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T. Ayalneh[*], T. Letta[**], M. Abinasa[***]

Oromia Agricultural Research Institute, Sinana Agricultural Research Center, Cereal Technology Generating Case Team, Breeding and genetics, P.O.BOX, 208 Bale Robe, Ethiopia,
Corresponding author e-mail : ayal.sarc@gmail.com

ASSESSMENT OF STABILITY, ADAPTABILITY AND YIELD PERFORMANCE OF BREAD WHEAT (*TRITICUM AESTIVUM L.)* CULTIVARS IN SOUTH ESTERN ETHIOPIA

ABSTRACT

The success of crop improvement and production activities can be enhanced with scientific information generated form genotype-environment interactions. GEI reduces the association between phenotype and genotype which result in relative ranking and stability differences of genotypes across environments. This study were conducted with the objective to identify stable, and adaptable bread wheat genotypes under various environments. Eighteen genotypes were tested across nine environments for two years on randomized block design of three replication. Plot size of 1.2 m × 2.5 m and 20cm spacing between rows were used. All recommended agronomic practices and managements were applied uniformly. Data were collected on plot basis and converted to ton ha$^{-1.}$ and analyzed with appropriate statistical software for stability parameters. Combined analysis over nine environments showed, variety Tuse (HAR-1407) ranked first in mean yield(3.11ton × ha^{-1}), and K-6295-4A ranked second (3.01 ton × ha^{-1}) and Dashen came third(2.98 ton ha^{-1}). 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) 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.

Key words: Adaptability, environment, igenotypes, nteractions, stability

INTRODUCTION

Limiting human population increase becoming a common practice but could not fully triggered its objective while sustainable food supply is an

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issue always question in minds of agricultural scientist and politicians. Yield increment per hectare through scientific research is one of the solutions to feed ever increasing human population.

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 factor over time with a given environment (stability). 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(1992), 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.

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.(2000), Gauch(2006), and Yan *et al.(*2007). Plant breeders use different methods for analysis of GEI, Linear Regression model (b_i) and deviation from regression mean square(S^2d_i)of Eberhart and Russell(1966), Ecovalence(W_i) of Wricke(1964), AMMI Stability Value(ASV) of Purchase(1997) , and Francis and Kannenburg(1978) coefficient of variability(CV_i) among stability/adaptability performance measures.

Bread Wheat (*Triticum aestivum L.*) is one of the most important cereal crop in Ethiopia. According to CSA (2011) report of Ethiopia, wheat covered 1.61 million hectares and ranks fourth after Tef (*Eragrostis tef*) 2.72 million ha. Maize (*Zea mays*) 2.15million ha. and Sorghum (*Sorghum bicolor*) 1.90million ha. 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 in Ethiopia and farmers majorly produce improved bread wheat varieties released both from regional and federal research centers. Sinana Agricultural Research Center in Bale, has been contributed a huge effort to equip farmers with improved wheat technologies and the causative center for technology spillover of wheat and modern production system in Bale zone and in some areas of west Arisi zone. Ashine *et al.*(2011) 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. Considering the problem, the study were conducted to identify stable, adaptable and well performed bread wheat cultivars across environments.

MATERIAL AND METHODS

Eighteen genotypes, all released varieties form both regional and federal bread wheat improvement program were tested across environment for two years on nine environments (Table 1). 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. 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 done in the main season under rain fed condition. All the agronomic management aspects were applied uniformly accordingly in test environments. Data were taken per plot basis and converted to ton × ha^{-1} basis.

Table-1

Eighteen improved bread wheat varieties, mean yield [ton × ha^{-1}], cultivar rank, standard deviation, and coefficient of variation [%] tested across environment in 2006 and 2007

Genotypes	Source	Year of release	Mean	Rank	Stdev	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	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

Statistical Analysis

Grain yield mean 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 system analysis software (SAS, V9). AMMI stability analysis was done by IRRI STAT computer software (IRRI STAT, 2003). Stability and adaptability performance across environments were estimated following different procedures. Regression coefficient (bi) were done following procedure developed by Finlay and Wikinson(19 63), later revised(b_i and S^2d_i) by Eberhart and Russell(1966). Ecovalence(W_i) which is the contribution of each genotype to the GEI sum of squares were also estimated with the method Wricke's (1964). ASV, and CV_i were done following the technique of Purchase (1997) , and Francis and Kannenburg (1978) respectively.

