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Identification of Stability and High Yielding Wheat Genotypes Using Safety First Rules in Pakistan

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Abstract

The objectives of the research work were to estimate the GE interaction and identify the stable and high yielding genotypes of bread wheat (Triticum aestivum L.). Twenty genotypes of wheat from the sixteen various locations of Pakistan were assessed applying a randomized complete block design (RCBD) having two replications in every environment by the National Uniform Wheat Yield Trials (NUWYT) during 2014-15 growing seasons. The Combined Analysis of Variance (ANOVA) was performed; the main effects of genotype, environment and GE interaction were extremely significant at ($P < 0.01$). Various uni-variate stability parameters and graphical methods were applied to quantify the stability of yield. It was difficult to reach at a unique decision about the stability of genotypes due to inconsistency in stability measures so therefore Safety first index/rule *(decision making tool) approach was applied. It was suggested that Safety first index/rule was the best technique that explicitly evaluate the importance of the stability relative to yield of genotypes. Accordingly it was concluded that the genotypes G16 and G17 be the most stable genotypes out of 20 genotypes across all 16 environments.*

Keywords: Stability, Safety first rule, Genotype, Environmental interaction

INTRODUCTION

Pakistan has the diverse agro-climate regions that include the high mountainous valleys and irrigated plains. The ecological and edaphic aspects such as rainfall, temperature, humidity, fertility position and features of soil play vital role in the performance of verities. Pakistan is a developing country with low income so agriculture is the supreme imperative sector of providing healthy food to the fast developing population with primary dependence of wheat crops. Wheat is the one of the main crops of agriculture with 80 percent of farmers cultivating it on the area of around 9 million hectares that is approximately 40% out of entire cultivation land in Pakistan through the winter or Rabi season. Pakistan adds 3.04 % to the overall world's wheat production. Wheat added around 14.4% of value added in agriculture and 3.0% of the gross domestic product (GDP) during the year 2014-15 in Pakistan (PARC, 2014-15).

Multi-environmental trials (METs) "a vital link between genetic improvement and production environment has been consecutively conducted to identify the superior, high yielding and sable genotypes across diverse environments that have been a persistent challenge for the agronomists, geneticists and plant breeders to increase yield also widen the genetic base of a crop to avoid its liability to the varying environments worldwide (Yan & Rajcan, 2002). The measured production of every genotype in each location is the result effect of genotype (G), environment (E) and genotypeenvironment interaction (GEI) (Yan & Kang, 2003). In most of the multi-environmental trials the genotype environmental interaction is observed when changes in environmental conditions do not have the same effect on all the genotypes (Kang, 1998).

Static and Dynamic are the complementary stability concepts (Becker & Leon, 1988). The term stability is applied to describe the genotype which shows the comparatively persistent yield and independent of varying environment surroundings. On the base of this concept the Type-1 stability is described as the genotype deliberated stable when the variance across locations is least. Type-2 stability is described as the genotype deliberated stable when its response to locations is analogous to the response of mean in genotypes included in the experiment and Type-3 stability is defined as the genotype considered stable when the residual mean squares from regression equation on the environmental index is insignificant (Eberhart & Russel, 1966; Shukla's, 1972; Lin *et al.*, 1986).

Two most important methods for evaluating the genotypeenvironment interaction (GEI) for identifying the adaptation of the genotypes. Generally applied method is parametric that depend on the assumptions of distribution about genotype effect (G), environment effect (E) and genotype environmental interaction effect (GEI). The secondly used method is non-parametric that needs not require any distributional assumption (Huehn, 1996). Any single stability method sufficiently cannot explain the performance of genotype across environments therefore mostly breeding programs are now incorporating the parametric and non-parametric methods both (Becker & Leon, 1988; Romagosa & Fox, 1993).

