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RESEARCH PAPER

Evaluation of agronomic performance and grain yield stability of bread wheat (*Triticum aestivum*) genotypes in East Shewa zone, Oromia

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Key Message: This study was conducted across three districts and two seasons to assess three commercial wheat varieties (Kingbird, Abay and Adola-1) and twelve advanced genotypes. The findings revealed that genotypes G-6, G-1, and G-5 exhibited high yield potential, stability, and disease tolerance, making them promising candidates for release in the study areas.

Abstract

A field experiment was conducted at Adami Tulu Agricultural Research Center, as well as in the Lume and Dugda Districts, during the main cropping seasons of 2022 and 2023. The purpose of this study was to identify stable and high yielder bread wheat genotypes in the East Shewa Zone across three distinct districts. These districts exhibit varying environmental conditions and altitudes, with a diversity of soil types characterized by differing compositions. A total of fifteen genotypes were precisely evaluated utilizing a randomized complete block design with three replications. Analysis of variance revealed significant effects of genotype, environment, and their interaction on grain yield. Additive Main Effects and Multiplicative Interaction (AMMI) analysis indicated that the environment significantly influenced yield, accounting for 48.78% of the total variation, followed by genotype (23.89%) and genotype × environment interaction (16.19%). The first two interaction principal components (IPCA-I and IPCA-II) explained 44.6% and 27.7% of the genotype × environment interaction, respectively, and were used to assess stability. Based on stability parameters (ASV and GGE-Biplot) and mean grain yield, genotypes G-6, G-1, and G-5 were identified as stable and high-yielding candidates for potential release. AMMI and GGE-biplot analyses revealed specific adaptation patterns among genotypes, with some performing better in particular environments. These findings highlight the importance of multi-environmental trials for accurate genotype evaluation. Given their yield and stability, genotypes G-6, G-1, and G-5 were promising resources for improving bread wheat productivity in East Shewa Zone and similar agro-ecologies. We recommend further validation trials and farmer participatory evaluations to ensure acceptability and performance under on-farm conditions. Additionally, these superior genotypes could be used as parents in future breeding programs.

Keywords: Additive main effects, Bread wheat, Genotype by environment interaction, GGE-Biplot, Multiplicative interaction, Stability

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Introduction

Wheat, being a staple food for over 2.5 billion individuals stands as the most extensively cultivated crop on an overwhelming 217 million hectares, yielding a remarkable 752 million tonnes annually (Iqbal et al., 2018; Abbas & Shafique, 2019; Alamgeer et al., 2022). Its remarkable adaptability allows for cultivation in a myriad of environments, spanning from cold arctic regions to tropical climates, and from below sea level to rising altitudes reaching 4,500 m in Tibet (Senbeta & Worku, 2023). Ethiopia emerges as Africa's second-largest wheat producer, boasting a yield of 5.5 Mt, which accounts for 21.7% of the continent's total production and encompasses 18.3% of its harvested area (Senbeta & Worku, 2023). So far, wheat production in Ethiopia is predominantly governed by a subsistence smallholding farming system, and its productivity is hindered by complicated biophysical and socio-economic challenges (Nigus et al., 2022). Wheat production and productivity have perennially lagged, resulting in food production trailing behind population growth (Hodson et al., 2020). In order to bridge the huge difference between wheat consumption and production, the nation has had to rely on significant imports of wheat for nearly half a century through both commercial means and food aid. Presently, the consumption of wheat is increasing at a higher rate compared to other food crops, driven by rapid population expansion, rising incomes, urbanization, climate variations, and evolving preferences towards wheat-based food choices (Sununtnasuk, 2013).

The primary objective of accessing stable wheat varieties is to account for environmental effects and delineate interactions. Enhanced wheat genotypes are assessed through multi-environment trials, which gauge their performance across diverse settings and aid in pinpointing the optimal genotypes for specific environments. Nonetheless, this procedure may diminish selection efficiency in various breeding programs due to the less predictable nature of traits being evaluated within the genotype-environment interaction (GEI) framework. These traits cannot be solely deciphered through main effects (genotype or environment) and necessitate a more comprehensive analysis (Rebollo et al., 2023). GEI holds substantial value for breeders as it assists in determining whether to cultivate varieties for all environments or specific ones (Bridges, 1989). The occurrence of GEI emerges when distinct cultivars or genotypes exhibit varying responses to diverse environments. Research indicates that comprehending the environmental and genetic factors underpinning this interaction, and evaluating their importance in G × E systems, profoundly impacts plant breeding (Magari et al., 1993). G × E interaction is universally manifested when appraising genotypes across multiple environments (Aliyi et al., 2022).

AMMI stability value (ASV) and yield stability index (YSI) are crucial in deciphering genotype-environment interactions (GEI) as they pertain to yield stability and regression coefficients (Becker & Leon, 1988). Summarizing GEI relationships (Zobel et al., 1988) through these indices also enhances the accuracy of yield estimates; by augmenting replicates two- to five-fold, experiment costs can be minimized by reducing replications or test environments, thereby allowing for more treatments or improved genotype selection (Cross et al., 1990). In regions of Ethiopia where bread wheat is cultivated, the escalating issue of low moisture stress is a growing concern. To tackle this challenge, a wheat-breeding initiative formulated product concepts and identified genotypes that demonstrate low susceptibility to moisture stress, early maturation, and other favorable agronomic traits (Borena et al., 2021). The demand for wheat in developing nations is anticipated to surge significantly by 2050 (Shiferaw et al., 2013). In Ethiopia, wheat production faces hindrances due to substantial genotype by environment interaction (GEI) (Gedisa & Abebe, 2020; Gedisa et al., 2021; Verma & Singh, 2021) and a deficiency of stable, high-yielding varieties suited to diverse agro-ecological zones. Additional challenges encompass biotic and abiotic stresses, sub-optimal farming practices, monoculture cultivation, and socio-economic factors (Habte et al., 2014; Hodson et al., 2020). Therefore, genotype by environmental interaction trials were intended with the objectives to estimate the magnitude of genotype by environment interactions and to identify high-yielding and stable bread wheat genotypes in the study areas.

