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Assessment of Stability, Adaptability and Yield Performance of Bread Wheat (*Triticum aestivum L.)* Cultivars in South Estern Ethiopia

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Abstract: The success of crop improvement and production activities can be enhanced with scientific information generated form genotype-environment interactions (GEI). GEI reduces the association between phenotype and genotype which result in relative ranking and stability differences of genotypes across environments. This study was conducted with the objective to identify stable and adaptable bread wheat genotypes under various environments in South Eastern part of Ethiopia. Eighteen bread wheat genotypes were tested across nine environments for two consecutive cropping seasons (2006-2007) using Randomized Complete Block Design (RCBD) with three replications. Plot size of 1.2m x 2.5m and 20 cm spacing between rows were utilized. All recommended agronomic and managements practices were practiced uniformly. Data were collected on plot basis and converted to ton ha$^{-1.}$ for subsequent analysis and statistical analysis was carried out using appropriate statistical software for stability parameters. Combined analysis over nine environments showed, variety Tuse (HAR-1407) ranked followed by variety K-6295-4A and variety Dashen with their mean yield of 3.11, 3.01 and 2.98 ton ha^{-1} respectively. Analysis of AMMI model showed that the first principal component, PCA 1, explained 53.72% of the interaction sum of squares, while the second principal component, PCA 2, explained 17.61% interaction sum of squares. Ecovalence (Wi) statistics revealed variety Sofumar (HAR-1889), variety Kubsa (HAR-1685), variety Tura (HAR-1407), variety Galema (HAR-604) and variety Wabe (HAR-710) had almost equally the lowest ecovalence and that evidenced less fluctuation across environments and considered to be stable. These varieties are more stable and are recommended for commercial production in South Eastern part of Ethiopia.

Key words: Stability · Genotypes · Environment · Adaptability · Interactions

INTRODUCTION

The success of crop improvement activities largely depends on the identification of superior genotypes for cultivation by assessing stability in performance of genotypes with respect to changes across environment (adaptability) and performance with respect to changing environmental factors over time with a given environment (stability). The performance of a variety is the resultant effect of its genotype and the environment in which the genotypes are tested. According to Prabhakaran and Jain [1], presence of GEI reduces the correlation between phenotype and genotype making it difficult to assess the genetic potential of a particular genotype whose relative ranking will be altered in different environments.

Knowledge of genotype-by-environment interaction can help plant breeders to reduce the cost of extensive genotype evaluation by eliminating unnecessary testing sites [2]. Conversely, the presence of a large GEI may necessitate the establishment of additional testing sites. Hence, if cultivars are being selected for a large group of environments, stability, adaptability and mean yield across all environments are more important than yield for specific environments [3].

Multi environment yield trial can be analyzed to extract more information on stability, adaptability and yield performance using various statistical methods and software suggested by different scholars: Hussein *et al.* [4], Gauch [5] and Yan *et al.* [6]. Plant breeders use different methods for analysis of GEI: Linear Regression

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model (b_i) and deviation from regression mean square (S^2d_i) of Eberhart and Russell [7], Ecovalence (W_i) of Wricke [8], AMMI Stability Value (ASV) of Purchase [9] and Francis and Kannenburg [10] coefficient of variability (Cv_i) among stability/ adaptability performance measures.

Bread Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in Ethiopia. According to Central Statistics Authority [11] report of Ethiopia, wheat covered 1.61million hectares and ranks fourth after Tef (*Eragrostis tef*) 2.72 million has, Maize (*Zea mays*) 2.15 million has and Sorghum (*Sorghum bicolor*) 1.90 million has. Bale and Arsi high lands of South Eastern Ethiopia is known by high bread wheat producing areas in the country. Especially Bale high lands are one of the most known wheat belt areas and some times considered as bread basket of the country and farmers majorly produce improved bread wheat varieties released both from regional and federal research centers. Sinana Agricultural Research Center located in Bale zone, has been contributed a huge effort to equip farmers with improved wheat technologies and the considered as causative center for technology spillover of wheat and modern production system in the zone and in some areas of west Arisi zone. Ashine *et al.* [12] also reported that Arsi and Bale zones are an extensive wheat producing areas in Ethiopia. Limitation of information on GEI of bread wheat cultivars in South Eastern of Ethiopia becoming an important issue by large scale producers (commercial farmers) and small scale farmers. In view of this, the current study was conducted to identify stability, adaptability and performance of bread wheat cultivars across environments in the South Eastern part of Ethiopia.