Several parametric (uni-variate and multi-variate) and graphical approaches have been proposed to weigh the constancy and compliance of genotypes across environments. The utmost broadly used parametric stability statistics are: Mean yield across environments (X_i), Variance of environments (S_i^2) (Lin *et al.,* 1986), Co-efficient of Variation (CV_i) (Francis & Kannenberg's, 1978), Geometric Adaptability Index (*GAI*), Superiority index (P_i), Spearman's Rank Correlation (r_s), Shukla's Variance of stability (σ_i^2) (Shukla, 1972), Wrick's Ecovalence (W_i^2), (Wricke, 1962); Slope of regression equation (b_i) (Finlay & Wilkinson, 1963); Regression co-efficient (b_i) and Regression deviation Variance (S_{di}^2), (Eberhart & Russell, 1966); AMMI analysis (based on the Principal Component axes 1 and 2), GGE biplot analysis.

None of the above mentioned stability statistics clearly specify to develop the operational index based on mean of yield and stability statistics, then the approaches for assessment making under possibility can be applied for making the stability indices that evaluate the significance of yield and stability (Hazell and Norton, 1986). A grouped method that make decisions 'that might be used for developing an index based on mean yield and stability when emerging genotypes for the extensive range of environments' is grounded on the *Safety first index/rule* assumption (Eskridge, 1990). It is mainly concerned with the selecting genotypes that require a low chance of generating low yield with avoidance of disaster.

The objectives of current research study 'on multi-environmental trials (METs) regarding genotypes of wheat carried out under National Uniform Wheat Yield Trials (NUWYT)' were to select superior genotype, to identify the high yielding genotype and environment that have low variation across environments as well as illustrate how the theory of decision making conception known as *Safety first index/rule* can be used to model the GE interaction behavior.

MATERIALS AND METHODS

Data Source

The trials were performed on 20 genotypes in 16 environments on the basis of randomized complete block design (RCBD) in diverse growing zone during Rabi 2014-15 under irrigated conditions. The experimental trials were accompanied by applying RCBD having 2 repetitions in each environment. Every plot was consisted of 6 rows having the length of 5m and 30 cm row to row distance planted in Alpha lattice design with two replications coordinated by Pakistan National Agriculture Research Centre (NARC) Islamabad.

Each genotype was given a code by the Federal Seed Certification and Registration Department (FSC&RD) of Pakistan (Table: 1). Out of 20 genotypes 9 genotypes were from Punjab province, 5 genotypes were from Khyber Pakhtunkhwa province, 2 genotypes were from Sindh province, 3 genotypes were from PNARC Islamabad and 1 local check was included.

Table: 1 Names, Codes and origin of 20 Genotypes (Irrigated 2014-15).

Code	Genotype	Institution/Station
G1	*V-109384*	Pari Bahawalpur
G2	PR-103	CCRI-Pirsabak
G3	99346	Pari Bahawalpur
G4	PR-107	CCRI-Pirsabak
G5	DN-93	ARI-D.I.Khan
G6	V-11005	WRS-Tandojam
G7	*SRN 09111*	NIFA-Peshawar
G8	NR-421	NARC-Islamabad
G9	V-09087	WRI-Faisalabad
G10	NR-419	NARC-Islamabad
G11	Guard-C	Hybrid-Guard
G12	V-11160	WRI-Faisalabad
G13	SAWSN-02 102	AZRC-D.I.Khan
G14	NN-Gandum1	NIBGE Faisalabad
G15	TD-1	WRI-Sarkand
G16	TW 96010	AZRI-Bhakkar
G17	Sehar-06	WRI-Faisalabad
G18	GALAXY 13	WRI-Faisalabad
G19	NIA-MN-08	NIA-Tandojam
G20	NARC-11	Wheat-NARC-Islamabad

Statistical Analysis

The combined ANOVA was undertaken for evaluating the possessions of genotypes, environments and genotype × environmental interaction (GEI) where the genotypes were deliberated as fixed variables whereas environments were taken as the random variables.