Materials and Methods

Study area

A multi-environmental field trial assessed 12 advanced bread wheat selections and improved varieties, including Abay, Kingbird, and Adola-1, for yield and related traits on smallholder farms across three districts (Adami Tulu Agricultural Research Center, Dugda, and Lume) in the East Shewa Zone during the 2022-2023 crop season under rain-fed conditions. Adami Tulu Agricultural Research Center (ATARC) is located 167 km south of Finfine on the way to Hawass Road, situated at a latitude of 7°9’N and longitude of 38°7’E, at an altitude of 1650 meters above sea level. ATARC receives an average annual rainfall of 760.9 mm, which is distributed in a bimodal pattern extending from February to September, with a dry period from March to June separating the "short" and "long" rainy seasons. The mean minimum and maximum temperatures are 12.6 °C and 27 °C, respectively. The soil is characterized as fine sandy loam, consisting of 34% sand, 48% clay, and 18% silt, with a pH of 7.88. Dugda district, located 130 km from the capital at 8°1'N and 38°75'E, has an altitude of 1950 meters above sea level. It experiences an average annual rainfall of 903 mm, concentrated in July and August, followed by a prolonged dry season. The mean minimum and maximum temperatures are 9°C and 26 °C, respectively. The soil is characterized as dark sandy loam (33% sand, 40% clay, 27% silt) with a pH of 7.6 (Dugda Woreda Office of Agriculture [DWOA], 2014). Lume district, situated between 8°38'42"N and 39°14'32"E, has an altitude of 2100 meters above sea level and dominant soil types of Sandy Loam (59%) and Clay Loam (41%) with a pH of 7.8. It receives an average annual rainfall of 1000.9 mm, primarily in July and November. The mean minimum and maximum temperatures are 10 °C and 24 °C, respectively.

Experimental design and management

A randomized complete block design (RCBD) was implemented to manage known variation and enhance treatment comparisons by evaluating each genotype under uniform conditions within blocks. Plots measured 3 square meters (1.2 meters × 2.5 meters), consisting of six rows spaced 0.2 meters apart and 2.5 meters long, with a 1-meter interval between blocks. The two outer rows of each plot functioned as borders. Fifteen genoypes were used as planting material (Table 1). The recommended seed and fertilizer rate in the area involved the application of NPS and urea at 100 kg/ha and 150 kg/ha, respectively, along with a seed rate of 150 kg/ha. Standard weeding practices and other prescribed agronomic methods were consistently implemented across all sites.

Data collection

Data regarding the agro-morphological characteristics of the bread wheat genotypes were gathered following the protocols outlined by Anderson et al. (2012) and the descriptors for barley (International plant Genetic Resource Institute [IPGRI], 2010). To obtain data on an individual plant basis, ten plants chosen at random from the central four rows within each plot were specifically marked, and information was collected from these selected plants, with the resulting average values being meticulously recorded. Plant height was determined as the mean height (in centimeters) of ten randomly selected plants per plot, measured from the soil surface to the tip of the spike (excluding the awns) of the bread wheat at the stage of maturity. Peduncle length was calculated as the average length (in centimeters) from the node to the tip, measured from ten randomly chosen plants in the central four rows of each plot. Spike length, representing the average length (in centimeters) from the base to the tip (excluding the awns) of the main plant, was measured from ten random plants per plot. Kernel number per spike, indicating the average number of kernels on the main tiller, was meticulously counted from ten randomly chosen plants in each plot. Days to heading were defined as the number of days from the emergence of seedlings to when 75% of the plot had developed heads. Days to maturity represented the number of days from seedling emergence to when 75% of the plot had attained maturity. Grain yield, quantified as the grain yield (in kg/ha) of the four central rows, was adjusted to account for 12.5% moisture content. Additionally, the thousand kernel weight was determined as the weight (in grams) of a thousand-seed sample per plot, adjusted to 12.5% moisture content.

Table 1 Lists of fifteen bread wheat genotypes used in the study

S.No.	Codes	Genotypes/Pedigree
1	Abay	Standard Check
2	Adola-1	Standard Check
3	G- 1	ATTILA*2/PBW65//PFAU/MILAN
4	G-2	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2
5	G-3	ATTILA*2/PBW65
6	G-4	ATTILA*2/PBW65//PFAU/MI
7	G-5	ATTILA*2/PBW65//PFAU/MI
8	G-6	ETBW 94546
9	G-7	SERI.1B//KAUZ/HEVO/3/AMAD/4/P
10	G-8	ATTILA*2/PBW65//PFAU/MI
11	G-9	SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN
12	G-10	ETBW 9129
13	G-11	ETBW 954776
14	G-12	ETBW 95454576
15	Kingbird	Standard check

Statistical analysis

AMMI Model: AMMI is utilized to analyze genotype-environment intelligent (GEI) for design recognizable proof and commotion diminishment. Its work is to recognize key breeding situations and select related test locales to decide which phenotype are best suited for adjustments (Angela et al., 2016).

$$\mathbf{Y_{ij}} = \mu + g_i + \mathbf{e_j} + \sum_{\mathbf{1}}^{\mathbf{N}} \text{ʎ}_{\mathbf{k}} \Upsilon_{\mathbf{ik}} \boldsymbol{\delta}_{\mathbf{jk}} + \mathcal{E}_{\mathbf{ij}}$$

Where Yij is the grain abdicate of the i-th genotype within the j-th environment, µ is the amazing cruel, gi and ej are the genotype and environment deviation from the terrific cruel, separately, ʎk is the eigenvalue of the vital component examination (PCA) pivot k, Yik and δjk are the genotype and environment central component scores for hub k, N is the number of principal components held within the show, and Ɛij is the remaining term.

