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Open Access Journal of Agricultural Research
ISSN: 2474-8846

Performance Evaluation of Advanced Bread Wheat Genotypes for Yield Stability Using the AMMI Stability Model

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Research Article

Volume 3 Issue 4

Received Date: May 26, 2018

Published Date: June 15, 2018

Abstract

Bread wheat (*Triticum aestivum* L.) is one of the staple foods for large proportion of the Ethiopian population. Ethiopia is the largest wheat producer in Sub-Saharan Africa, The country cultivates a total of more than 1.6 million hectares, and yet imports about 1/3 of the national requirement to make up for annual deficits. To increase wheat production in the country, adaptive breeding has been in progress to develop promising lines for broad adaptation or to develop wheat varieties that perform well over diverse agricultural environments. In this study a total of fifteen genotypes, eight advanced lines from CIMMYT/ICARDA source, five Ethiopian crosses, and two checks, were tested across six locations during 2017 and 2018 seasons. Yield stability index (YSI) was calculated by ranking the mean grain yield of genotypes (RY) across environments and by ranking the AMMI stability values (RASV). The smallest YSI value of 5 was exhibited by variety Hidass and entries ETBW8084, ETBW9037, ETBW9470 and ETBW8459 had YSI values of 6, 7, 12, and 12, respectively, and indicated stability across locations with comparatively higher yields. The highest YSI (30) was recorded by genotype ETBW8075 which is characterized as unstable and low yielder. ETBW 8084 was high yielder and with bi<1, (but bi is 1.236) it indicated that it will perform well in diverse environments including marginal and low yielding areas. On the other hand ETBW8075, with high deviation from regression, S_i^2= 4.77, was the lowest yielder and poor performance across tested locations. Therefore, ETBW8084 is recommended for production in diverse agro-ecological environments, and ETBW9470 is recommended for optimum environment. These two lines will be tested national variety verification trials (NVVT) in 2018 as candidate varieties for a possible release for production by the resource poor farmers.

Keywords: Bread Wheat; AMMI; YSI; Stability

Introduction

Bread wheat (Triticum aestivum L.), is the staple food for a large proportion of the Ethiopian population. The country is the largest wheat producer in sub- Saharan Africa, next to South Africa [1]. Wheat is found at altitudes ranging from 1700 to 2900 masl. Rainfall In these areas is bimodal and varies from 600 to 2000 mm. Most wheat is produced during the main rainy season, June to September, although some is produced during the light rain season, March to May. Virtually all wheat is produced under rain fed conditions. Central and south eastern highlands of the countries are major wheat producing areas. Therefore, Arsi, Bale and part of Shoa are considered wheat growing belt.

Although Ethiopia is largest wheat producing country, the average productivity of the country is 2.5 t/ ha which is lower than world wheat productivity, 3.09 qt/ha (https://www.statista.com/statistics/237705/global-wheat-production/) and 6-7 t/h of potential farmers in the country (personal observation) [2]. Biotic stress, abiotic stress and conventional management practices are among major constraints for wheat production. In particular the breakout out of new races of wheat rusts, like Ug 99 and Digelu races throughout time made popular and wider adapted varieties out of production.

Wheat producers in developing countries, like Ethiopia which use restricted inputs and grow wheat under harsh and unpredictable environments require stable wheat varieties. The development of varieties which can be adapted to a wide range of environments with high grain yield is the final goal of any plant breeders in a crop improvement program. High yield stability usually refers to a genotype's ability to perform consistently across a wide range of environments [3]. In order to ensure consistent stability and high yields, new lines are developed, and tested for their yield performances in different environments [4]. Genotype × environment interactions are of major importance, because they provide information about the effect of different environments on genotype performance and have a key role in assessment of stability of the breeding materials [5].

Quantitative trait like yield mainly dependent on G×E interaction as it obscures the interpretation of genetic experiments and makes predictions difficult. In such circumstances it is difficult to select and suggest one better genotype across various locations. A wider adapted Genotype performs consistently over a wider range of environment. To ensure valid genotype recommendation and to identify promising genotypes, a breeder should conduct multi location yield trials across different environments.

Materials and Methods

A total of fifteen genotypes: eight advanced genotypes initially introduced from CIMMYT and ICARDA and then evaluated and selected for four consecutive years, five Ethiopian crosses, and two checks Hidasse and Lemu were evaluated in six location: Kulumsa, Arsi robe, Assasa, Bokoji, Holota and Ofla during 2016 and 2017 cropping season. Details of each location are shown in table. A randomized complete block design with three replication was used.