Table: 2 Names and Codes of 16 Environments (Irrigated, 2014-15)

Environments	District/Location
E1	Islamabad/NARC
E2	Sarkand/WRI
E3	Larkana/QAARI
E4	Tandojam
E5	Multan/CRS
E6	DG Khan/Moza Srawar Wali
E7	Bahawalpur/RARI
E8	Faisalabad/AARI/WRI
E9	Charsada
E10	Sahiwal/MMRI
E11	Sargodha/IARS
E12	Faisalabad/Gojra
E13	Quetta/ARI Sariab
E14	Peshawar/NIFA
E15	Gujranwala/ARF
E16	D.I.Khan/AZRI

Various stability statistics were applied for the yield stability of each genotype across environments. Mean yield ($\bar{X}_{i.}$) was performed to identify the genotype that produces the highest mean yield and lowest mean yield in each environment. Variance across environments (S_i^2) and Co-efficient of variation (CV_i) stability measures were determined to identify the stable genotypes under diverse environments by the low values of S_i^2 and CV_i. Geometric adaptability index was determined for adaptability of genotypes and the genotypes having higher value of *GAI* would be desired (Mohammadi & Amri, 2008). Superiority index (P_i) was calculated as an estimate of adaptability for genotypes across environments and highest P_i value would be desired as stable genotype. Wrick's Ecovalence (W_i^2) was determined as the stability measure of a genotype to the sum of square's interaction and low value of W_i^2 indicated the high stability. Shukla's Variance of stability (σ_i^2) for stable genotypes was determined by the minimum value. W_i^2 and σ_i^2 were equivalent for ranking purpose. Linear regression co-efficient (b_i); Slope of regression (b_i) and deviation variance of regression (S_{di}^2) were applied to specify the enactment of one genotype across the range of environments. Genotypes having the values $b_i > 1$ was considered more adopted to environments with higher yield, $b_i < 1$ would be adopted to unfavorable environments and $b_i = 1$ were considered as an average adaptation to all the environments. Accordingly the genotype having the values $S_{di}^2 = 0$ were considered to have high predictable behavior and $S_{di}^2 > 0$ had high unpredictable behavior across environments. Spearman's Rank Correlation (r_s) was performed for all pair-wise comparisons of the stability statistics to understand the interrelationship among the various stability statistics of genotypes. Anderson darling test of normality and Levene test of variances homogeneity were performed to check the normality of the mean yield data.

Safety first index/rule (Eskridge, 1990; Annicchiarico, 2002) based on the four stability statistics (1) Environmental Variance (*EV* index); (2) Shukla's stability variance (*SH* index); (3) Finlay and Wilkinson's Slope of regression (*FW* index); (4) Eberhart & Russell's by linear regression co-efficient and mean square deviation about regression $(S_{di}^2)(ER$ index) were evaluated that explicitly quantify how plant breeders weigh the relative importance of yield in the selection of genotypes. The proposed model is:

$$\bar{X}i. - Z(1 - \alpha)(V_i)^{\frac{1}{2}}$$

Where V_i is the stability measure.

$\bar{X}i.$ is mean yield of genotypes in all locations.

$Z(1 - \alpha)$; $(1 - \alpha)$ percentile from the Standard Normal Distribution.

GGE Biplot analysis for graphical display of GE interaction design of multi-environmental trials (METs) data was performed with first two principal components (PC) (mentioned as the primary and secondary possessions) for average tester coordinates (ATC). The overall statistical calculations and evaluation were performed through different statistical softwares such as: Minitab-17, SPSS-21, R-packages-3.2.3, GGE biplot and Microsoft excel-2016.

RESULT AND DISCUSSION

Analysis of GE interaction

The Combined ANOVA of mean yield of 20 genotypes in 16 environments was performed and specified the highly significant GE interaction that indicated the influence of changes in locations on the yield enactment of the genotypes evaluated (P < 0.01). The genotype main effect and environment main effect were also significant extremely (P < 0.01). In overall variation 3.17% was explained by genotype (G), 59.98% was explained by environment (E) and 28.55% was explained by the genotype environmental interaction (GEI) respectively (Table: 3).