GGE- biplot: GGE biplot analysis, a visual statistical tool for plant breeding and agronomy, analyzes genotype by environment interactions (G×E) in multi-environment trials (METs). Based on the biplot concept and GGE framework, it identifies superior, stable genotypes and visualizes complex relationships between genotypes, environments, and their interaction with the GGE framework (Yan et al., 2000).

AMMI Stability Value (ASV): In plant breeding, the Additive Main Effects and Multiplicative Interaction (AMMI) model's "ASV" statistic assesses a genotype's stability across environments. Lower ASV values, calculated from IPCA1 and IPCA2 scores (Purchase, 1997), indicate greater stability and consistent performance. Conversely, higher ASV values suggest sensitivity to environmental changes and potentially inconsistent performance. It was calculated using the IPCA1 and IPCA2 based on the following formula:

$$\mathrm{ASV} = \sqrt{[(\mathrm{SS}_{\mathrm{IPCA1}} \div \mathrm{SS}_{\mathrm{IPCA2}})(\mathrm{IPCA1}_{\mathrm{Score}})]^2 + (\mathrm{IPCA2}_{\mathrm{Score}})^2}$$

Where SSIPCA1/SSIPCA2 is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares.

Genotype Selection Index (GSI): A genotype which has higher yielded and superior ones may not always the most stable. To combine higher yielder and stability is important to identify stable genotypes. Therefore, a genotype selection index (GSI) was calculated for each genotype based on ranks of both mean grain yield (RYi) and AMMI stability value (RASVi) across environments and calculated by the succeeding expression:

GSIi = RASVi + RYi

Results and Discussion

Combined analysis of variance

Pooled ANOVA revealed significant ($P < 0.01$) effects of genotype, environment, and their interaction on grain yield (Table 2) consistent with previous bread wheat G×E studies (Alemu et al., 2019; Borena et al., 2021; Nigus et al., 2022; Mulualem et al., 2024). Environment explained the largest proportion of variance (48.78%), followed by genotype (23.89%) and G×E interaction (16.49%) (Table 4). This significant G×E interaction indicates inconsistent genotypic performance across environments (Ayalneh et al., 2014), potentially due to rank changes or altered magnitude of genotypic differences (Asmare et al., 2020). Therefore, identifying stable genotypes is critical for breeding, particularly when environmental factors impact genetic potential. The strong influence of environment on wheat genotypes has also been documented by others (Borena et al., 2021; Megerssa et al., 2024). However, the G×Y interaction (Genotype by year) was non-significant indicating that the studied genotypes do not show significant variations yield performance, when grown in different years. It simplifies breeding by reducing the need for specific adaptation to yearly environmental fluctuations and facilitating the selection of reliably performing genotypes and improving the efficiency of breeding recommendations and selections.

Table 2 ANOVA for combined mean grain yield of bread wheat genotypes over locations and year

Source of variation	d.f.	Sum of squares	Mean square	v.r.	F pr.
Replications	2	60.53	30.26	0.43	0.652
Genotype (G)	14	3489.34	249.24	3.54	<.001
Location (L)	2	4101.77	2050.88	29.09	<.001
Year (Y)	1	19413.43	19413.43	275.4	<.001
G×L	28	3213.67	114.77	1.63	<.001
G×Y	14	1265.15	90.37	1.28	0.222
L×Y	2	2615.03	1307.51	18.55	<.001
G×L×Y	28	2485.33	88.76	1.26	<.001
Residual	178	12547.55	70.49		
Total	269	49191.8			

G = Genotype, L = Location, Y = Year, G×L = Genotype by location, G×Y = Genotype by year, L×Y = Location by year, G×L×Y = Genotype by location by year interactions

Mean performance of the other agronomic traits

The study's findings revealed significant variation in the number of days to heading and maturity among the different bread wheat genotypes in the study area. The mean number of days to heading for the genotypes ranged from 53.1 to 59.18 days with an overall average of 59.9 days (Table 3). This suggests that nearly all genotypes exhibited a narrow range of heading dates. Furthermore, there was minimal variation among the genotypes regarding days to maturity, indicating that the tested genotypes can be categorized into similar maturity groups. Genotypes that head and mature earlier may be preferred in areas with shorter growing seasons, while those with later maturity may be more suitable for regions with longer growing seasons. Plant height ranged from 48.74 to 71.9 cm, with the minimum recorded in genotype G-12 and the maximum observed in Adola-1 and G-3. Regarding their reaction to diseases, G-6, G-5, and G-1 showed more disease resistance than the other genotypes, while G- 4 and G- 2 show less tolerance to major wheat diseases. Therefore, the genotype exhibiting greater disease resistance also yielded more than the others, making such genotypes crucial for bread wheat production in that region.

Performance of bread wheat genotypes across tested environment

Table 4 shows significant environmental variation observed in bread wheat grain yield. The grain yield ranged from 2683.3 kg/ha ATARC during 2023 to 5408.0 kg/ha Dugda during 2022 with having the grand mean of 3598.6 kg/ha. Similar study was reported by Alemu et al. (2019) large variation within different lines of bread wheat across different environment. Genotype G-6 is the highest yielder than that of other genotypes (4312.1 kg/ha), while G-12 is the lowest yielder genotype (3024.6 kg/ha). G-6, G-1, and G-5 consistently outperformed other genotypes, while G-94 showed the lowest yield potential, aligning with previous findings Dinsa & Balcha, 2024; Mulualem et al., 2024). Varying yield rankings across locations indicate significant crossover interactions (Purchase et al., 2000; Yan et al., 2007), likely driven by genetic potential. A genotype which has consistent performance across the study area will be selected for the production of the area.