MATERIALS AND METHODS

Eighteen bread wheat genotypes, all released varieties form both regional and federal bread wheat improvement program were tested across environments for two consecutive years in nine environments (year-location combinations during 2006 and 2007 cropping seasons). One local and two standard checks along with 15 bread wheat varieties were evaluated for their yield performance at five locations namely Sinana, Sinja, Agarfa, Gassera and Adaba representing the major wheat growing areas of the Highlands of Bale, South Easter part of Ethiopia. The trials was laid in randomized complete block design with 3 replications on plot size of 1.2 m wide (6 rows with 20 cm apart) by 2.5 m length of which four central rows were harvested for grain yield estimate. Seed rate of 150 kg ha^{-1} and fertilizer rate of 41/ 46 N/ P_2O_5 kg ha^{-1} was utilized. The experiment was conducted in the main season under rain fed condition. All the agronomic managements and practices were adopted as per recommendation for each location. Yield data was taken per plot basis and converted to ton ha^{-1} for carrying out subsequent statistical analysis.

Statistical Analysis: Mean grain yield data per plot was converted to ton ha^{-1} and subjected to analysis of variance in order to partition sum of squares to genotype, environment and genotype-environment interaction effect using Statistical Analysis Software (SAS, V9). AMMI stability analysis was carried out using IRRISTAT computer software (IRRI STAT, 2003). Stability and adaptability performance across environments was estimated following different procedures: Regression coefficient (bi) was done following procedure developed by Finlay and Wikinson [13], later revised (b_i and S^2d_i) by Eberhart and Russell [7]. Ecovalence (W_i) which is the contribution of each genotype to the GEI sum of squares was estimated with the method Wricke's [8]. ASV and Cv_i was also done following the technique of Purchase [9] and Francis and Kannenburg [10], respectively.

RESULTS AND DISCUSSION

Combined analysis across nine environments revealed that variety Tuse (HAR-1407) ranked first in mean yield (3.11 t ha^{-1}) and followed by variety K-6295-4A with mean yield of 3.01 t ha^{-1} and variety Dashen with mean yield of (2.98 t ha^{-1}). High coefficient of variability as indicated in the parenthesis, was observed for variety Madawalabu (45.45%) which ranked fifth in mean yield (2.88 t ha^{-1}), followed by variety Tuse (HAR-1407) (39.89%) and variety Dashen (36.88%).The two varieties Madawalabu (HAR-1480) and Tuse (HAR-1407) can be considered as the most unstable genotypes because stability is characterized by providing high yield and low CV% Francis and Kannenburg [10]. However, from their background history, these two bread wheat varieties have been widely cultivated in Bale, South Eastern part of Ethiopia by commercial state farms and small scale farmers. Besides, the nine testing environments were assessed for their yield contribution or productivity (Table 2). High productivity was observed for E1 (Sinana 2006), 3.86 t ha^{-1}, E6 (Sinana 2007) , 3.33 t ha^{-1} and E4 (Gassera 2006), 3.23 t ha^{-1} and the lowest productivity was observed at E9 (Adaba 2007). The three environments with high yield potential (E1 (Sinana 2006),

Table 1: Eighteen improved bread wheat varieties, mean yield ($t\ ha^{-1}$), cultivar rank, standard deviation and coefficient of variation (%) tested across environment in 2006 and 2007 cropping seasons.

Variety names	Breeding Institute	Year of release	Mean yield	Rank	SD	CV(%)
Madda walabu (HAR-1480)	SARC	1999/00	2.88	5	1.22	45.45
Sofumar (HAR-1889)	SARC	1999/00	2.52	14	0.74	27.57
Dure (HAR-1008	SARC	2001	2.33	15	0.65	24.21
Kubsa (HAR-1685)	KARC	1995	2.84	6	0.72	26.82
Tura (HAR-1407)	KARC	1998/99	2.74	9	0.95	35.39
Dashen	KARC	1984/85	2.98	3	0.99	36.88
Galema (HAR-604)	KARC	1995/96	2.81	7	0.74	27.57
Simba (HAR-2536)	KARC	1999/00	2.71	10	0.92	34.27
Shina (HAR-1868)	AdARC	1998/99	2.75	8	0.73	27.19
Megal (HAR-1595)	KARC	1997	2.57	12	0.85	31.66
Mitike (HAR-1709)	KARC	1994	2.58	11	0.87	32.41
Wabe (HAR-710)	KARC	1995	2.26	18	0.81	30.17
Hawi	KARC	1999/2000	2.32	16	0.24	8.94
Holandi	-	-	2.31	17	0.37	13.78
Paven-76	KARC	1982	2.97	4	0.65	24.21
Tuse (HAR-1407)	KARC	1997	3.11	1	1.07	39.86
K-6295-4A	KARC	1980	3.01	2	0.65	24.21
ET-13A2	KARC	1981	2.53	13	0.61	22.72

Table 2: Environment name, environment code, mean yield ($t\ ha^{-1}$), rank and coefficient of variation (%) of nine testing environments.