Table: 3 ANOVA for mean yield of 20 Genotypes across 16 Environments.

Source of variation	DF	SS	MS	F-Ratio	P-Value	Explained
Environment	15	254494110	16966274	235.54**	0.000	59.98%
Genotype	19	13458698	708353	9.83**	0.000	3.17%
Environment X Genotype	285	121150656	425090	5.90**	0.000	28.55%
Replication(Environment)	16	13269758	829360	11.51**	0.000	3.13%
Error	304	21897928	72033			
Total	**639**	**424271150**				

**Significant at 1% level of significance

Eleven out of 20 genotypes had the higher mean yields while 9 had the mean yields lower than overall mean yield. Genotype G10 had highest yield followed by G17 and G7 while the genotypes G14 had the lowermost yield tailed by G15 and G8 among all mean yields of 20 genotypes.

Ten out of 16 environments had greater mean yield while 6 environments had lower in comparison with total mean yield of 16 environments. Environment E7 had largest mean yield tailed by E3 and E6 while the environment E13 had lowest mean yield followed by E10 and E9 in 16 environments.

Stability Analysis

According to the Environmental variance (S_i^2) and Coefficient of variation (CV_i) stability statistics the genotype G16 had the lowest environmental variance and coefficient of variation values followed by G5 and G3 so therefore considered as the most stable genotype while the genotype G2 followed by the G9 had the largest values of criterion so therefore declared as the unstable genotype (Table: 4).

Geometric adaptability index (G*AI*) with higher value is desirable so accordingly the genotypes the G10 had the maximum mean yield value followed by G17 and G7 so was considered the best and adaptable genotypes. The genotype G14 followed by G15 and G8 so therefore considered the worst and unstable genotypes across 16 environments.

The genotype would be superior with lowest value of Superiority index (P_i). Accordingly the genotypes G16 had the smallest Superiority index value and followed by G5 and G11 so they were considered to be the superior genotypes. Similarly G19 followed by G6 and G9 had the least P_i results so they were considered as the unstable genotypes.

According to Wrick's Ecovalence (W_i^2) and Stability Variance by Shukla (σ_i^2) the genotypes having least values are considered stable so by the criterions the genotypes G5 followed by G11 and G15 had lowest W_i^2 and σ_i^2 values and considered to be stable genotypes while the genotype G2 followed by G19 and G7 highest W_i^2 and σ_i^2 values therefore they were considered to be the unstable genotypes in all environments.

Regression Coefficient (b_i) approximating 1.0 coupled with Eberhart & Russell Variance of regression deviation (S_{di}^2) zero indicate average stability. According to Regression Coefficient (b_i) the genotypes (G1, G2, G4, G6, G8, G9, G10 and G20) had the slope value greater than 1.0 that showed below average stability though (G3, G5, G7, G11, G14, G16, G17, G18 and G19) had b_i value lower than 1.0 that showed above average stability. Accordingly the genotype G16 followed by G5 and G3 had the lowest values of S_{di}^2 so they were considered stable though the genotype G2 tailed by G9 and G10 had the maximum values of S_{di}^2 so therefore they were considered to be the unstable genotypes.

