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Original Research Article

Adaptability Study of Yield and Yield Related Trait Performance of Improved Bread Wheat (*Triticum aestivum L.*) Varieties in North Shewa Zone Oromia, Ethiopia

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Abstract: Bread Wheat *(Triticum aestivum L.)* is an important cereal crop, which receives the most attention of specialists in plant breeding and production as worldwide. The Knowledge of the interaction between genotypes and environment with yield and yield components is a key aspect of effective selection in crop improvement. Therefore, the objective of this study was: to identify Adaptable bread wheat variety/ies with high level of grain yield and yield stability across locations. The study used 16 bread wheat released varieties, against local check at Fitche Agricultural Research Center (FiARC) in 2020-2022 cropping season. Ten important agronomic traits data were evaluated. Analysis of variance noticed significant difference, among varieties in both separated and combined analysis of variance. The combined ANOVA and the additive main effects and multiplicative interactions (AMMI) analysis for grain yield across environments exhibited significantly affected by environments, which explained 76.6% of the total variation. The genotype and genotype environmental integration were significant and accounted for 8 and 13.1%, respectively. Principal component (PCA) 1 and 2 accounted for 6.5 and 3.5% of the GEI, respectively, with a total of 10% variation. Generally, Sanete and Dandaa varieties were identified for yielding ability and stability, and recommended for the study area and similar agro-ecologies.

Keywords: AMMI, GGEI, Performance, Stability, Triticum aestivum L.

1. INTRODUCTION

In Worldwide, wheat (Triticum aestivum L.) is an important cereal crop, which receives the most attention of specialists in plant breeding and production. Yet, its production is limited by the adverse environmental conditions. Environmental fluctuation and interaction with crop plant are the major limitation to wheat production and productivity. Genotype x environment (GE) interaction reduces genetic progress in plant breeding programmes through minimizing the association between phenotypic and genotypic values (Comstock and Moll, 1963). Therefore, multi-environment yield trials are essential in estimation of genotype by environment interaction (GEI), identification of superior and stable genotypes in the final selection cycles (Kaya *et al*., 2006; Mitrovic *et al*., 2012). Phenotypes are a mixture of genotype (G) and environment (E) components, and their interactions (G x E). Genotypes by environment interactionn (GEI) are a complicate process of selecting genotypes with superior performance. As a result, Multi-environment trails (METs) are widely used by plant breeders to evaluate the relative performance of genotypes for target environments (Delacy *et al*., 1996). The additive main effects and multiplicative interaction (AMMI) model have led to more understanding of the complicated patterns of genotypic responses to the environment (Gauch, 2006). These patterns have been successfully related to biotic and abiotic factors. Yan et al. (2000), proposed another methodology GGE-biplot for graphical display of GE interaction pattern of MET data with many advantages. GGE biplot is an effective method based on principal component analysis (PCA), which fully explores MET data. It allows visual examination of the relationships among the test environments, genotypes and the GE interactions. The first two principle components (PC1 and 2) are used to produce a two dimensional graphical display of genotype by environment interaction (GGE-biplot). If a large portion of the variation is explained by these components, a rank-two matrix, represented by a GGE- biplot, is appropriate (Yan et al,. 2003). Using a mixed model analysis may offer superior results when the regression of genotype by environment interaction on environment effect does not explain all the interaction (Yan and Rajcan, 2002).

So the objective of this study was: to identify adaptable bread wheat varieties with high level of grain yield and yield stability across environments.

2. MATERIALS AND METHODS

2.1. Study sites

This adaptation trial was conducted in North Shewa zones of Fitche Agricultural Research Center at Degem, Wachale, Derbe-tsege and Hidabu Abote FTC and on Kuyu main station during the 2020-2022 main cropping season.