RESULT AND DISCUSSION

Combined analysis across nine environments showed that variety Tuse (HAR-1407) ranked first in mean yield (3.11 ton × ha^{-1}), and K-6295-4A ranked second (3.01 ton × ha^{-1}) and Dashen came third(2.98 ton × ha^{-1}). High coefficient of variability was observed in Madawalabu (45.45%) which ranked fifth in mean yield (2.88 ton × ha^{-1}), Tuse (HAR-1407) (39.89%) and Dashen (36.88%) respectively. 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(1978). From their background history, the two bread wheat varieties have been widely cultivated in Bale, south eastern part of Ethiopia by commercial state farms and small scale farmers. The nine environments were assessed for their yield contribution or productivity (Table 2). High productivity were observed in E1 (Sinana) , 3.86 ton × ha^{-1} , E6 (Sinja), 3.33 ton × ha^{-1} and E4 (Herero), 3.23 ton × ha^{-1}. The two environments E1 (Sinana), and E6 (Sinja) characterized by bimodal rain fall pattern and E4(Herero) is mono modal one. In all the three environments there are large scale commercial farms (state farms) which produce a huge amount of bread wheat product every year and contribute to GDP of the county.

Table-2

Environment name, environment code, mean yield ([ton × ha^{-1}], rank and coefficient of variation [%] of nine test environment

Environment	Environment code	Mean	Rank	CV [%]
SINANA	E1	3.86	1	27.68
SIN-III	E2	3.07	4	15.33
SEROFTA	E3	2.62	6	25.11
HERERO	E4	3.23	3	27.65
HUNTE	E5	2.79	5	25.86
SINJA	E6	3.33	2	32.16
GASERA	E7	2.00	8	12.72
AGARFA	E8	2.11	7	13.09
ADABA	E9	1.32	9	14.21

Analysis of variance: pooled analysis of variance of eighteen genotypes in nine environments were presented (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(1988), Mohammed(2009), Das *et al.* (2010), Tiawari *et al.(*2011) and Jalata(2011). 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. The report by Letta(2009), and Das *et al.(*2010) also suggested that high source of variation were observed in 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 experiment. The second high magnitude of variation (43.2%) were observed in GEI which discriminate the correlation between phenotype and genotype making it difficult to assess the genetic potential of 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.

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 2006 and 2007

Source	DF	SS	MS	F -Value	Explained.
Envs.	8	176.8	22.10	29.32**	50.2%
Gens.	17	23.41	1.37	1.83*	6.6%
Envs. × Gens.	136	152.48	1.12	1.49**	43.2%
Total	161	352.69	24.59		100%
Analysis of Variance for the Ammi Model					
Envs.	8	88.63	11.08		
Gens.	17	11.62	0.68		
Envs. × Gens.	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			

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. 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(2011) and Letta(2009) also indicted that high % interaction effects were explained by PCA1 and PCA2 (Table 4).

Stability analysis: Mean yield, AMMI model, joint regression, and other stability parameters were presented in table-4. From the analysis output mean yield is within the range of 2.26 ton × ha^{-1} and 3.11 ton × ha^{-1}. According to Eberhart & Russell (1966) model a stable genotype has high mean yield, bi = 1 and $S^2di = 0$. In line with this model, G4 (Kubsa (HAR-1685)), bi = 1.03 , G12 (Wabe (HAR-710)), bi = 1.04 and G12 (Sofumar (HAR-1889)), bi =0.99 are relatively the most stable genotypes and G13 (Hawi), bi =0.090, and G12(Holandi) bi =0.47 are relatively unstable genotypes according to the model (Table 4).

Table 4

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

Entry	Mean	AMMI Model			Rank	Joint regression		Other stability parameter	
		PCA1	PCA2	ASV		bi	S^2di	W^2i	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

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 score respectively. So according to (Purchase, 1997), the stated genotypes above with relatively the lowest IPCA1 score are stable. Genotypes showed the lowest IPCA2 score are G12 (Wabe (HAR-710)) = 0.001 followed by G17 (K-6295-4A) = 0.004 and G7(Galema (HAR-604)) = 0.111 considered to be 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(2007) also noted that the two IPCA (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 (1997) 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(1962).