Safety first rule / Index Analysis

The stability statistics explained above provided the meaningful information for genotype's stability and adaptability of but could not provide a unique decision so therefore we used *Safety first rule / Index* to overcome such issues. *Safety first rule / Index* are beneficial when there is purpose to believe that mean and stability measures varied from each other. *Safety first rule / Index* based on four stability measures were determined with probability value ($\alpha = 0.05$) and ($\alpha = 0.01$) (Table: 5). According to *EV* index the genotypes G16 tailed by G17, G3 and G5 had the higher value of lower confidence limit so therefore thy are considered as stable genotypes whereas the genotypes G2 followed by G8, G14 and G15 had higher lower confidence limit values so considered as unstable genotypes. Accordingly *SH* index specified that the genotypes G10 followed by G17, G20 and G3 with higher value of lower confidence limit were deliberated as stable genotypes. However G14 tailed by G15, G8 and G2 were considered as unstable genotypes. Rendering to criterion of *FW* index the genotype G16 followed by G7, G17 and G3 were considered as the stable genotype while the genotype G9 followed by G8, G15 and G2 were considered as the unstable genotypes across environments. *ER* index specified the Genotypes G16 followed by G17, G3 and G5 with lower values as stable though the genotype G2 tailed by G8, G14 and G15 with greater values were deliberated as the unstable.

Interrelationship among Stability measures

The rank correlation of average yield and stability measures are given in (Table: 6). The mean yield ($\bar{X}_{i.}$) had the positive correlation with CV_i, *GAI, EV, SH, ER* and *FW* while had the weak negative correlation with the S_i^2, P_i, W_i^2, σ_i^2, b_i and S_{di}^2. The Ranks result of $\bar{X}_{i.}$ was significant with *GAI, SH, SH and FW* (P <0.05) while was not significant with all the other stability measures. Environmental variance (S_i^2) had the positive correlation with all the stability parameters except *GAI*. Stability measures Pi, b_i, Sdi^2, *EV, ER* and *FW* were highly correlated with S_i^2 and significant (P<0.05). Previously reported results were similar (Temesgen, 2015). CV_i had positive relationship with all the stability measures and the similar stability statistics were significant (P<0.05) as S_i^2. The Geometric Adaptability Index (*GAI*) was negatively correlation with P_i, W_i^2, σ_i^2 and S_{di}^2 while had positive correlated with all the other stability statistics under study and was significantly correlated with all the *Safety first rule /Index* of stability statistics *EV, SH,, ER* and *FW* (P<0.05).

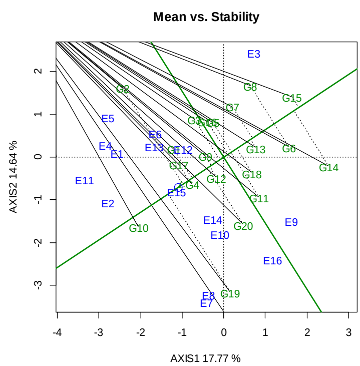
The Superiority index (P_i) was having positive association with all the stability statistics, similarly as CV_i. The P_i had weak to positive correlation with *SH* whereas it had moderate to strong positive significant correlation (P<0.05) with stability statistics W_i^2, σ_i^2, S_{di}^2, *EV* and *ER*. Wricke's Ecovalence (W_i^2) and Shukla's Stability Variance (σ_i^2) had similar results of rank correlation. Both measures had negatively weak correlated with the *FW* but had weak positive correlation with all the other stability parameters. Regression Co-efficient (*bi*) had strong positive significant correlation (P<0.05) with S_{di}^2, *EV, ER* and *FW* but had weak negative correlation with *SH*. Variance of regression deviation (S_{di}^2) had strong positive significant correlation (P<0.05) with *EV, ER* and *FW* while S_{di}^2 had weak positive correlation with the *SH*.

EV index had strong to perfect positive significant correlation (P<0.05) with *ER, FW* while had the moderate positive correlation with *SH*. The *SH* index had weak to moderate positive significant correlation (P<0.05) with *ER* and *FW* and was significantly. *ER* index had the similar rankings results as *EV* index. *ER* had the strong positive significant correlation (P<0.05) with *FW*. Three Safety first indices *EV, ER* and *FW* had moderate positive correlation with mean yield while only *SH* had strong positive correlation with mean yield (Table: 6).