2.2. Breeding materials and experimental design

Totally 16 released bread wheat varieties (Dambal, Dandaa, Gelan, Hawi, Hibist, Hidase, Huluka, Jajabo. Liban, Limu, Mandoye, Ogolcho, Sanate, Sinja. Sora and Wane) were evaluated against local check. Randomized complete block design (RCBD), with three replications, were used. Six rows per plot of 0.2 m spacing between rows and 3m row length, and harvestable plot size was $2.4m^2$ (four harvestable rows per plot). Seed rate of 150 $kgha^{-1}$ and fertilizer rate of $100kgha^{-1}$ NPS and $150kgha^{-1}$ UREA were used. UREA was applied in split form. All other agronomic practices were performed as per the recommendation for the crop. The trial was raised under rain fed across all the test locations. The data considered for analysis was from the candidates of the net plot, thus the four central harvestable rows. The harvested varieties were sundried before being tested for moisture content where 12% was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale.

2.3. Statistical analysis

Analysis of variance was calculated using the model:
Yij=μ + Gi + Ej + GEij

Where: Yij is the corresponding variable of the i-th genotype in j-th environment, μ is the total mean, Gi is the main effect of i-th genotype, Ej is the main effect of j-th environment, GEij is the effect of genotype x environment interaction.

The AMMI model used was:
$$Yij=\mu + gi + ej + \sum_1^N \lambda k\ Yik\ \delta jk + \varepsilon ij$$

Where: Yij is the grain yield of the i-th genotype in the j-th environment, μ is the grand mean; gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Yik and δjk are the genotype and environment principal component scores for axis k, N is the number of principal components retained in the model, and Ɛij is the residual term. GGE-biplot methodology, which is composed of two concepts, the biplot concept (Gabriel, 1971) and the GGE concept (Yan *et al*., 2000) was used to visually analyse the METs data. This methodology uses a biplot to show the factors (G and GE) that are important in genotype evaluation and that are also the sources of variation in GEI analysis of METs data (Yan, W. 2001). The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al*., 2002).

2.4. AMMI Stability Value (ASV)

ASV is the distance from the coordinate point to the origin in a two-dimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model (Purchase, 1997).Because the IPCA1 score contributes more to the GxE interaction sum of squares, a weighted value is needed. This weighted value was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction sum of squares as follows:
$$ASV=\sqrt{[(SSIPCA1 + SSIPCA2)\ (IPCA1score)]2 + (IPCA2score)2}$$

Where, SS_{IPCA1}/SS_{IPCA2} is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable genotypes across environments (Purchase, 1997)

2.5. Genotype Selection Index (GSI)

Stability is not the only parameter for selection as most stable genotypes would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value RASVi), genotype selection index (GSI) was calculated for each genotype as:
GSIi = RASVi + RYi

A genotype with the least GSI is considered as the most stable (Farshadfar E., 2008). Analysis of variance was carried out using statistical analysis system (SAS) version 9.2 software (SAS, 2008).

Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package (VSN International, 2012).

2.6. Data collection method
Ten plants were sampled randomly before heading from each row (four harvestable rows) and tagged with thread and plant-based data were collected from the sampled plants.

2.6.1. Plant-based
Plant height, Spike length, and spikelet per spike, seed per spike, seed per spikelets, and tiller per plant. Plant height (cm); was measured and recorded when reached at 90% physiological maturity from the ground level to the base of the spike of plant. Spike length (cm); was measured from the base of the spike to the tip of the highest spikelet excluding awns. Spikelets per spike; is the average number of spikelets of the ten plants randomly selected.

