



Grain yield Performance Evaluation of Bread Wheat (*Triticum aestivum* L.) Varieties in East Gojjam Zone

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Abstract

Bread wheat is the most important cereal crop in the world and a staple food for more than one-third of the world's population. However, its production and productivity are significantly decreased due to a lack of improved and adaptable variety, inadequate management techniques, biotic and abiotic variables, and other factors. To address these challenges, recently released high-yielding improved varieties alongside a standard check, were evaluated and selected high-yielding, and best-performance bread wheat varieties to improve the crop yield over two years (2020 and 2021) in two districts (Machakel and Gozamin) of East Gojjam Zone through using Randomized Complete Block Design with three replications. SAS 9.4 was used to examine their quantitative parameters and showed significant differences in all parameters across years and locations, except for the productive tiller number. Variety, location, and year interactions significantly influenced all bread wheat varieties. Significant differences in phenology and growth characteristics were observed among bread wheat cultivars. Danphe exhibited the largest biomass at 10.83 t/ha, the tallest spikes measuring 10.17 cm, and the highest tiller number at 5.64, demonstrating exceptional adaptability. The variety Danphe achieved the highest combined mean grain yield (3.66t/ha⁻¹), followed by Ogolcho (3.14 t/ha⁻¹), which explained their best performance among the tested varieties. Gozamen was identified as a high-yielding environment compared to the relatively low-yielding Machakele. The study concludes that specific bread wheat varieties, particularly Danphe, exhibit superior adaptability and performance in Northwestern Ethiopia. It recommends the promotion of these varieties to improve bread wheat production and advises ongoing adaptability assessments to sustain crop productivity under varying environmental conditions.

Keywords: Adaptable, Bread wheat, Grain Yield, Performance evaluation, Variety.

1. Introduction

Bread wheat (*Triticum aestivum* L) is a self-pollinating, allopolyploid annual plant that

belongs to the Gramineae (Poaceae) family of true grasses. It is widely cultivated as a staple food source worldwide (Arya, 2022; Tadesse *et al.*, 2018). Bread wheat originated

from three subgenomes: A, B, and D, with a genomic composition of BBAADD and a chromosome number of $2n=6x=42$ (Rosyara *et al.*, 2019). Currently, there are approximately 25,000 different cultivars of bread wheat globally (Benavente, 2021). This crop is highly adaptable, thriving in tropical, sub-tropical, and temperate regions. Wheat is cultivated between latitudes of 6–16° N and latitudes of 35–42° E, at altitudes up to 3,300 m.a.s.l., with an optimal range between 1,900–2,700 m a.s.l. (Watira, 2016). Ideal germination occurs at a temperature of 20–25°C; However, wheat seeds can germinate at temperatures of 3.5 to 35°C. Physiological maturity requires a temperature of 14–15°C (Nahusenay & Kibebew, 2015).

Wheat is the second-most important crop for basic foods, following tef (Berhan & Bekele, 2021). A third of the global population relies on wheat grains for subsistence (Senbeta & Worku, 2023). It serves as a significant energy source with high nutritional value, particularly in terms of protein (Mitiku *et al.*, 2018). Wheat seeds are nutrient-rich, containing 1.72% fat, 12% protein, 69.6% carbohydrate, and 27.2% minerals (Madhu *et al.*, 2018). This crop is vital for nutrition and is key to achieving national agricultural policies and food self-sufficiency (Dibaba & Goshu, 2019). Consequently, it stands as a focal point in the planned pursuit of a national food independence program.