GGE Biplot Analysis

GGE Biplot analysis (graphical method) is an ideal tool for the METs data and of GE interaction that delivers the preeminent technique for visualization of interaction pattern between the mean yield data of genotypes and locations (Yan & Kang, 2003). The genotype stability and yield performance were evaluated by the approach of Average environment coordinate (AEC) (Yan & Hunt, 2002).

Figure: 1 Mean versus Stability and Average Tester Coordinate (ATC) view of the GGE based on mean yield performance and stability of genotypes

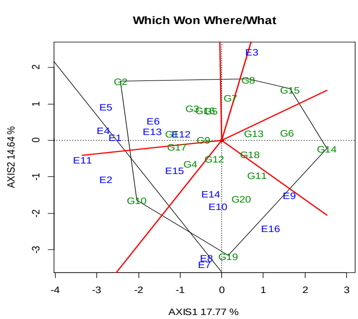


PC1=17.77% , PC2=14.64%, Sum=32.41% , Transform=0 , Scaling=1, SVP=1

The single arrowed line called abscissa of AEC that refers to greater mean yield in environments (Figure: 1). Thus G10 was identified as the highest yielding and stable genotype followed by G4 while G13 and G15 were stable with had low yielding. G19 followed by G2 with high yielding were found to be unstable. Accordingly G14 followed by G8 with low in yield were unstable. Analysis by Mean yield and stability performance was previously done by (Karimizadeh R. *et al*., 2013), (Kumar *et al*., 2018).

The "which-won-where" method is a distinctive feature of GGE biplot analysis. The polygon is shaped via joining the indicators of genotypes that are farthest from the origin of biplot in such way that all the genotypes are included in it. Genotypes placed on the apexes of polygon are considered the superlative or worst in an environment or in the number of environments. (Kaya *et al*., 2006). The polygon was distributed in 6 sectors that was having 3 mega-environments (Figure: 2). The genotypes which were linked by the equality lines in polygon were G2, G8 G15, G14, G19 and G10. The first mega-environment contained the six environments E1, E4, E5, E6, E12 and E13. The genotype G2 was the best in the first mega-environment. Second mega-environment was consisted of six environments E7, E8, E9, E10, E14 and E16 where the genotype G19 was best in second mega-environment. The third mega-environment contained the environments E2, E11 and E15 where G10 did well in third mega-environment. The genotypes G8 and G15 performed well in a single environment E3 while the genotypes G6, G7, G13, G14 and G18 did not perform well in any of the environments so therefore they were considered among the worst performers in all genotypes. The G2 and G19 were the winning genotypes in mega-environments. Similar results of PC1 (18.9%) and PC2 (13.8%) were attained in preceding research study on maize hybrids (S. Alwala *et al.*, 2010).

Figure: 2 GGE biplot Polygon view of winning genotypes and associated mega-environments.



PC1=17.77% , PC2=14.64%, Sum=32.41% , Transform=0 , Scaling=1, SVP=1

Table: 4 Mean Yield and Estimates of (Parametric Stability Statistics) 20 Genotypes in 16 Environments