2.6.2. Plot Based
Days to heading, days to maturity, Grain filling period and grain yield. Days to heading; was recorded by counting the number of days from sowing to the time when at least 50% of the heads of the plot fully exerted from the boom or flowered. Days to maturity; was recorded by counting the number of days from sowing to the days when 95% of the heads of the plot were physiologically matured. Grain yield per plot (g); yield per plot was taken and moisture was adjusted to the standard moisture content of 12% moisture basis after threshing the crop using moisture tester by the following formula. It was calculated as:
Adjusted yield per plot=Actual yield per plot (100-Y/100-X)

Where=Actual yield is yield per a given area in a unit at threshing
Y=is moisture in % age at threshing
X=is standard moisture in % age

Table 1: Analysis of variance (ANOVA) for grain yield and yield related traits of bread wheat genotypes evaluated in 2020-2022 main cropping season

S.V	DF	DH	DM	GFP	PH	SL	Spkltspike	sdspike	sdspikelet	Tiller	YLDKgha
Yr	1	33117.7**	89791.8**	13846.3**	61.5ns	55.1**	26516.9**	11057.9**	13.5**	2.8*	17446280**
Loc	5	6026.1**	8743.4**	697.9**	1805.6**	47.3**	2320.7**	4184.3**	3.9**	6.8**	46838083**
Vrt	16	901.0**	531.9**	114.5**	3424.4**	10.8**	230.6**	16.3**	0.65**	1.3**	1637860**
yr.vrt	16	22.9**	37.9**	44.5**	48.7ns	2.3**	166.1**	14.6*	0.64**	1.5**	399594**
loc.vrt	80	27.1**	20.8**	42**	28.2ns	0.14ns	9.8ns	2.8ns	0.05ns	0.17ns	457470**

Whereas, DF= degree of freedom, DH=Days to heading, DM= Days to maturity, GFP = Grain filling period, PH = plant height, SL = Spike length, Spkltspike= spikete per spike, sdspike = seed per spike, sdspikelet= seed per spikelet, YLDKgha = Yield Killo gram per hectare

3. RESULTS AND DISCUSSION
3.1. Combined Analysis of Variance (ANOVA)
Mean square of analysis of variance for all varieties at different environmental conditions, for grain yield and yield related traits, are presented in Table1. Highly significant differences were detected among years ($P \leq 0.01$) for all parameters, except for plant height. The combined analysis of variance revealed that year and location effects were significant for all parameters. Year*varieties effects were significant for all parameters, excluding plant height. Varieties*location were significant for some traits such as days to heading, days to maturity, grain filling period and yield.

3.2. Yield across Environments
The performance of the tested bread wheat varieties for grain yield across location and year are presented in Table 2. Some varieties (e.g., Dandaa and Sanete) are constantly performed best in a group of environments, while other varieties (such as Gelan and Hawi etc) are fluctuated across location. The average grain yield ranged from the lowest (1008kgha^{-1}) at Debre-tsege site in 2022 to the highest (3774kgha^{-1}) at Hidabu Abote site in 2022, with the grand mean of 2155.833 kgha-1 (Table 2). The grain yield across environments ranged from the lowest of 1824 kgha^{-1} for sinja variety to the highest of 2519kgha^{-1} for Sanete variety (Table2). This wide variation might be due to their genetic potential of the varieties. Sanete variety was the top-ranking in all environments, except at Wachale in 2022. Similarly, Dandaa variety ranked first at all sites, except at Wachale in 2020 cropping season. However, Sinja variety ranked the least in all environmental sites throughout cropping season except at Wachale in 2022 cropping season (Table 2). The difference in yield rank of varieties across the locations exhibited the high crossover type of variety x environmental interaction (Yan and Hunt, 2001).

Table 2: Mean grain yield (kgha-1) of bread wheat genotypes evaluated at three environments