Table 3 Combined mean agronomic performance and disease reaction of 15 bread wheat genotypes tested in regional variety trials at Adami Tulu, Dugda and Lume during the year 2022-2023

Genotype	DH	DM	NS/p	PH (cm)	PL (cm)	SL (cm)	YLD (kg/ha)	Disease	
								Stem rust	Leaf rust
Abay	54.5^{a}	90.17^{a}	48.84^{bc}	62^{c}	31.38^{bc}	8.906^{cde}	3670.4	15ms	20ms
Adola-1	56.28^{ab}	94.39^{ab}	55.54^{a}	71.9^{a}	35.71^{a}	9.744^{ab}	3454.3	10mr	10mr
G-1	58.17^{ab}	87.39^{ab}	49.29^{bc}	68.46^{ab}	32.09^{bc}	9.139^{bcd}	4135.4	10mr	10mr
G-2	59.18^{b}	87.17^{ab}	54.69^{ab}	66.85^{b}	33.12^{abc}	9.539^{bc}	3204.0	20s	15ms
G-3	55.28^{ab}	97.39^{ab}	55.54^{a}	71.9^{a}	35.71^{a}	9.744^{ab}	3657.6	20mr	10mr
G-4	56.83^{a}	89.1^{a}	44.83^{c}	68.06^{ab}	30.41^{cd}	8.753^{de}	3393.7	30s	15ms
G-5	54.67^{ab}	89.11^{a}	45.99^{c}	58.5^{c}	28.33^{de}	8.347^{ef}	4045.1	5mr	10mr
G-6	55.44^{ab}	89.11^{a}	43.89^{c}	57.4^{c}	27.23^{e}	8.567^{de}	4312.1	tmr	5mr
G-7	53.5^{b}	87.89^{ab}	43.96^{c}	48.74^{d}	23.71^{f}	7.93^{f}	3092.3	15mr	5mr
G-8	54.61^{ab}	98.56^{bc}	45.21^{c}	70.77^{ab}	32.65^{bc}	8.942^{cde}	3682.3	10mr	15ms
G-9	57.17^{a}	86.67^{b}	55.71^{a}	69.45^{ab}	33.55^{ab}	10.25^{a}	3294.8	15mr	20ms
G-10	55.39	88.26	48.8	64.22^{c}	30.82	9.01	3610.9	5mr	15ms
G-11	54.7^{ab}	89.11^{a}	45.99^{c}	58.53^{c}	28.33^{de}	8.347^{ef}	3767.1	10mr	10mr
G-12	53.10^{b}	87.89^{ab}	43.96^{c}	48.74^{d}	23.71^{f}	7.931^{f}	3024.6	15mr	10mr
Kingbird	56.83^{a}	89.11^{a}	43.89^{c}	57.4^{c}	35.71^{a}	9.744^{ab}	3634.0	10mr	10mr
Mean	55.9	88.26	48.8	64.22	30.82	9.01	3598.8		
CV	6.4	4.6	17.4	11.2	11.3	1.43	22.44		
LSD	5.44	4.49	13.73	12.6	6.67	10.2	445.21		

CV = Coefficient of variation, LSD = Least significant difference, DH = Days to heading, DM = Days to maturity, NS/p = Number of seed/plants, PH = Plant height (cm), PL = Panicle length (cm), SL = Spike length (cm), YLD = Grain yield (kg/ha)

Table 4 Mean grain yield (kg/ha) per location and years

Genotype	ATARC		Dugda		Lume		Mean
	2022	2023	2022	2023	2022	2023	
Abay	3013.3	2775.0	4946.7	2975.0	5458.3	2854.0	3670.4
Adola-1	3503.3	2750.0	3708.3	2950.0	4985.0	2829.0	3454.3
G- 1	3925.0	2608.3	6933.3	3475.0	4850.0	3020.7	4135.4
G-2	4078.3	2141.7	4150.0	2341.7	4291.7	2220.7	3204.0
G-3	3383.3	2750.0	6233.3	2616.7	4500.0	2462.3	3657.6
G-4	3591.7	3016.7	4150.0	2883.3	3291.7	3429.0	3393.7
G-5	3975.0	2625.0	6516.7	3491.7	4791.7	2870.7	4045.1
G-6	3691.7	3183.3	7158.3	3493.3	5150.0	3195.7	4312.1
G-7	3408.3	2608.3	4900.0	2475.0	2808.3	2354.0	3092.3
G-8	3850.0	2708.3	5648.3	2908.3	4191.7	2787.3	3682.3
G-9	4406.7	2575.0	5525.0	2441.7	2500.0	2320.7	3294.8
G-10	4111.7	2808.3	5958.3	2575.0	3758.3	2454.0	3610.9
G-11	4581.7	2700.0	6041.7	2900.0	3600.0	2779.0	3767.1
G-12	2560.3	2333.3	4500.0	2533.3	3941.7	2279.0	3024.6
Kingbird	4275.0	2666.7	4750.0	2866.7	4500.0	2745.7	3634.0
Mean	3757.0	2683.3	5408.0	2861.8	4174.6	2706.8	3598.6
LSD 0.05	1269.4	645.3	1520.3	662.0	1551.0	605.6	445.2
CV (%)	24.32	17.312	20.23	16.63	26.74	16.10	22.44

Additive main effects and multiplicative interaction

The combined analysis of variance and AMMI analysis is shown in Table 5. The AMMI model analysis of variance (ANOVA) for grain yield showed highly significant differences ($P \leq 0.01$) for genotypes, environments and genotypes by environments interactions. The first two IPCA1 and IPCA2 of genotype by environment interaction (G×E) were highly significant ($P \leq 0.01$), showing 49.44% (IPCA1) and 37.44% (IPCA2) of the G×E interaction, cumulatively accounting for 86.88%. This strong fit justifies using the first two components, consistent with findings that the primary G×E pattern is captured in IPCA1 (Mattos et al., 2013; Regis et al., 2018; Dagnachew et al., 2020). Capturing most of the G×E sum of squares in the first principal component is crucial for accurate insights (Purchase et al., 2000). The high percentage of G×E variation explained by IPCA1 and IPCA2 suggests a relatively simple interaction pattern where genotypes and environments with similar IPCA scores exhibit similar responses. While IPCA1's substantial contribution aligns with previous research, interpreting both IPCA1 and IPCA2 is crucial for clear understanding because

IPCA2 explains a significant portion of the interaction. Further investigation into environmental and genotypic factors associated with these principal components could elucidate the drivers of these interactions.