Entry	Genotype	Pedigree	Selection history
1	Lemu	WAXWING*2/HEILO	
2	ETBW8070	Line 1 Singh/ETBW4919	KU07-01-0KU-0KU-0KU-0BK2-22KU
3	ETBW8078	Line 1 Singh/(Cham6/WW1402)	KU07-04-0KU-0KU-0KU-0BK1-4KU
4	ETBW8084	Line 3 Singh/(Cham6/WW1402)	KU07-07-0KU-0KU-0KU-0BK1-3KU
5	ETBW8311	ND643/2*WBLL1/3/KIRITATI//PRL/2*PASTOR/4/KIRITATI//PBW65/2*SERI.1B	CMSS07B00823T-099TOPY-099M-099Y-099M-7WGY-0B
6	ETBW8065	Line 1 Singh/ETBW4919	KU07-01-0KU-0KU-0KU-0BK1-5KU
7	ETBW8427	SERI.1B//KAUZ/HEVO/3/AMAD/4/PYN/BAU//MILAN/5/ICARDA-SRRL-1	ICW06-50208-5AP-0AP-0AP -02 SD
8	ETBW8459	CHIL-1//VEE'S'/SAKER'S'	ICW99-0026-7AP-0AP-0AP-9AP-0AP-0DZ/0AP-0DZ/0KUL/0SIN/0AP-0NJ/0AP-0ALK/0AP
9	ETBW9037	SWSR22T.B./2*BLOUK #1//WBLL1*2/KURUKU	CMSS08Y01116T-099M-099Y-099M-099NJ-099NJ-23WGY-0B
10	ETBW9045	KINDE/4/CMH75A.66//H567.71/5*PVN/3/SERI	CMSS09Y00603S-099Y-17M-0WGY-6B-0Y

11	ETBW8075	Line 1 Singh/(Cham6/WW1402)	KU07-04-0KU-0KU-0KU-0BK1-1KU
12	ETBW9464	MARCHOUCH*4/SAADA/3/2*FRET2/KUKUNA//FRET2*2/4 /TRCH/SRTU//KACHU	CMSS10B00928T-099TOPY-099M-099NJ-099NJ-13WGY-0B
13	ETBW9466	ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA/ /TSI/VEE#5/4/CROC_1/AE.SQUARROSA (224)//2*OPATA*2/6/HUW234+LR34/PRINIA//UP2338*2 /VIVITSI	CMSS10B01047T-099TOPY-099M-099NJ-099NJ-2WGY-0B
14	ETBW9470	BAVIS #1/5/W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	CMSA10M00485S-099ZTM-099NJ-099NJ-6WGY-0B
15	Hidasse	YANAC/3/PRL/SARA//TSI/VEE#5/4/CROC-1/AE.SQUAROSA(224)//OPATTA	

Table 1: Pedigree and history of fifteen genotypes tested for yield performance and wheat rust resistance.

Location	Altitude (m)	Representing Agroecology	Soil type	Rainfall	Temp	
					max	Min
Kulumsa	2200	Mid-altitude	Clay soil (luisols)	820mm	22.8	10.5
Arsi robe	2420	Water logged vertisoil	Heavy clay soil (vertisiol)	890mm	22.1	6
Assasa	2340	Terminal drought prone	Clay loam soil(gleysols)	620mm	23.6	5.8
Bokoji	2780	Highland/haigh rainfall	Clay siol(nitosols)	1020mm	18.6	7.9
Holota	2400	M2-5	Nitosols	1144	22	6
Ofla	2490	-	clay	-	22.2	7.7

Table 2: Information on Altitude, Soil, rainfall and temperature of tested location.

Statistical Analysis

Four internal rows were harvested and grain yield per plot was converted to ton per hectare. Analysis of Variance was computed to determine the effects of genotype, environment, and GE interactions on grain yield. The stability of yield performance for each genotype was calculated by regressing the mean grain yield of individual genotypes on environ-mental index and calculating the deviation from regression as suggested by Eberhart and Russell as [6]:

$$Y_{ij} = \mu_i + \beta_i I_j + \delta_{ij}$$

where: Y_{ij} is the variety mean of the i^{th} environment, μ_i is the mean of i^{th} variety over all environments, β_i is the regression coefficient that measures the responseof the i^{th} variety to varying environments, δ_{ij} is the deviation from regression of the i^{th} variety at the j^{th} environment, and I_j is the environmental index obtained as the mean of all varieties at the j^{th} environment minus the grand mean. regression coefficient (bi) close to unity and deviation from regression (S^2d_i) near to zero, was defined as a stable cultivar [6].

AMMI Stability Value (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 [7]. 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:

$$ASV = \sqrt{\left[\left(SS_{IPCA1} \div SS_{IPCA2}\right)\left(IPCA1score\right)^2 + \left(IPCA2score\right)^2\right]}$$

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. Either the larger negative ASV value or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable genotypes across environments [7].