varieties	Grain Yield Kgha							
	Year						Mean	YLA (%)
	2020		2022					
	Locations							
	Degem	Wachale	D.Stege	Wachale	H.Abote	Kuyu		
Dambal	1906.1g-j	1549.0de	936.97fg	2585.9d	4859.7a	1458.6efg	2216	6.2
Dandaa	**2943.3a**	**1569.6cd**	**1198.4bc**	**3055.8ab**	**3966cde**	**2168.6ab**	**2484**	**19.1**
Gelan	1947.1fgh	1964.6a	973.3ef	2050.2e	4299.2bc	1982.4bcd	2203	5.6
Hawi	2703.5bc	2000.8a	814.7ghi	3286a	3574.2e-h	1402.5fg	2297	10.1
Hibist	1752.5jk	1866.1ab	1125.8cd	3036.8ab	3701.3d-g	2384.7a	2311	10.8
Hidase	1749.9jk	1120.4hi	1282.9b	3183.5a	3127.4h	1424efg	1981	-5
Huluka	2270.9e	1215.7gh	922.7fg	2340.3de	3416.7fgh	1479.7efg	2145	2.8
Jajabo	1922.1ghi	1416.2ef	1207.7bc	3039.2ab	4608.5ab	2291.9ab	2414	15.8
Liban	2555.3cd	1202.6gh	917.8fgh	3002.7abc	3992.1cde	1736.5def	2235	7.1
Limu	2618.3bc	1530.4de	1108.9cde	3319.3a	3564e.h	2128.8abc	2378	14
Local	2093.07f	691.9j	772.2hij	914.2f	2485.4i	957.6h	2086	0
Mandoye	2406.7de	1727.3b	1000.8def	3131.5a	3874.4c-f	2306.7ab	2408	15.4
Ogolcho	1855.3hij	1561.8de	765.1ij	2037.5e	5047.8a	1536ef	2134	2.3
Sanate	**2743.9b**	**1716.3bc**	**1555.4a**	**2676.1bcd**	**4102.8cd**	**2320.7ab**	**2519**	**20.8**
Sinja	1592.5k	1018.9i	701.97ij	3251.3a	2596.4i	1785.3cde	1824	-12.5
Sora	1765.8ij	1487.4de	1109.2cde	3302.1a	3547.1e-h	1479.3efg	2115	1.4
Wane	2024.6fg	1294.1fg	650.6j	2607.1cd	3391.8gh	1149.4gh	1853	-11.2
MEAN	2168	1467	1008	2754	3774	1764	2155.833	
LSD5%	160.6	151.5	150.3	408.8	478.7	368.4		
CV%	4.5	6.2	9	8.9	7.6	12.6		

Whereas, LSD% =least significant difference, CV% = Coefficient of variation, YLA% = yield advantage

3.3. Agronomic Performance

Combined mean grain yield and other agronomic traits are presented in Table 3. High mean of days to heading, days to maturity, plant height, spike length and seeds per spike were recorded by local checks. These offer great flexibility for developing improved varieties suitable for various agro-ecologies with variable length of growing period and high in grain yield status. However, Hawi variety was with short mean of days to heading and days to physiological maturity, Plant height, spike length and seeds per spike indicating that early maturing varieties were desirable when moisture was the limiting factors of production. Similarly, the local check was recorded with high plant height, indicating that the variety might be susceptible to lodging. Sanete and Dandaa varieties were with medium plant height indicated, and the possibility for developing resistant varieties against lodging problems. Moreover, Sanete and Dandaa varieties recorded the highest grain yield and had 20.8% and 19.1% yield advantages respectively (Table 2).

Table 3: Combined mean grain yield and other agronomic traits of bread wheat varieties