Table 5 The additive main effect and multiplicative interaction analysis of variance

Sources of variation	d.f.	Sum of squares	Mean square	Ex. SS%
Total	269	49192.3		
Genotypes	14	9489.23	39703.34**	23.89
Environments	5	16130.56	33062.54***	48.78
Block	12	1651.33	47541.56*	3.47
Interactions	70	6964.32	42228.55**	16.49
IPCA1	18	3443.65	191.61**	49.44
IPCA2	16	2608.63	162.97**	37.44

AMMI stability value (ASV) and genotype selection index (GSI)

Lower AMMI stability values (ASV) indicate greater stability, while higher values suggest instability and indicated in Table 6. AMMI analysis revealed that G-5, G-6, G-1, and G-12 as the most stable genotypes with lower ASV values, suggesting wider adaptation (Table 6). However, Adola-1 and G-8 exhibited the highest ASV values, indicating specific adaptation and least stability. Since, stability alone is insufficient for selection. The genotype selection index (GSI), which integrates yield and stability, is crucial for identifying superior genotypes. In this study, GSI identified G-6, G-1, and G-5 as top performers with both stability and high grain yield, consistent with findings by Alemayehu et al. (2024); Dinsa & Balcha (2024); Megerssa et al. (2024) for durum wheat and Alemu et al. (2019); Nigus et al. (2022) for bread wheat. These genotypes are recommended for further evaluation and potential release due to their desirable combination of yield potential and stability. Multi-location trials over several years are recommended to validate these results and assess their performance across diverse environments. Such trials will provide a more robust evaluation of their stability and adaptability. Furthermore, disease resistance and grain quality should be considered alongside yield and stability for long-term sustainability and marketability.

Table 6 IPCA1, IPCA2 scores, AMMI stability value, and Genotype Selection Index of bread wheat genotypes

Genotype	Mean yield	Ryi	IPCA1	IPCA2	ASVi	RASVi	GSI
Abay	36.7	7	-2.0394	-1.82893	2.9183	11	18
Adola-1	34.54	10	-3.20448	0.15618	65.74927	15	25
G- 1	41.35	2	1.04907	-1.66247	1.789426	3	5
G-2	32.04	13	-1.40666	0.72685	2.817648	10	23
G-3	36.58	6	0.88203	-1.96253	2.002166	6	12
G-4	33.94	12	-1.31068	2.21372	2.945796	12	24
G-5	40.45	3	0.87972	-1.27521	1.412258	1	4
G-6	43.12	1	1.0012	-1.10114	1.42871	2	3
G-7	30.92	14	0.63808	2.41559	2.421463	9	23
G-8	36.82	4	1.298	-0.05992	28.11762	14	18
G-9	32.95	11	2.02826	2.33901	2.926487	13	24
G-10	36.11	9	1.32469	0.40263	4.376911	7	16
G-11	37.67	5	1.54128	1.10073	2.42265	8	13
G-12	30.25	15	-1.04615	-0.64825	1.808461	4	19
Kingbird	36.34	8	-1.09496	0.68373	1.882109	5	13

RYi = Rank of food barley yield, IPCA = Interaction principal component axis, ASV = AMMI stability value, ASVi = Rank of AMMI stability value, GSI = Genetic selection index

Evaluation of genotype based on the GGE-biplot model

Genotype stability was estimated using Average Environment Coordination (AEC) methods (Yan, 2001; Yan & Chase, 2001). The average environment, defined by the mean PC1 and PC2 values across all conditions, is represented as a circle, with the Average Ordinate Environment (AOE) as a perpendicular line to the Average Environment Axis (AEA) through the origin. The yield increases along the AEA genotype G-6, G-1, and G-5 indicated along AEA which were being the highest yielding and conversely genotype Adola-1, G-12, and G-2 place against AEA which show lower yields (Fig. 1). Stability, determined by proximity to the AE axis and the center of concentric circles (Yan & Tinker, 2006), indicates closeness to the ideal genotype. G-6, G-1, and G-5 are the most stable within the high-yielding group (Fig. 1). Ideal genotypes, such as G-6 and G-1, display high and consistent yields. Genotypes further from the AE axis, like G-12, are less stable due to greater yield fluctuations. The AOE differentiates genotypes with similar yields but different adaptation patterns; those above the AOE are adapted to above-average conditions, while those below are suited to below-average conditions. This information enables targeted selection based on environmental context. Further research should investigate the environmental factors driving genotype-by-environment interactions for improved genotypes recommendations and breeding strategies.