Wheat ranks 3rd in total production after tef and barely contributes 17.71% to Ethiopia's cereal crop production (ESS, 2022; CSA, 2022). Globally, wheat is one of the most cultivated crops, covering approximately 223 million hectares and producing about 778.6 million tons of grain in the 2021/22 cropping season (FAO, 2022). In Africa, wheat is

grown on an estimated 10.4 million hectares, yielding around 29.7 million tons, with Ethiopia cultivating about 1.87 million hectares and achieving a grain yield of approximately 5.8 million tons during the same period (ESS, 2022). The Amhara region is a significant contributor, accounting for 33.1% of national production and covering 37% of the area. Specifically, the East Gojjam Zone represents about 24.1% of the Amhara region's wheat area coverage and 27.6% of its total production (ESS, 2022). Wheat productivity has been significantly hindered by the reliance on local varieties and the repeated cultivation of a single improved variety, Kakaba, over several years. The yields achieved through this practice are considerably lower than the potential of other improved varieties, underscoring a major limitation in optimizing wheat production systems (Anteneh and Asrat, 2020; Zegeye *et al.*, 2020). Ethiopia's regional and national agriculture research institutions have released several bread wheat cultivars (Degife and Demis, 2022). However, most of these varieties were not evaluated country-wide, including in areas of the northwestern regions of Ethiopia due to logistical challenges associated with multi-location trials, a lack of cooperation among research institutions, and limited resources, the effective evaluation and optimization of wheat varieties across different environments is significantly hindered (Damtie *et al.*, 2022; Delesa *et al.*, 2022; Kefale and Menzir, 2019).

Although Ethiopia's research organizations have released a significant number of bread wheat cultivars, there is limited knowledge regarding their performance and adaptability to various environmental conditions

(Semahegn *et al.*, 2021). The over-reliance on local varieties and a small number of improved cultivars, such as Kakaba, has resulted in inadequate productivity compared to the potential of newer varieties. This lack of thorough evaluation across the country's agroecological zones has restricted the widespread adoption of high-yielding and adaptable cultivars due to poor variety-environment matching (Tadesse *et al.*, 2022). To enhance wheat production, food security, and resilience to environmental variability, it is essential to develop targeted intervention measures based on solid knowledge of the performance and adaptability of various cultivars (Mekonnen *et al.*, 2020). To solve these problems, the evaluation and selection of bread wheat varieties are compulsory to increase productivity and total production in the country. Therefore, the present

investigation evaluated and selected high-yielding, and best-performance bread wheat varieties to improve the crop yield in the East Gojam Zone in northwestern Ethiopia.

2. Materials and Methods

2.1. Description of study area

The research was conducted in the 2020 and 2021 main cropping season of wheat growing areas of East Gojjam Zone, Ethiopia, specifically in Machakel, and Gozamin, at the farmer's training center. In Machakel and Gozamin, the main soil types are red soils and vertisols, with a pH of 5.5 to 6.5 and organic matter content of 2.0% to 3.5%. The experimental sites were selected based on their history of precursor crops and fertility status.

