4	2734.5
Werer 2	2762.4	3214.3	2988.6
Fentale 2	2625.7	4177.9	3401.9

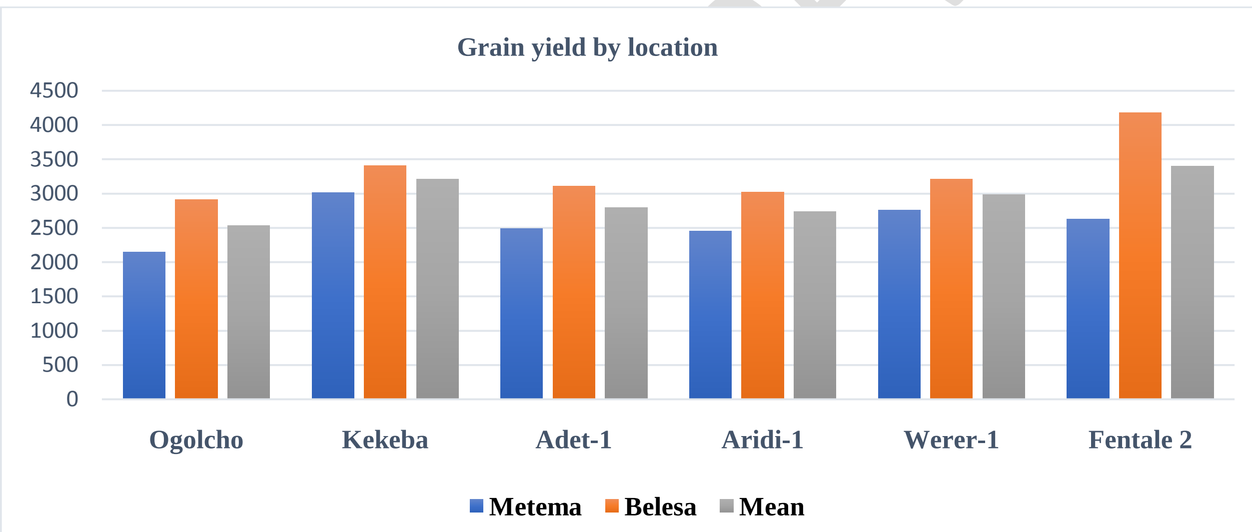

Fig 3. Grain yield performance of bread wheat varieties demonstration by location and its mean

5. CONCLUSIONS AND RECOMMENDATIONS

The analysis of variance indicated that there was a highly significant difference ($p<0.01$) among the varieties almost in all parameters measured in both sets. In the heat, tolerance varieties Fental-2 and Werer-2 were the outstanding variety in all parameters and had grain yields of 6195.10 and 6212.80 kg ha-1 to the standard check Fentale-1. From varieties released under rain feed conditions Ogolcho and Adet-1 were high-yielding varieties. Fentaale-2 also showed the consistent and best performance in the adaptation and also from the demonstration across years and locations in mean grain yield and other yield-related traits. Farmers also selected Fentale-2 as the first from both locations during field evaluation. Grain yield showed a positive and highly significant correlation ($P<0.01$) with biological yield and thousand seed weight. There was also a highly significant (0<0.01) correlation from (r=0.55) to (r=0.79) between plant height with thousand seed weight, spike length and biological yield, and spikelets per spike, these traits could be used as indirect selection traits for grain yield according to the significance correlation suggestion. More than 90% of the farmers who were asked during a field visit to evaluate the performance of the heat tolerance bread wheat varieties said that they were new to the technology of producing the wheat with irrigation, which at first was quite impressive. However, they were shown field performance during the maturation phase, and they approved and confirmed wheat production by irrigation. Additionally, they examined the variations in the field and chose and observed the best-performing bread wheat varieties based on their performance in the field. Because of early maturing ability and yield performance Fentale-2 and Werer-2 varieties can produce under irrigation so, farmers preferred the technology. Farmers and extension workers were motivated by the demonstrated technology and awareness creation activities. Because of the high demand for technology, pre-scaling-up activities should be proposed for the coming irrigation season in Metema and Belesa districts.

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