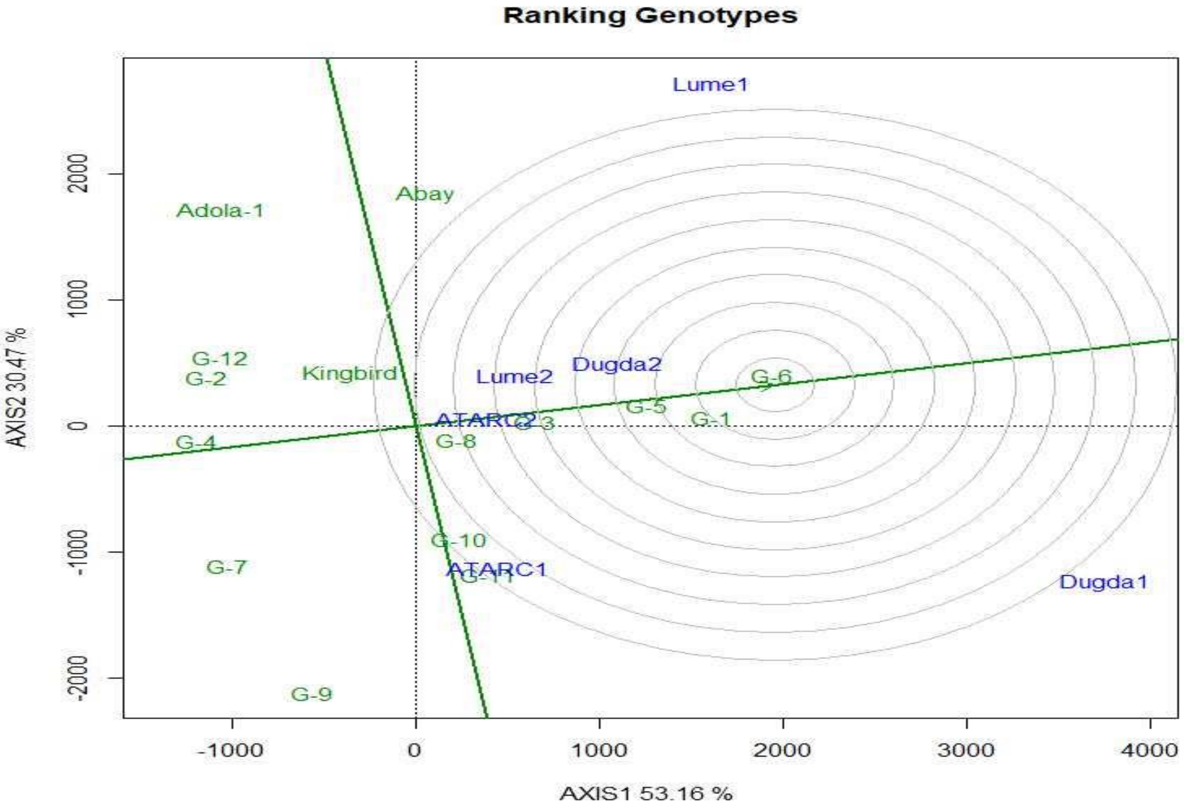

Fig. 1 GGE biplot based on genotypes focused scaling for comparison of genotypes for their yield potential and stability

GGE biplot analysis

The GGE biplot ('mean vs. stability') showed that PCA1 and PCA2 accounted for 53.16% and 30.4% of GGE variation, respectively (Fig. 2), enabling visualization of bread wheat genotype yield and stability. With SVP=1, the average environment coordinate (AEC) intersects the biplot origin. Following Yan and Rajcan (2002), environmental performance is represented by PCA1 and PCA2 mean scores. The AEC and SVP facilitate genotype evaluation based on both yield and stability (Fig. 2). Genotypes are arranged along the AEC abscissa line in ascending order of yield; G-6, followed by G-1, displayed the highest yield and stability. Genotypes farther from the AEC are less stable, with distance from the AEC indicating instability. G-2 and G-5, distant from the AEC, showed lower stability. The GGE biplot effectively differentiates genotypes by yield potential and environmental responsiveness, offering valuable insights for breeding high-yielding and stable bread wheat varieties.

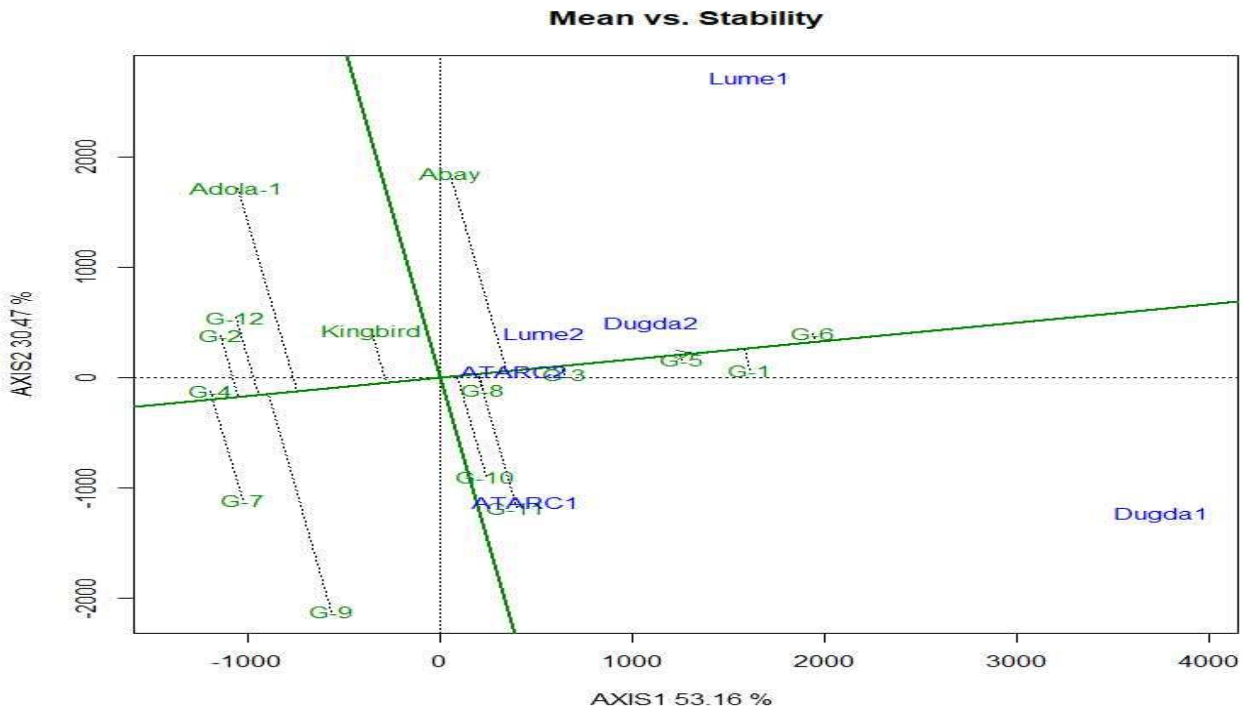

Fig. 2 GGE ranking bi-plot shows means performance and stability of bread wheat genotypes