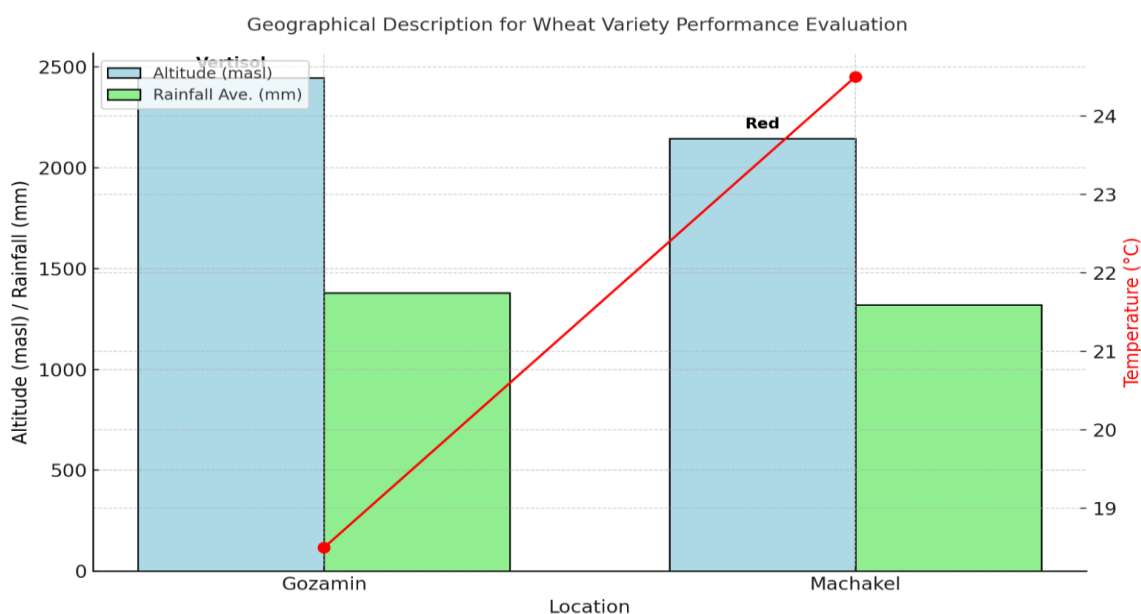


Figure 1. Geographical description of the study area.

Where: Alt: Altitude, Temp.: temperature, and RF.: Rainfall

2.2.Experimental Plant Materials

Five improved bread wheat varieties were collected from the Ethiopian Institute of Agricultural Research's Kulumsa Agricultural Research Center (KARC). The experimental trial including five improved bread wheat varieties along with a standard check variety (Kekeba) was used and conducted at two districts of East Gojjam Zone, including Machakel, and Gozamin for two consecutive cropping years (2019/20 and 2020/21). The descriptions and their passport data of the varieties used in the experiments are summarized below (Table 1).

replications, using plot sizes of 3.6 m² (2 m x 1.8 m). Each plot comprised nine rows, 2 m in length and spaced 0.2 m apart, with 0.5 m between plots and 1 m between blocks. Wheat seeds were sown manually at a rate of 150 kg/ha. Fertilization involved 200 kg/ha of urea and 100 kg/ha of NPSB blended fertilizer, applied uniformly across seasons and locations. At sowing, 100 kg/ha NPSB and 67 kg/ha ($\frac{1}{2}$ of urea) were applied, while the remaining 133 kg/ha urea was applied at late tillering (35 days after sowing). Standard agronomic practices were followed per the wheat production manual.

2.3.Experimental Design and Trial Management

The experiment followed a randomized complete block design (RCBD) with three Table 1. The descriptions of the varieties.

No	Name varieties	Breeder Center	Year of release	Productivity (tha ⁻¹)		Suitable Agro-ecology		
				On station	On-farm	Rainfall	Alt (m.a.s.l)	Long and lati
1	Ogolcho	KARC	2012	3.3-5.0	3.0-3.5	500-1000	1800-2700	39.17 ° E & 7.07 ° N
2	Wane	KARC	2016	3.0-4.0	2.1-2.3	600-1000	1900-2700	39.45 ° E & 7.3 ° N
3	Lemu	KARC	2016	3.5-4.5	2.8-3.5	500-800	1800-2600	39.23 ° E & 7.53 ° N
4	Kingbird	KARC	2015	3.6-5.3	3.0-3.8	600-1000	2000-2800	39.27 ° E & 8.53 ° N
5	Kekeba	KARC	2010	3.3-4.2	2.3-3.0	500-900	1800-2600	39.63 ° E & 9.12 ° N
6	Danphe/ Danda'a	KARC	2010	4.0-5.5	3.3-4.0	600-1000	- 2000-2800	40.15 ° E & 7.3 ° N

Where: KARC: Kulumsa Agricultural Research Center, Alt: altitude, masl: meter above sea level, RF: rainfall, Long: Latitude: and lati: Longitude.

Source: Amara Regional Research Office (ARAR) and Ethiopian Institute of Agricultural Research (EIAR)

2.4.Data Collected

Days to 75% heading, days to 90% maturity, biomass yield, grain yield, and harvesting index were recorded on plot bases. The number of productive tillers, number of spikelets per spike, plant height, and spike length were recorded as plant-based traits from ten randomly selected plants at times scheduled, following standard procedures for each parameter. The disease does not happen during the field experiment.