Yield stability index (YSI), is calculated by ranking the mean grain yield of genotypes (RY) across environments and rank of AMMI stability value (ASV). The YSI incorporates both mean yield and stability in a single criterion as follows: YSI = RASV + RY [8,9]. Ecovalnce (W_i^2) and stability variance ($\sigma i2$) were computed as suggested by Wricks's and Shukla's [10,11].

Result and Discussion

GEN	Mean	ASV	YSI	RASV	RYI	W_i^2	σi2	s_i^2	bij	Sd^2_i
Lemu	5.17	0.6834	14	5	9	17.26	3.662091 ns	1.818214 ns	0.408	0.21
ETBW8070	5.61	1.3542	20	14	6	30.56	6.731099 ns	4.355622 ns	0.286	0.008
ETBW8078	4.19	0.8852	21	8	13	14.46	3.016039 ns	3.570220 ns	0.807	0.006
ETBW8084	6.04	0.4525	6	4	2	5.68	0.991338 ns	0.892331 ns	1.236	0.434
ETBW8311	4.04	0.9258	24	10	14	22.6	4.890277 ns	5.565642 ns	1.283	0.123
ETBW8065	5.05	1.3461	23	13	10	31.39	6.923159 ns	7.167105 ns	0.559	0.491
ETBW8427	5.66	0.8858	14	9	5	12.89	2.652924 ns	2.987167 ns	0.77	0.042
ETBW8459	5.02	0.093	12	1	11	7.91	1.505092 ns	1.909821 ns	1.097	0.192
ETBW9037	5.74	0.3589	7	3	4	4.36	0.684794 ns	0.950139 ns	0.962	0.418
ETBW9045	5.41	0.7073	13	6	7	12.3	2.517762 ns	3.215418 ns	1.068	0.024
ETBW8075	2.35	1.6888	30	15	15	55.26	12.430907 **	14.024556 **	0.555	4.779
ETBW9464	4.5	1.2541	24	12	12	31.54	6.959196 ns	5.583620 ns	1.623	0.128
ETBW9466	5.24	0.7975	15	7	8	14.44	3.013000 ns	1.164301 ns	1.576	0.36
ETBW9470	7.13	1.1078	12	11	1	25.87	5.649403 ns	3.096933 ns	1.706	0.033
Hidasse	6	0.2096	5	2	3	5.06	0.847359 ns	1.133583 ns	1.062	0.368

Table 3: Results of AMMI stability values.
mean= mean grain yield, ASV=AMMI stability value, YSI= yield stability index , RASI= rank of AMMI stability value RYI= rank of yield index, *Wi2*= Wrick's ecovalance,σi2=Shukla's stability, s_i^2=stability variance, bij=regression coefficient and Sd^2_i= deviation from regression.

Lemu and Hidase, released varieties in 2016 and 2012 respectively by Kulumsa Agricultural Research Center (KARC) were used as checks. Most of the time genotypes showed inconsistency in rank of grain yield across different tested environment; genotype ranked first in one environment may not be first at another tested environment. and hence, It is advantageous to look for a single criteria which help researchers to identify elite genotypes simultaneously for their high yielding and stable across tested environment. YSI is a single criteria for stability and high grain yield which successfully used by Bose, et al., Bavandpori, et al., to interpret interaction between genotype performance and environments [8,9]. High yielding genotype with better stability has smallest values of YSI. The smallest Yield stability index (YSI) exhibited by variety Hidasse (YSI=5) and Advanced genotypes: ETBW8084 (YSI=6), ETBW9037 (YSI=7), ETBW9470(YSI=12) and ETBW8459(YSI=12). These genotypes were high yielder and comparatively stable. The Highest YSI(YSI=30) exhibited by genotype ETBW 8075 which was highly unstable and lowest yielder among tested genotypes.

As suggested by Wricke, ecovalance (W_i^2) used as stability parameters [10]. The smaller the values, the stable the genotype was. The W_i^2 was lower for ETBW9037 W_i^2 (=4.36), Hidasee (W_i^2=5.06), ETBW8084 (W_i^2=5.68), ETBW8459=(W_i^2=7.91), so that, they are stable. Like Ecovalance, the stability variance S_i^2 also showed that smaller values for ETBW8084(S_i^2=0.89), ETBW9037 (S_i^2=0.95) and Hidasse (S_i^2=1.13) [12]. The ecovalance and the stability variance gave nearly similar results and have positive correlation as proved by Kilic H. et al [13].