Conclusion

Analysis of genotype by environment interaction (GEI) is crucial for improving bread wheat (Triticum aestivum) productivity and yield stability in the East Shewa Zone. Significant grain yield variations confirmed GEI, highlighting the importance of genotype adaptability. GGE bi-plot, AMMI stability analysis, and genotypic selection index values identified G-6, G-1, and G-5 as promising genotypes due to their high yield, stability, and disease tolerance, making them potential candidates for release in the study areas and similar agro-ecologies. These genotypes offer a valuable resource for breeding climate-resilient wheat varieties with enhanced adaptability and yield performance. Further investigation into the physiological and genetic traits contributing to the stability and yield of G-6, G-1, and G-5 is warranted to optimize selection in future breeding cycles. The disease tolerance of these genotypes is particularly important for ensuring stable yields and reducing reliance on chemical controls. Integrating disease resistance genes from these lines into breeding programs will contribute to minimizing yield losses. Increased and more reliable yields will benefit farmers in the East Shewa Zone, enhancing their livelihoods and food security. Continued multi-location trials and participatory variety selection are recommended to validate performance and accelerate adoption of these promising genotypes.

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References

Abbas, Q., & Shafique, A. (2019). Integrated use of organic and inorganic fertilizers improves soil health, growth and yield of wheat (*Triticum aestivum* L.). *Advances in Agriculture and Biology*, *2*(1), 48-54.

Alamgeer, M., Chaudhry, L. A., Anum, W., Ali, A., Zafar, D., Hamid, A., & Abbas, R. (2022). Effect of different sowing dates, planting methods and irrigation intervals on performance of wheat varieties under agro-climatic conditions of Bahawalpur region. *Advances in Agriculture and Biology*, *5*(1), 35-45.

Alemayehu, Z., Yewubdar, S., Mekuria, T., Shitaye, H., & Wasihun, L. (2024). Genetic variability and stability analysis of multi environments trials for durum wheat grain yield in Ethiopia. *Journal of Plant Breeding and Crop Science*, 16(1), 8–14. https://doi.org/10.5897/JPBCS2023.1021

Alemu, G., Mohammed, H., Asnake, D., & Alemu, T. (2019). Genotype × environment interaction and yield stability of bread wheat genotypes in central Ethiopia. *Journal of Plant Breeding and Genetics*, *7*, 87–94. https://doi.org/10.33687/pbg.007.02.2847

Aliyi, K., Hussein M., & Tesfaye, L. (2022). GGE biplot analysis of genotype by environment interaction on bread wheat (*Triticum aestivum* L.) genotypes in southern Oromia. *Journal of Chemical, Environmental and Biological Engineering*, *6*(1), 1-9.

Anderson, P. M., Oelkeand, E. A., & Simmons. S. R. (2012). *Growth and development guide for spring barley*. http://www.Extension/.umn.edu/. Anonymous 2000. SAS/STAT. *Guide for Personal Computers*, Version 9.0 editions. SAS Institute Inc, Cary, NC, USA.

Angela, P., Mateo, V., Gregorio, A., Francisco, R., Marco, L., Jose, C., & Juan, B. (2016). *GEA-R (Genotype ×Environment Analysis with R for Windows) Version 4,1*. CIMMYT Research Data and software Repository Network.

Asmare, B., Bishaw, F., & Gezie, T. (2020). On-farm evaluation the effective microbes and urea treated rice straw on performance of local dairy cows and farmers perception in Ethiopia. *AgroLife Scientific Journal*, *9*(2), 35-44.

Ayalneh, T., Letta, T., & Abinasa, M. (2014). Assessment of stability, adaptability and yield performance of bread wheat (*Triticum aestivum* L.) cultivars in South Estern Ethiopia. *Plant Breeding and Seed Science*, *67*(1), 3–11. https://doi.org/10.2478/v10129-011-0065-3

Becker, H. C., & Leon, J. (1988). *Stability analysis in plant breeding. Plant Breeding*, *101*, 1-23.https://doi.org/10.1111/j.1439-0523.1988.tb00261.x

Borena, A., Alemu, G., Ayana, N., Delesa, A., Solomon, T., Zegeye, H., Asnake, D., Bikila, B., Duga, R., Getamesay, A., Zewudu, D., Tadesse, Z., Girma, B., Badebo, A., & Abeyo, B. (2021). Genotype × environment interaction and stability analysis for grain yield of bread wheat (*Triticum aestivum*) genotypes under low moisture stress areas of Ethiopia. *American Journal of Plant Biology*, *6*, 44–52. https://doi.org/10.11648/j.ajpb. 20210603.12

Bridges, W. C. (1989). *Analysis of a plant breeding experiment with heterogeneous variances using mixed model equations*, pp.145-151. In: Applications of mixed models in agriculture and related disciplines cultivars. Bull. No.343, *Louisiana Agricultural Experiment Station*, Baton Rouge, LA

Crossa, J., Gauch, J.r H. G., & Zobel, R. W. (1990). Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. *Crop Science*, *30*(3), 493–500.

Dagnachew, B., Asefa, F., Niguse, G., Redwan, Mo., Lijalem, K., (2020). Grain yield stability analysis of desi chickpea (*Cicer arietinum* L.) advanced genotypes across potential growing areas of Ethiopia. *Ethiopian Journal of Crop Science*, 8(1), 71-85.

Dinsa, T., & Balcha, U. (2024). Adaptation studies of durum wheat varieties for yield and yield components in East Shewa Zones. *Advances in Crop Science and Technology*, *12*(6). 707.

Dugda Woreda Office of Agriculture (DWOA) (2014). Baseline data of total land coverage and agricultural activity. Unpublished document.

Gadisa, A., & Abebe, D. (2020). Evaluation of grain yield stability analysis in bread wheat (*Triticum aestivum* L.) genotypes using parametric method. *American Journal of Life Sciences*, *8*(6), 189–195.

Gadisa, A., Alemu, D., Nagesh, G., Ruth, D., Tafesse, S., Habtemariam, Z., Abebe, G., Abebe, D., Dawit, A., Bayisa, A., Yewubdar, S., Bekele, G. A., & Ayele, B., (2021). Genotype×environment interaction and selection of high yielding wheat genotypes for different wheat-growing areas of Ethiopia. *American Journal of Bio-Science*, *9*(2), 63–71.