2.5.Data Analysis

To demonstrate the existence of significant variations across varieties for various parameters with year and location, the Combined Analysis of Variance (ANOVA) was computed. The data collected for each trait were analyzed using Proc GLM procedures of SAS version 9.4 (SAS Institute, 2013). Following ANOVA testing, which indicates significant differences among varieties, mean comparisons were conducted using Fisher's least significant difference (LSD) test at a 5% significance level. This means that at the 5% level, the LSD test was used to separate the means of the different varieties to determine which ones were significantly different from each other.

3. Results and Discussion

3.1.Combined Analysis of Variance (ANOVA)

The combined ANOVA of two cropping years with two location results revealed that the traits were highly significant ($P \leq 0.01$) to the varieties of bread wheat (Table 2). Crop variety revealed highly significant differences on days to heading and maturity (DH & DM), plant height (PH), spike length (SL), number of tillers (NT), grain and biomass yields (GT & BY), and harvest index (HI). The year was highly significant to DM, PH, SL, NSPS (number of spikelets per spike), and GY meanwhile significant ($P < 0.05$) to plant height. The location had a highly significant influence on the DH, PH, SL, BY, HI, and GY while significant to DM and NSPS. The combined effect of location and year showed a highly significant influence on the DH, DM, PL, BY, and GY, meanwhile significant to the number of the tiller. As shown in Table 2, the combined effect of location and variety had a highly significant influence on the DH, DM, HI, and GY but significant to PH and BY. The interaction of variety and year had a highly significant influence on the DH, PH, HI, and GY, meanwhile significant to TN and NSPS.

Furthermore, the interaction effect of year, variety, and location had a highly significant influence on DH, DM, PH, BY, GY, and HI whereas significant on SL (Table 3). The significant interaction among location, variety, and year on key wheat characteristics indicates that annual variability and environmental factors greatly influence the performance of different varieties. This

underscores the importance of conducting evaluations across multiple locations and years to identify cultivars that consistently perform well. Generally, the combined analysis revealed that bread wheat genotypes had shown significant variations on most parameters of the crop. In line with these findings, previous studies have also reported similar results, demonstrating significant variation among wheat varieties regarding traits such as days to heading, maturity, plant height, and yield components (Gebrie *et al.*, 2022). This underscores the importance of evaluating varieties across diverse environments to identify those that exhibit optimal performance.

Significant variation in agronomic characteristics among bread wheat types highlights the crucial role of genetic variability in performance. Traits such as the number of tillers, spike length, plant height, days to heading and maturity, grain yield, biomass yield, and harvest index exhibited notable differences, indicating the potential for selecting cultivars tailored to diverse environmental conditions. The study also revealed that environmental factors, including year and location, significantly influenced variety performance, suggesting that some cultivars may be better suited for specific regions or climates while others demonstrate greater adaptability. The observed variability emphasizes the need to test cultivars in different locations and years to identify those with stable performance, crucial for developing adaptable high-yielding varieties.

The coefficient of variation (CV) value for most traits indicated good experiment precision since the value is within an acceptable range for agricultural field

experiments. The highly significant influence of bread wheat varieties lined with also the previous findings (Alemu *et al.*, 2021; Workineh, 2014).

Table 2. The two years (cropping season) combined ANOVA results of nine quantitative traits from two locations.