Awidely adapted cultivar had high mean grain yield, regression coefficient close to unity and deviation from regression coefficient near to zero [6]. ETBW9470, with highest mean grain yield exhibited higher regression coefficient, b_i >1, which means this genotype was widely adapted to high yielding environments or optimum areas. A cultivar Hidase, genotypes: ETBW9045, ETBW8084 and ETBW8427 were high yielder and bi close to unity and S_i^2 near to zero. And therefore, they were widely adapted genotypes. ETBW 8084 was high yielder and bi<1, indicted that the genotype well perform to environmental changes and low yielding areas [14]. ETBW8075 with high deviation from regression S_i^2= 4.779 (table.) delivered the lowest yield and poor performance across tested location.

Genotypes	Arsirobe	Assasa	Bokoji	Holota	Kulumsa	Ofla
Lemu	4.6	5.2875	4.8125	4.9625	6.675	4.685714
ETBW8070	4.9125	6.85	6.7	4.7625	5.625	4.785714
ETBW8078	3.8375	4.5125	2.575	3.0625	5.6375	5.514286
ETBW8084	6.8375	6.7	5.1625	3.55	7.9875	5.985714
ETBW8311	4.4375	5.9	1.4375	2.1125	5.2	5.171429
ETBW8065	3.9	6.8625	5.925	4.1125	5.8	3.685714
ETBW8427	5.725	6.975	6.1375	3.9875	6.625	4.5
ETBW8459	5.375	6.3625	4.8	2.2625	5.775	5.557143
ETBW9037	6.2375	6.575	5.2625	4	7.4125	4.942857
ETBW9045	4.8375	7.4875	5.6625	3.1875	6.475	4.828571
ETBW8075	1.5125	2.0375	0.8625	1.2	3	5.485714
ETBW9464	5.3625	6.05	1.425	2.3125	7.025	4.814286
ETBW9466	5.65	6.1125	3.775	2.5375	8.15	5.242857
ETBW9470	8.4	8.725	6.5286	3.4375	9.325	6.371429
Hidasse	6.0625	6.2	5.4	3.925	8.1	6.328571

Table 4: Mean grain yield of fifteen genotypes across six location for two years.

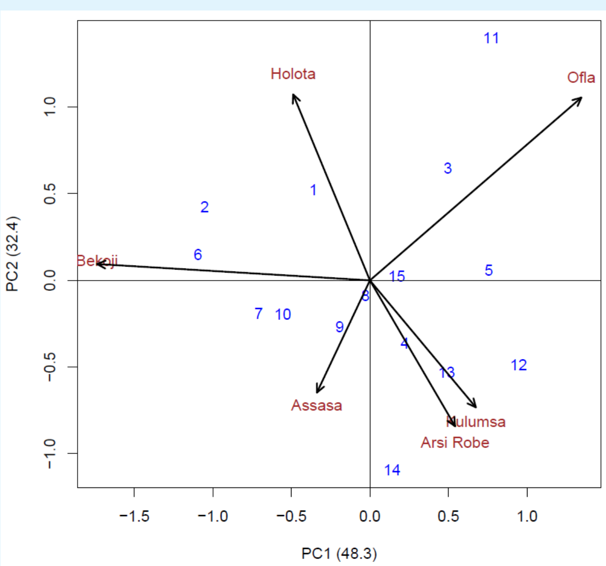

Figure 2: A graphical analysis was generated and used.

Mean grain yield for two years ranges from the highest 9.33t/ha to the smallest 0.86t/ha. The highest grain yield performed By genotype ETBW9470 at Kulumsa and the lowest grain yield delivered by genotype ETBW 8075 at Bokoji. Mean grain yield for tested genotypes were lower relative to other location. The high incidence of Septoria was to saw the interaction effect, a graphical analysis was generated and used (fig.). Graphical result from AMMI model showed that the first principal component PC1, explained 48.3% of interaction some of square while the second principal component,PC2 explained 32.4% of some of square interaction(Fig.). The first two principal component together addressed 80.7 % of interaction effect which indicate the majority of interaction fell on PC1 and PC2 [15-31].

Conclusion and Recommendation

To develop varieties for different environments, very essential for breeders to evaluate their genotypes based on many years and several locations. Environmental variations are important in determining performance of elite materials. Genotype ranks consistently across different tested location has less response for highly unstable environment. Genotype 8084 is high yielder than the two checks and stable across tested location. Therefore this genotypes recommended as candidate variety for next year to release as a variety for wider environment. Genotype 9470 with highest mean grain yield and best performance at potential environments recommended as candidate variety for optimum areas.

Acknowledgement

This work would not have been possible without the financial support EIAR, Collaborating regional and federal research centers and wheat breeding teams of Kulumsa Agricultural Research Center (KARC). I am grateful to all of those with whom I have had the pleasure to work during this and other related projects.

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