varieties	DH	DM	GFP	PH	SL	sdspike	Spkltspike	sdspikelet	Tiller	kgha
Dambal	**77.9hij**	**138.6e**	**60.7bcd**	**76.4bcd**	**7.8de**	**22.8ab**	**32.9e-h**	**1.9ef**	**2.3c-g**	**2216.1de**
Dandaa	**85.2d**	**143.5c**	**58.3efg**	**78.3bc**	**7.6def**	**23.2ab**	**34.5c-g**	**2.0def**	**2.6abc**	**2483.6ab**
Gelan	**84.1d**	**142.5cd**	**58.4efg**	**76.9bcd**	**8.3bc**	**22.1abc**	**37.4bcd**	**2.4ab**	**2.2fg**	**2202.8de**
Hawi	**76.9ij**	**136.8f**	**59.9cde**	**66.9g**	**7.2fg**	**20.9cd**	**33.8d-h**	**2.2bcd**	**2.8ab**	**2296.9cd**
Hibist	**82.4ef**	**141.8d**	**59.4c-f**	**73.0def**	**7.6def**	**23.1ab**	**43.4a**	**2.6a**	**2.2d-f**	**2311.2cd**
Hidase	**78.8h**	**137.7ef**	**58.9d-g**	**67.05g**	**7.0g**	**22.5abc**	**35.9b-f**	**2.4abc**	**2.6abc**	**1981.4f**
Huluka	**94.5b**	**146.9b**	**52.4i**	**77.6bc**	**7.8de**	**21.8abc**	**40.0ab**	**2.5a**	**2.2efg**	**1940.98fg**
Jajabo	**85.1d**	**146.2b**	**61.2abc**	**75.03cde**	**8.6ab**	**21.6bc**	**39.1b**	**2.3abc**	**2g**	**2414.3abc**
Liban	**83.7de**	**142.1cd**	**58.3efg**	**69.3fg**	**7.4efg**	**23.25a**	**36.9b-e**	**2.1c-f**	**2.5b-f**	**2234.5de**
Limu	**88.2c**	**145.7b**	**57.5fgh**	**75.1cde**	**7.9cd**	**23.1ab**	**37.4bcd**	**2.1c-f**	**2.9a**	**2378.3bc**
Local	**103.2a**	**159a**	**55.8h**	**126.5a**	**8.7a**	**23.3a**	**29.8h**	**1.9f**	**2.5b-f**	**2086h**
Mandoye	**78.5hi**	**137.9ef**	**59.4c-f**	**65.3g**	**6.3ij**	**21.8abc**	**34.8c-f**	**2.2bcd**	**2.7ab**	**2407.9abc**
Ogolcho	**80.7g**	**139e**	**58.3efg**	**76.9bcd**	**7.96cd**	**22.5abc**	**32.6fgh**	**2.0def**	**2.6a-e**	**2133.9e**
Sanate	**81.6fg**	**141.1d**	**59.5c-f**	**79.96b**	**7.1g**	**23.3a**	**38.5bc**	**2.2bcd**	**2.1fg**	**2519.2a**
Sinja	**74.8k**	**138.2ef**	**63.4a**	**73.2def**	**6.9gh**	**22.2abc**	**33.6d-g**	**2.1c- f**	**2.7abc**	**1824.4g**
Sora	**76.5j**	**139e**	**62.5ab**	**71.8ef**	**6.6hi**	**19.96d**	**30.6gh**	**2.2b-e**	**2.6a-d**	**2115.1e**
Wane	80.7g	137.8ef	57.1gh	65.4g	5.9j	21.2cd	39.34ab	2.5a	2.6abc	1852.9g
MEAN	83.1	142	58.9	76.2	7.5	22.3	35.9	2.2	2.5	2154.9
LSD5%	1.6	1.6	2.3	4.3	0.4	1.5	4.2	0.2	0.4	124.8
CV%	3	1.7	5.8	8.7	8.8	10.4	17.7	16	23.4	8.8

Whereas, DH=Days to heading, DM= Days to maturity, GFP = Grain filling period, PH = plant height, SL = Spike length, Spkltspike= spikete per spike, sdspike = seed per spike, sdspikelet= seed per spikelet, YLDKgha = Yield Killo gram per hectare, LSD% =least significant difference, CV% = Coefficient of variation