SOV	Mean squares									
	DF	DH	DM	PH	TN	SL	NSPS	BY	GY	HI
Replication	2	0.25ns	5.50ns	7.35ns	0.75ns	0.179ns	9.49ns	1.33ns	0.097ns	2.29ns
Variety(V)	5	250.8**	963.67**	1857.68**	23.65**	63.57**	732.54**	6.13**	14.36**	837.07**
Year (Y)	1	0.07ns	126.56**	176.02*	0.51ns	39.18**	421.34**	1.49ns	1.32**	29.49ns
Location(L)	1	7.50**	11.30*	1153.48**	0.59ns	3.57**	53.52*	12.17**	1.21**	148.43**
L*V	11	1.63**	21.13**	79.36*	0.28ns	0.59ns	8.74ns	2.28*	0.39**	36.54**
V* Y	5	3.04**	4.09ns	78.52**	1.04*	0.36**	44.04*	2.74ns	3.72**	182.86**
L*Y	3	7.75**	54.69**	292.56**	0.52*	0.97ns	16.12ns	19.60**	0.01**	132.33**
V*L*Y	21	1.50**	16.64**	92.54**	0.542ns	0.75*	7.16ns	3.97**	0.49**	21.42**
Error	22	3.17	1.72	32.62	0.31	0.40	11.67	0.95	0.08	9.13
R ²		0.92	0.97	0.84	0.82	0.91	0.81	0.72	0.93	0.89
CV%		2.88	1.24	6.48	11.87	4.57	9.67	8.86	8.31	9.55

Where: SOV: source of variation, **: highly significant at $p \leq 0.01$, *: significant at $p \leq 0.05$, and ns: non-significant, DF: Degrees of freedom, DH: days of heading, DM: 90 % days to maturity, PH: plant height, TN: Productive tiller number, SL: spike length, NSPS: number of spikelets per spike, BY: biomass yield, GY: grain yield, and HI: harvesting index.

3.2. Mean Performance of Varieties.

The mean number of DH of the bread wheat variety was 57.33 days but significant variation occurred among Wane (50.75 days) Ogolcho (58.90 days) and Lemu (58.45 days) (Table 4). In this regard (Gebrie and Abebe, 2020; Meles *et al.*, 2020) reported significant differences among improved varieties. In contrast to this finding, Chimdesa *et al.* (2018) disclosed that insignificant difference in days to heading of bread wheat varieties.

According to the combined analysis result, the average number of 90% days to maturity was 104.25 days. However, the days to maturity ranged from 93.5 days for (Wane) to 112.66 days (Danphe). This shows that Danphe was relatively the late maturing variety compared to the others, while Wane was an early matured than other bread wheat varieties (Table 4). Early-maturing varieties need less time to reach maturity, while late-heading ones require more time. Significant differences among variety in days to maturity were observed (Yaregal *et al.*, 2022). Early maturing varieties can be harvested quickly, avoiding exposure to harsh environmental conditions (Azene *et al.*, 2020).

The mean plant height of bread wheat varieties was recorded as 87.67 cm long (Table 3). The most extended plant height (99.84cm) was recorded from the Danphe variety but the shortest height (76.94cm) was observed from the Wane variety (Table 3). Taller plants exhibited greater grain yield and above-ground biomass. Several studies have also documented significant variations in plant height between bread wheat genotypes (Bakala *et al.* 2018; Yan & Tinker, 2006).

The mean number of productive tillers was 3.69 while it ranged from 3.69 for (Wane) to

5.56 (Danphe) (Table 4). The maximum number of productive tillers was observed from Danphe (5.64) and then followed by Ogolcho variety (3.84) (Table 3). This shows that Danphe was the best fit, adapting the tested location and year over the other six bread wheat varieties. The number of productive tillers significantly influences yield increases because a greater number of tillers leads to the production of more spikelets, ultimately resulting in higher overall yield. Therefore, varieties with higher productive tillers are the most important for yield increment. This result agrees with many research outputs, which observed a significant difference in the number of productive tillers number in different bread wheat varieties (Benavente, 2021; Kefale and Menzir, 2019).

The mean spike length was 7.43 but ranged from 5.67 (Wane) to 10.17cm (Danphe) (Table 3). The most extended spike length was obtained from Danphe(10.17cm) and Ogolcho (8.37cm), while the shortest spike length was obtained from Lemu (6.30 cm), Kingbird (6.22 cm), and Wane (5.97 cm). The mean NSPS was 52.32 while it ranged from 29.62 (Wane) to 43.63 (Danphe) (Table 3). The highest NSPS was obtained from Danphe (43.63) and then from Ogolcho (37.57), but the lowest from Lemu (30.33), Kingbird (30.17), and Wane (29.62), respectively. Spike length and NSPS were significantly and positively related to grain yield; thus, the varieties with extended spike length and more spikelets per spike could give the highest biomass and grain yield (Nkalubo *et al.*, 2024).