Environment	Mean	Rank	CV (%)	Code
Sinana 2006	E1	3.86	1	27.68
Sinja 2006	E2	3.07	4	15.33
Agarfa 2006	E3	2.62	6	25.11
Gassera 2006	E4	3.23	3	27.65
Adaba 2006	E5	2.79	5	25.86
Sinana 2007	E6	3.33	2	32.16
Sinja 2007	E7	2.00	8	12.72
Agarfa 2007	E8	2.11	7	13.09
Adaba 2007	E9	1.32	9	14.21

E6 (Sinana 2007) and E4 (Gassera 2006) are characterized by bimodal rain fall patterns and the lowest yielding environment E9 (Adaba 2007) is characterized by monomodal rainfall patterns. Locations such as Sinana and Adaba are locations where large scale commercial farms (state farms) which produce a huge amount of bread wheat every year and contribute too much to growth Domestic Product (GDP) of the county.

Analysis of variance: pooled analysis of variance of eighteen genotypes in nine environments is presented in Table 3. Highly significant ($P<0.01$) variation were observed in environment and genotype-environment interaction, while significant ($p<0.05$) variations noted in genotypes. Significance of GEI is an indication for inconsistency of genotypes in response to changing environments due to genotype-environment interaction. Similar results were reported by Brandle and Mcvetty [14], Mohammedp [15], Das *et al.* [16], Tiawari *et al.* [17] and Jalata [18]. Partitioning of the sum of squares showed that high percent contribution to source of variation was attributed to environment (50.2%) followed by 43.2% of environment-genotype interaction and 6.6% of variation effects caused by genotypes. This is in agreement with those obtained by Letta [2] and Das *et al.* [16] they reported that high % of source of variation is due to environment. The highest magnitude of variation caused by environment is an indicative that complex external factors (biotic and abiotic) are number one challenges in crop improvement because of most of the elements of environment are difficult to manage in the best interest of breeder during field trial. The second high magnitude of variation in percent (43.2%) was seen in GEI which is the main cause in reducing the correlation between phenotype and genotype making it difficult to assess the genetic potential of a particular genotype whose relative ranking changed in different environments. One way of reducing GEI is stratification of environment but this may have another face of problem which goes to large unpredictable environmental variation still may exist within the different strata of environment.

Analysis of AMMI model showed that the first principal component, PCA 1 explained 53.72% of the interaction sum of squares while the second principal

Table 3: Combined analysis of variance, Gollop test of interaction principal component in AMMI for grain yield (ton/ha.) and % explained of bread wheat tested in nine environments in 2006 and 2007 cropping seasons.

Source	df	SS	MS	F -value	Explained.
Combined Analysis					
Environments (E)	8	176.81	22.10	29.32**	50.20%
Genotypes (G)	17	23.41	1.37	1.83*	6.60%
G x E	136	152.48	1.12	1.49**	43.20%
Total	161	352.69	24.59		100%
AMMI analysis					
Environments (E)	8	88.63	11.08		
Genotypes (G)	17	11.62	0.68		
G x E	136	76.25	0.56		
AMMI Component 1	24	40.97	1.71	5.42**	53.72%
AMMI Component 2	22	13.43	0.61	2.51**	17.61%
AMMI Component 3	20	12.66	0.63	4.82**	16.61%
AMMI Component 4	18	3.74	0.21	1.98*	4.90%
GXE Residual	52	5.46			
Total	161	176.51			

Table 4: Mean yield across environment, Additive Main effect and Multiplicative Interaction (AMMI) and joint regression analysis of bread wheat genotypes in nine environments in 2006 and 2007 cropping seasons.