3.4. Additive Main Effects and Multiplicative Interaction (AMMI) Model

The combined ANOVA and AMMI analysis for grain yield at six environments exhibited by bread wheat grain yield (Table 4), was significantly affected by environments. This explained 76.6% of the total treatment variation, while the G and GEI were significant and accounted for 8 and 13.1%, respectively (Table 4). Similar findings have been reported in previous studies (Farshadfar *et al*., 2012; Kaya *et al*., 2006).A study by Gauch and Zobel (1997), reported in standard multi-environment trials (METs), environment effect contributes 80% of the total sum of treatments and 10% effect of genotype and interaction. In additive variance, the portioning of GEss data matrix using AMMI analysis indicated the first PCAs were significant ($P < 0.01$). PCA 1 and 2 accounted for 6.5 and 3.5% of the GE interaction, respectively; representing a total of 10% of the interaction variation (Table 4). Similar results have been reported in earlier studies (Mohammadi and Amri, 2009). Large yield variation explained by environments indicated that environments were diverse, with large differences between environmental means contributing maximum of the variation in grain yield.

Table 4: Additive main effect and multiplicative interaction analysis of variances (AMMI) for grain yield of 17 bread wheat released varieties evaluated at six environments

Source	DF	SS	EX. SS%	MS	F pr
Total	305	328452980	100	1076895	
Treatments	101	320833519	97.7	3176569	<0.001
Genotypes	16	26205761	8.0	1637860	<0.001
Environments	5	251636695	76.6	50327339	<0.001
Block	12	639737	0.2	53311	0.1397
Interactions	80	42991063	13.1	537388	<0.001
IPCA 1	20	21265217	6.5	1063261	<0.001
IPCA 2	18	11343207	3.5	630178	<0.001
Residuals	42	10382639		247206	<0.001
Error	192	6979724		36353	

Whereas DF=degree of freedom, SS=sum of squares, MS=mean squares, IPCA=Interaction Principal Component Axis, EX. SS%=Explained Sum of square ns *, ** non-Significant, Significant at the 0.5% and 0.1% level of probability, respectively

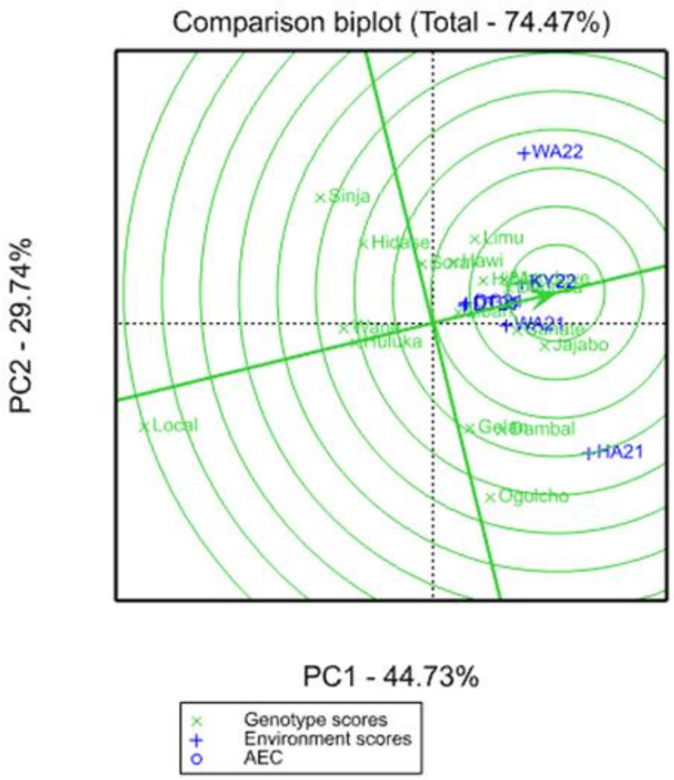

Figure 1: GGE bi-plot based on variety-focused scaling for comparison of varieties for their yield potential and stability of bread wheat varieties at North Shewa Oromia in Ethiopia