The mean biomass yield of varieties was recorded as 8.99 t/ha⁻¹ (Table 4). Danphe produced the relatively highest biomass yield

(10.83 t/ha⁻¹) of all the other varieties, whereas a lower biomass yield was recorded from variety wane (4.66 t/ha⁻¹) (Table 3). Based on the combined analysis results, Danphe and Ogolcho varieties performed better, and Lemu performed poorly in biomass yield, explaining their adaptability across locations in two cropping seasons. According to Degife & Demis, (2020), among the examined varieties, Danphe gave the maximum above-ground biomass yield (10.7 t/ha⁻¹) while the lowest (6.22 t/ha⁻¹) was from Hidase variety.

The mean grain yield was 3.08 t/ha⁻¹ but the highest grain yield was recorded from Danphe (3.66 t/ha⁻¹) and Ogolcho' (3.14 t/ha⁻¹) with relatively higher spike length but the lowest grain yield from Wane (2.52 t/ha⁻¹) and Kingbird (2.7 t/ha⁻¹) (Table 3). Similarly, Gebrie *et al.* (2022) reported that Ogolcho had a higher production potential among the six varieties they investigated in the Guagusa-shikudad district of Northwestern Ethiopia. Therefore, the above variety performed better than all other varieties and could be selected for further evaluation to develop high-yielding varieties. The substantial effects of variety on the environment also showed how important it is to assess bread wheat varieties at multiple sites to investigate how different varieties respond to various environments, whether for broad or specific adaptability. Accordingly, Danphe and Ogolcho showed better performance, thus the development organization should be focused on disseminating such varieties to increase bread wheat yield in East Gojjam Zone.

3.3. Mean performance of grain yield in each test location and years

Among the testing locations, the highest grain yield (3.69 t /ha⁻¹) was recorded in Gozamen district but the lowest grain yield (2.77 t/ha⁻¹) was observed from Machakel district. The superior performance of the Gozamen district can be attributed to the uniform distribution of rainfall and favorable environmental conditions throughout the cropping season, which create a suitable ecological environment for wheat cultivation. These consistent climatic factors likely contribute to the enhanced growth and yield of crops in this region. The tested variety exhibited inconsistent yield advantages across environments, which can be attributed to both environmental factors and the genetic makeup of the varieties. Different genotypes may respond variably to changing conditions, leading to fluctuating performance. Understanding these genetic differences is essential for improving yield consistency across various settings. The average grain yield of variety over location showed that Danphe (3.54 t/ha⁻¹), Ogolcho (3.26 t/ha⁻¹), and Kekeba (3.19 t /ha⁻¹) were the highest-yielding varieties. In contrast, Wane (2.32 t/ha⁻¹) and Kingbird (2.54 t/ha⁻¹) were low-yielding cultivars (Table 4).

The mean grain yield of the genotypes varied ranging from 3.54 to 2.32 t/ha⁻¹ for Danphe and Wane, respectively. Gozamen were relatively high-yielding environments compared to Machakel. Apart from this, the bread wheat varieties with higher grain yield at specific locations were Danphe and Ogolcho, at Gozamen.

Table 3. The combined mean performance evaluation of grain yield and yield-related traits of two locations in the 2019/ 2020 and 2020/2021 cropping seasons.