	AMMI Model				Joint regression	Other stability parameter			
Entry	Mean	PCA1	PCA2	ASV	Rank	bi	S2di	W2i	CV (%)
G1	2.88	-0.388	-0.132	1.190	13	1.543	0.75	1.45	45.45
G2	2.52	-0.082	0.303	0.392	3	0.991	0.24	0.00	27.57
G3	2.33	0.263	0.159	0.817	9	0.807	0.27	0.18	24.21
G4	2.84	0.027	-0.230	0.244	2	1.034	0.20	0.01	26.82
G5	2.74	-0.162	0.602	0.778	8	1.454*	0.13	1.01	35.39
G6	2.98	-0.529	0.226	1.629	17	1.257	0.32	0.33	36.88
G7	2.81	-0.391	-0.111	1.197	14	0.965	0.19	0.01	27.57
G8	2.71	-0.335	0.149	1.032	10	1.227	0.28	0.25	34.27
G9	2.75	0.171	-0.512	0.730	7	0.880	0.28	0.07	27.19
G10	2.57	2.274	0.213	6.940	18	0.832	4.76	0.14	31.66
G11	2.58	0.050	0.689	0.705	6	1.204	0.46	0.20	32.41
G12	2.26	-0.396	-0.001	1.208	15	1.041	0.23	0.01	30.17
G13	2.31	0.111	-1.028	1.082	12	0.090*	0.11	4.07	8.94
G14	2.31	0.089	-0.484	0.554	4	0.472*	0.07	1.37	13.78
G15	2.97	0.030	-0.176	0.198	1	0.909	0.18	0.04	24.21
G16	3.11	-0.210	0.827	1.046	11	1.626*	0.18	1.93	39.86
G17	3.01	-0.397	-.0049	1.211	16	0.849	0.31	0.11	24.21
G18	2.53	-0.131	-0.482	0.626	5	0.819	0.30	0.16	22.72

component, PCA 2 explained 17.61% interaction sum of squares. The other interaction effects explained by the remaining principal components. The two principal components (PCA1 and PCA2) together captured 71.33% interaction effects which indicate the majority of interaction effects are trapped by Principal component one (PCA1) and principal component two (PCA2). Sadeghi [19] and Letta [2] also indicted that higher % of interaction effects were explained by the first two principal components.

Stability Analysis: Mean yield, AMMI model, joint regression and other stability parameters were presented in Table 4. The analysis revealed that, mean grain yield ranges from 2.26 to 3.11 t ha^{-1}. According to Eberhart and Russell [7] model, a stable genotype has high mean yield, bi = 1 and $S^2di = 0$. According to this model, G4 (Kubsa (HAR-1685)) G12 (Wabe (HAR-710)), and G12 (Sofumar (HAR-1889)), with bi values of 1.03, 1.04 and 0.99 are relatively the most stable genotypes while bread wheat varieties such as G13 (Hawi) and G12 (Holandi) have the lowest bi values of 0.090 and 0.47, respectively are relatively considered to be unstable genotypes according to this stability model.

Interaction principal component analysis IPCA1 showed that G4 (Kubsa (HAR-1685)), IPCA1= 0.027, G15 (Paven-76), IPCA1= 0.027 and G11 (Mitike (HAR-1709)), IPCA1=0.05 have the smallest interaction principal component scores and hence they are considered to be stable genotypes according to Purchase, [9] stability model. Where as, considering IPCA2 scores, genotypes such as G12(Wabe(HAR-710)), G17 (K-6295-4A) and G7 (Galema (HAR-604) with IPCA scores of 0.001, 0.004 and 0.111 respectively relatively showed lower IPCA scores and thus, based on this parameter of stability [9], they are considered as stable genotypes. Even if both IPCA1 and IPCA2 use for stability indication, variation was observed in measuring the stable genotypes between the two IPCA that means genotype which considered to be stable in IPCA1 not shown itself stable in IPCA2 as the first case. Letta [2] also noted that the two IPCAs (1,2) have different meanings in measuring the stability. The difference in stability measurement of the two principal components can be compensated by proportional difference between the IPCAs (1:2) then determined by Pythagoras theorem in effect of AMMI stability value. Purchase [9] noted that AMMI stability value (ASV) does not for quantitative stability measure rather quantify and rank genotypes according to their yield stability. So based on ASV, G15 (Paven-76) ranks first, followed by G4 (Kubsa(HAR-1685)) and G2 (Sofumar (HAR-1889)) which have yield stability across environment whereas, G10 (Megal (HAR-1595)), G6 (Dashen) and G17(K-6295-4A) were observed to be the most unstable genotypes in yield, respectively.

From result observed, ecovalence (Wi) analysis showed that G2 (Sofumar (HAR-1889)), G4 (Kubsa (HAR-1685)), G5 (Tura (HAR-1407)), G7 (Galema (HAR-604)), G12 (Wabe (HAR-710)), almost equally the lowest ecovalence that evidenced less fluctuation across environment and found to be stable according to Wricke [8].

CONCLUSION

The significant genotype by environment interactions and change in ranks of genotypes across environments suggests a breeding strategy of specifically adapted genotypes in homogeneously grouped environments. In general, the current study revealed that, bread wheat genotypes under in this study showed differences in stability and performance across environment and the importance of genotype by environment interactions has been clearly observed. Therefore, exploiting the useful side of genotype-environment interaction in crop improvement activities to identify superior genotype has a paramount importance.

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