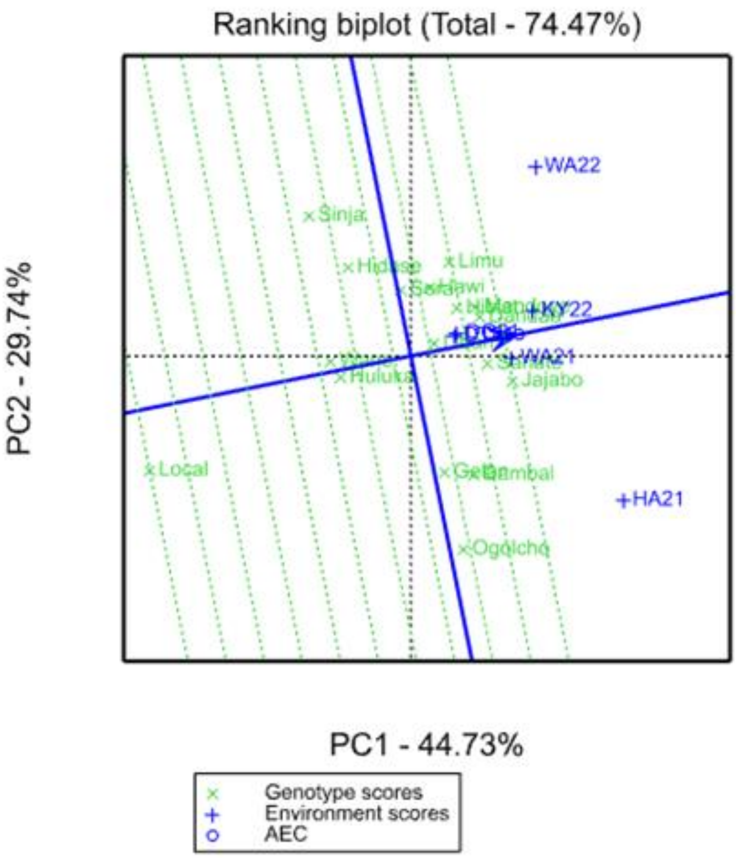

Figure 2: GGE bi-plot based on tested environments-focused comparison for their relationship
WA= Wachale, KY = Kuyu, DT= Debre-tsege, HA= Hidabu Abote, 21= 2021, 22= 2022 (year)

3.5. Additive Main Effects and Multiple Interactions (AMMI)

3.5.1. AMMI Stability Value (ASV)

Varieties exhibited significant Varieties by environment interaction effects and the additive and multiplicative interaction effect stability analysis (ASV) implied splitting the interaction effect. In view of the mean grain yield as a first criterion for evaluating, Sanete variety was the highest mean grain yield (2519 kgha^{-1}), followed by the varieties Dandaa and Jajabo with the mean grain yield of (2484 and 2414kgha^{-1}, respectively). Whereas, Sinja, Wane and Hidase varieties were with low mean grain yields across the testing locations (Table 5). The IPCA1 and 2 scores in the AMMI model are indicators of stability (Purchase, 1997). Considering IPCA1, Sanete variety was the most stable genotype with IPCA1 value (-3.39031), followed by Dandaa with IPCA1 value of (2.95354). Likewise, in IPCA2, Sora variety was the most stable with interaction principal component value (-11.3185). The two principal components have their own extremes; however, calculating the AMMI stability value (ASV) is a balanced measure of stability (Purchase, 1997). Varieties with lower ASV values are considered more stable and with higher ASV are unstable. According to the ASV ranking in the (Table 5), Liban variety was the most stable with an ASV value of 1 followed by Wane with ASV value 2. However, Ogolcho variety was the most unstable since higher ASV value of 17. The stable variety was followed with mean grain yield above the grand mean and this result was in agreement with Hintsa and Abay (2013) who has used ASV as one method of evaluating grain yield stability of bread wheat varieties in Tigray and similar reports been made by Abay and Bjørnstad (2009); Sivapalan *et al*., (2000) in barley in Tigray and bread wheat using AMMI stability value. A variety with the least of genotype selection index (GSI) is considered as the most stable genotype (Farshadfar, 2008). Accordingly, Sanete and Dandaa varieties were the most stable varieties since with the low of genotype selection index (GSI) and the highest mean grain yield.