CONCLUSION

Bread wheat genotypes showed differences in stability and performance across environment and the importance of genotype by environment interactions were clearly observed. Therefore, exploiting genotype-environment interaction in crop improvement activities is the main target of plant breeder to identify superior genotype.

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REFERENCE

Ashinie, B., Kedir N. and Habtamu S. Selection of some morphological traits of bread wheat That Enhance the Competitiveness Against Wild Oat (Avena fatua L.) World Journal of Agricultural Sciences 7 (2): 128-135, 2011

Brandle J. E. and Mcvettv P. B. E. 1988. Genotype x environment interaction and stability analysis of seed yield of oilseed rape grown in Manitoba. Can. J. Plant Sci. 68: 381-388.

CSA 2011. Agricultural Survey Sample: Report on area and production of different crops. (Meher season, private holdings). Central Statistical Agency: Addis Ababa, Ethiopia.

Das S., R.C. Misra, M.C. Patnaik and S.R. Das. G X E interaction, adaptability and yield stability of mid-early rice genotypes. Indian J. Agric. Res., 44 (2): 104 – 111

Eberhart S.A., Russell W.A., 1966. Stability parameters for comparing varieties. Crop Sci. 6, 36–40.

Finlay, K. W. and G.N. Wilkinson (1963). The analysis of adaptation in a plant-breeding program. Aust. J Agric. Res. 14:742-754.

Francis T.R., Kannenberg L.W. 1978. Yield stability studies in short-season maize: I. A descriptive method for grouping genotypes. Can J Plant Sci 58, 1029-1034.

Gauch H.G. 2006. Statistical analysis of yield trials by AMMI and GGE. Crop Sci. 46:1488–1500.

Hussein M.A, Asmund B. and Aastveit A.H. 2000. SASG X ESTAB: A SAS Program for Computing Genotype X Environment Stability Statistics. Published in Agron. J. 92:454-459.

Jalata Z. 2011. GGE-biplot of multi environment yield trials of barley (Hordeium vulgare L.) in south eastern of Ethiopia. Internaional Journal of plant breeding and genetics 5(1): 59-75. ISSN 1819-3595/ DOI:10.3923/ijpbg.2011.59.75

Letta T. 2009. Genotype environment interactions and correlation among stability parameters yield in durum wheat (*Triticum durum* Desf) genotypes grown in south east Ethiopia. African crop science proceedings vol. 8. Pp. 693-698

Mohammed M. I. 2009. Genotype X Environment Interaction in Bread Wheat in Northern Sudan Using AMMI Analysis. American-Eurasian J. Agric. & Environ. Sci., 6 (4): 427-433.

Prabhakaran V.T and Jain J.P. 1992. Statistical techniques for studying genotype-environment interaction. South Asian Publishers Pvt. Ltd. New Delhi.

Purchase R.L. 1997. Parametric analysis to describe genotype by environment interaction and yield stability in winter wheat. Ph.D. Thesis, Department of Agronomy, Faculty of Agriculture of the University of the Free State, Bloemfontein, South Africa.

Sadeghi S.M, H. Samizadeh, E. Amiri and M. Ashouri.2011. Additive main effects and multiplicative interactions (AMMI) analysis of dry leaf yield in tobacco hybrids across environments. African Journal of Biotechnology Vol. 10(21), pp. 4358-4364

Tiawari D.K, P. Pandey, R.K Singhi, S.P Singhi and S.B Singhi. Genotype X environment interaction and stability analysis in elite clones of sugarcane (*Saccharium officinarium L.*). Internaional Journal of plant breeding and genetics 5(1): 93-98. ISSN 1819-3595/DOI:10.3923/ijpbg.2011.93.98

Wricke G. 1964. Zur Berechnung der Ökovalenz bei Sommerweizen und Hafer. Z. Pflanzenzüchtung 52: 127-138.

Yan W., M.S. Kang, B. Ma, S. Woods, and P.L. Cornelius. 2007. GGE- biplot vs. AMMI analysis of genotype -by-environment data. Crop Sci. 47:643–655.