Variety	Mean values								
	DH	DM	PH	TN	SL	NSPP	BY	GY	HI
Ogolcho	58.92a	107.50b	92.94b	3.84b	8.37b	37.57b	10.30ab	3.14b	38.47a
Wane	50.75c	93.5e	76.94c	3.02c	5.97d	29.62d	9.55c	2.52e	25.83d
Lemu	58.45b	103.5d	81.16c	3.20c	6.30d	30.33d	9.65bc	3.00d	28.15bc
Kingbird	58.46b	102.9d	80.93c	3.16c	6.22d	30.17d	9.58bc	2.70de	27.36cd
Danphe	58.90a	112.66a	99.84a	5.64a	10.17a	43.63a	10.83a	3.66a	39.51a
Kekeba	58.5b	105.45c	90.87b	3.29c	7.57c	34.60	11.04bc	3.07c	30.37b
Mean	57.33	104.25	87.11	3.69	7.43	34.32	9.99	3.08	31.62
LSD	0.28	0.99	4.33	4.42	0.48	6.04	0.79	0.21	2.29
CV	0.64	1.24	6.48	11.87	7.57	9.67	8.86	8.31	9.55

Where; LSD = least significant difference and CV= coefficient of variation, DH: days of 75% heading, DM: 90% days to maturity, PH: plant height, TN: Productive tiller number, SL: spike length, NSPS: number of spikelets per spike, BY: biomass yield, GY: grain yield, and HI: harvesting index. N.B. Mean with the same letter is not significantly different.

The variety Danphe performed best in most environments, followed by the variety Ogoicho. The significant variation in grain yield among the six bread wheat varieties at the two locations is likely attributed to differences in climatic and soil conditions that affect variety performance. This

underscores the importance of selecting varieties that are well-suited to specific environmental factors. Similarly, inconsistent grain yield performances of bread wheat varieties have been found across locations (Jifar *et al.*, 2019; Seyoum, 2021).

Table 4. Mean performance of grain yield (t/ha) in each test location/environment and across years.

Variety tested	Locations and Years						Overall	
	2020			2021			Mean	Rank
	Gozamin	Machakel	Mean	Gozamin	Machakel	Mean		
Daphe	3.72a	3.41a	3.72	3.69a	3.32a	3.36	3.54	1
Ogolocho	3.54b	3.19b	3.34	3.17b	3.22a	3.19	3.26	2
Kekeba	3.46b	3.00bc	3.23	3.00b	3.32b	3.16	3.19	3
Lemu	3.38c	2.70d	3.04	2.50d	2.35d	2.42	2.73	4
Kingbird	2.51d	2.60d	2.55	2.95b	2.12d	2.53	2.54	5
Wane	2.50d	2.30e	2.40	2.39d	2.10d	2.24	2.32	6
Mean	3.19	2.91		2.92	2.77			
CV	8.73	12.30		5.60	8.42			
LSD	0.57	0.18		0.24	0.44			

4. Conclusions and Recommendation

The combined analysis over the years disclosed that varieties were significantly different for whole tested parameters of the crop including grain yield. Variety Danphe, followed by Ogoicho, revealed consistently higher phenotypic performance of all traits under the study. A combined analysis of variance revealed highly significant variation among genotypes, environments, and the genotype-by-environment (GxE) interaction. This indicates the need for further investigation into the sources of variation within the GxE interaction to better understand how different genotypes perform across varying environmental conditions. The significant variation in grain yield among the

six bread wheat varieties at the two locations is likely attributed to differences in climatic and soil conditions that affect variety performance. This underscores the importance of selecting varieties that are well-suited to specific environmental factors. Bread-wheat breeding programs can benefit from the significant genetic variability observed among different genotypes. Studies indicate that there are considerable differences in traits such as grain yield, plant height, and thousand kernel weight among bread wheat genotypes, which provide a valuable resource for selecting high-yielding and adaptive varieties. This variability is crucial for developing improved cultivars that can thrive under various environmental conditions and meet the increasing demand

for wheat globally. The Gozamen district is considered a more suitable agroecological zone for wheat production due to its favorable climatic and soil conditions. From the tested varieties, Danphe was screened for its good performance in the experimental locations. Hence, cultivation of these bread wheat varieties was recommended in the East Gojam zone and other similar bread wheat variety growing areas in agroecology and soil type.

Conflict of Interests

The authors declare that there are no conflicts of interest in this work.

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