Table 5: AMMI Stability Value, AMMI Rank, Yield, Yield Rank and Genotype Selection Index (GSI)

Varieties	ASV	ASV rank	YLD	YLD rank	GSI	IPCAg1	IPCAg2
Sanate	12.3	7	2519	1	8	-3.39031	10.51568
Dandaa	9.3	4	2484	2	6	2.95354	7.44796
Jajabo	20.9	10	2414	3	13	-8.70257	-13.13
Mandoye	7.3	3	2408	4	7	3.71925	-2.08943

Varieties	ASV	ASV rank	YLD	YLD rank	GSI	IPCAg1	IPCAg2
Limu	21.1	11	2378	5	16	11.27516	1.4748
Hibist	11.5	6	2311	6	12	3.95429	-8.7504
Hawi	16.3	8	2297	7	15	8.66911	1.9053
Liban	1.2	1	2235	8	9	0.63472	0.23029
Dambal	38.2	15	2216	9	24	-19.6306	-10.511
Gelan	32.1	13	2203	10	23	-17.1082	2.30185
Huluka	9.5	5	2145	11	16	0.69298	9.42715
Ogolcho	54.8	17	2134	12	29	-29.1282	-6.18691
Sora	19.8	9	2115	13	22	8.66969	-11.3185
Local	32.6	14	2086	14	28	-2.26773	32.27348
Hidase	27.6	12	1981	15	27	14.39543	-5.98555
Wane	5.0	2	1853	16	18	2.61518	0.77463
Sinja	43.2	16	1824	17	33	22.64823	-8.37942

4. CONCLUSION AND RECOMMENDATION

Combined analysis of variance revealed significant effect of variety, location, year and their interactions for most of agronomic traits, indicating the significant influence of location and over year fluctuating weather condition on considered observation. The study found that Sanete and Dandaa had shown significantly higher mean values of grain yield with the best yield advantage over the local check. Based on the two analyses of AMMI and GGE-bi-plot models, these varieties considered by high yield and more stability, adaptable to a wide range of environmental conditions and were recommended to the study areas and other areas having similar agro-ecologies.

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APPENDIX

Appendix table 1 Genotype means and scores

Genotype	Number	Mean	IPCAg1	IPCAg2
Dambal	1	2216	-19.6306	-10.511
Dandaa	2	2484	2.95354	7.44796
Gelan	3	2203	-17.1082	2.30185
Hawi	4	2297	8.66911	1.9053
Hibist	5	2311	3.95429	-8.7504
Hidase	6	1981	14.39543	-5.98555
Huluka	7	1941	0.69298	9.42715
Jajabo	8	2414	-8.70257	-13.13
Liban	9	2234	0.63472	0.23029
Limu	10	2378	11.27516	1.4748
Local	11	2086	-2.26773	32.27348
Mandoye	12	2408	3.71925	-2.08943
Ogolcho	13	2134	-29.1282	-6.18691
Sanate	14	2519	-3.39031	10.51568
Sinja	15	1824	22.64823	-8.37942
Sora	16	2115	8.66969	-11.3185
Wane	17	1853	2.61518	0.77463

Whereas, IPCAg1= interaction principal component axis one of genotype, IPCAg2 = interaction principal component axis two of genotype.

Appendix table 2 Environment means and scores

Environment	Number	Mean	IPCAe1	IPCAe2
DG21	1	2168	5.62827	29.95125
DT21	2	1003	4.22925	10.45179
HA21	3	3774	-40.3456	-15.1909
KY22	4	1764	3.80633	0.00451
WA21	5	1467	-4.18942	1.34653
WA22	6	2754	30.87121	-26.5632

Whereas, DG= Degem site, DT= Derbetsege site, HA= Hidabu Abote site, KY= Kuyu site, WA= Wachale site, 21= 2021, 22= 2022, IPCAe1= interaction principal component axis one of environment, IPCAe2 = interaction principal component axis two of environment