Habte, D., Tadesse, K., Admasu, W., Desalegn, T., & Mekonen, A. (2014). Agronomic and economic evaluation of the N and P response of bread wheat growing in the moist and humid mid highland vertisols areas of Arsi zone, Ethiopia. *African Journal of Agricultural Research*, *10*, 89–99.

Hodson, D. P., Jaleta, M., Tesfaye, K., Yirga, C., Beyene, H., Kilian, A., Carling, J., Disasa, T., Alemu, S. K., Daba, T., Misganaw, A., Negisho, K., Alemayehu, Y., Badebo, A., Abeyo, B., & Erenstein, O. (2020). Ethiopia's transforming wheat landscape: tracking variety use through DNA fingerprinting. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-75181-8

International plant Genetic Resource Institute [IPGRI], (2010). Descriptors' for Barley (*Hordeum vulgare* L.). *International plant Genetic Resource Institute*, Rome, Italy.

Iqbal, J., Shah, S. F. H., & Ahmad, I. (2018). Effect of sowing time, advanced genotype, and potassium application on seed cotton yield in relay cropping with wheat. *Advances in Agriculture and Biology*, *1*(1), 15-22.

Magari, R., & Kang, M. S. (1993). Genotype selection via a new yield-stability statistics in maize yield trials. *Euphytica*, *70*, 105-111.

Mattos, P. H. C., Oliveira1, R. A. J., Filho, C. B., Daros, E., & Verissimo, M. A. A. (2013). Evaluation of sugarcane genotypes and production environments in Parana by GGE biplot and AMMI analysis. *Crop Breeding and Applied Biotechnology*, *13*, 83–90. doi:10.1590/ S1984-70332013000100010

Megerssa, S. H., Ishetu, Y. S., Hailu, M., & Lemma, A. Z. (2024). Genotype by environment interaction and stability analyses of durum wheat elite lines evaluated in Ethiopia. *Crop Breeding and Applied Biotechnology*, *24*(1), e45542417. https://doi.org/10.1590/1984-70332024v24n1a07

Mulualem, G. M., Raju, U. J. P., Stojanovic, M., & Sorí, R. (2024). The phenomenon of drought in Ethiopia: Historical evolution and climatic forcing. *Hydrology Research*, *55*(6), 595-612.

Nigus, M., Shimelis, H., Mathew, IsacK., & Abady, S. (2022). Wheat production in the highlands of Eastern Ethiopia: Opportunities, challenges and coping strategies of rust diseases. *Acta Agriculturae Scandinavica, Section B - Soil & Plant Science*, *72*(1), 563–575. https://doi. org/10.1080/09064710.2021.2022186

Purchase, J. L., Hatting, H., & Vandenventer, C. S. (2000). Genotype × environment interaction of winter wheat in south Africa: II. Stability analysis of yield performance. *South African Journal of Plant and Soil*, *17*, 101-107.

Purchase, J. L. (1997). *Parametric analysis to describe G×E interaction and yield stability in winter wheat* (PhD thesis). Department of Agronomy, Faculty of Agriculture, University of the Orange Free State, Bloemfontein, South Africa.

Rebollo, I., Aguilar, I., Pérez de Vida, F., Molina, F., Gutiérrez, L., & Rosas, J. E. (2023). Genotype by environment interaction characterization and its modeling with random regression to climatic variables in two rice breeding populations. *Crop Science*, *63*(4), 2220–2240. https://doi.org/10.1002/csc2.21029

Regis, J. A. V. B., Andrade, J. A. C., Santos, A., Moraes, A., Trindade, R. W. R., Henriques, H. J. R., … Oliveira, L. C. (2018). Adaptability and phenotypic stability of sugarcane clones. *Pesquisa Agropecuária Brasileira*, *53*(1), 42–52. doi:10.1590/S0100-204X2018000100005

Senbeta, A. F., & Worku, W. (2023). Ethiopia's wheat production pathways to self-sufficiency through land area expansion, irrigation advance, and yield gap closure. *Heliyon*, *9*(10), e20720. https://doi.org/10.1016/j.heliyon.2023.e20720

Shiferaw, B., Smale, M., & Braun, H. J. (2013). Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. *Food Security*, *5*, 291–317.

Sununtnasuk. (2013). Calculating wheat flour consumption: Sources and methods, in: *Smarter Features Cost and Economic Benefit Training Workshop*, USAID SPRING.

Verma, A., & Singh, G. P. (2021). Combining AMMI and mean yield of wheat genotypes evaluated under rainfed conditions of northern hills zone for stability analysis. *International Journal of Bio-resource and Stress Management*, *11*(6), 590–600. doi: HTTPS://DOI. ORG/10.23910/1.2020.2162b

Yan, W. (2001). GGE bi-plot- a windows application for graphical analysis of multi-environment trial data and other types of two-way data. *Journal of Agronomy*, *93*, 1111-1118.

Yan, W., Hunt, L. A., Sheng, Q., & Szlavnics, Z. (2000). Cultivar evaluation and mega-environment investigation based on the GGE bi-plot. *Crop Science*, *40*(3), 597-605.

Yan, W., & Tinker, N. A. (2006. Biplot analysis of multi-environment trial data: Principles and applications. *Canadian Journal of Plant Science*, *86*, 623-45. https://doi.org/10.4141/p05-169.

Yan, W., & Rajcan, I. (2002). Biplot analysis of test sites and trait relations of soybean in Ontario, *Crop Science*, *42*, 11-20. doi:10.2135/cropsci2002.0011

Yan, W., Kang, M. S., Woods, B. M., & Cornelius, P. L. (2007). GGE- biplot vs. AMMI analysis of genotype-by environment data. *Crop Science*, *47*, 643-655.

Zobel, R.W, Wright, M. J., & Gauch, H. G. (1988). Statistical analysis of a yield trial. *Agronomy Journal*, *80*(3), 388–393.