Genotype	Code	$\bar{X}_i$	S_i^2	S_i	CV_i	GAI	P_i	W_i^2	σ_i^2	b_i	S_{di}^2
V-109384	**G1**	3846.22	692667.7	832.27		3751.70	812050.1	2754112	181463.12		737592.5
					21.64					1.100	
PR-103	**G2**	3937.13	1055252		26.09	3799.64	145481	5612770	382070.66	1.303	1088948
				1027.25							
99346	**G3**	3960.65	467550.5	683.77	17.26	3902.89	742269	2355592	153496.81	0.866	492790
PR-107	**G4**	3899.84	694593.1	833.42	21.37	3805.90	1200300	3154393	209553.02	1.071	741923.2
DN-93	**G5**	3849.25	389147.1	623.82	16.21	3797.60	563695.5	1904532	121843.43	0.809	400373.4
V-11005	**G6**	2838.94	741967.8	861.38	22.50	3735.30	2193038	3067870	203481.21	1.134	786862
SRN 09111	**G7**	3993.25	573117.1	757.05		3923.97	1329709	4482772	302772.55		599864.8
					18.96					0.823	
NR-421	**G8**	3657.91	669364.5	818.15	22.37	3568.11	1192364	2348508	152999.63	1.104	712215.2
V-09087	**G9**		867676.6	931.49	23.98	3775.18	2095845	2339182	152345.22	1.339	877431.9
		3884.50									
NR-419	**G10**	4136.72	842410.2	917.83	22.19	4031.05	1110424	3186035	211773.47	1.243	875824.7
Guard-6	**G11**	3798.19	504248.7	710.11	18.70	3731.05		2102428	135730.92	0.929	537987.2
							663543.4				
V-11160	**G12**	3942.81	530626.4	728.44	18.48	3879.91	931062.1	2291402	148992.24	0.945	567174.7
SAWSN-02-	**G13**	3903.97	663409.7	814.50	20.86	3820.85	1388531	3716678	249011.58	0.989	710750.2
102	**G14**	3530.03	533637.5	730.51	20.70	3455.90	1250503	3404333	227092.65	0.862	563038.6

NN-	**G15**	3555.63	545153.4	738.35	20.77	3478.98	975390.7	2111282	136352.19	0.977	583846.3
Gandum1	**G16**	3863.22	324483.9	569.64	14.75	3821.15	482408.5	3135127	208200.98	0.636	287487.2
TD-1	**G17**	4019.16	499836.9	706.99	17.60	3956.87	1098048	2485962	162645.56	0.894	530417.9
TW 96010	**G18**	3801.31	528355.8	726.68	19.12	3729.14	838655.1	2706650	178132.43	0.910	562423.8
Sehar-06	**G19**	3955.06	690944.4	831.23	21.02	3882.68	3422530	5178027	351562.38	0.908	736414
GALAXY 13	**G20**	3982.56	707133.5	840.91	21.11	3892.57	1243985	2236973	145172.66	1.156	746331.2
NIA-MN-08											
NARC-11											

Table: 5 Safety First Index of (Parametric Stability Statistics) 20 Genotypes in 16 Environments.

Genotype	Code	*EV* (α=0.05)	*EV* (α=0.01)	*SH* (α=0.05)	*SH* (α=0.01)	*ER* (α=0.05)	*ER* (α=0.01)	*FW* (α=0.05)	*FW* (α=0.01)
V-109384	**G1**	2477.14	1907.04	2577.33	2048.95	2429.63	1839.75	2705.08	2229.89
PR-103	**G2**	2247.29	1543.62	2469.84	1858.84	2192.02	1465.33	2585.65	2022.88
99346	**G3**	2835.84	2367.46	2721.95	2206.13	2797.55	2313.22	3062.30	2688.21
PR-107	**G4**	2528.86	1957.97	2601.35	2060.64	2481.02	1890.20	2788.98	2326.40
DN-93	**G5**	2823.07	2395.76	2645.61	2144.40	2789.70	2348.48	3009.99	2660.52
V-11005	**G6**	2411.98	1821.93	2536.78	1998.40	2363.18	1752.81	2653.09	2163.45
SRN 09111	**G7**	2747.91	2229.34	2601.04	2021.25	2706.07	2170.06	3139.21	2783.58
NR-421	**G8**	2312.05	1751.62	2419.74	1904.15	2265.42	1685.57	2512.19	2035.10
V-09087	**G9**	2352.20	1714.13	2647.05	2131.76	2303.99	1645.85	2495.53	1917.15
NR-419	**G10**	2626.89	1998.18	2835.91	2294.24	2576.80	1927.22	2847.68	2310.91
Guard-6	**G11**	2630.07	2143.64	2579.04	2071.37	2589.39	2086.02	2834.32	2432.95
V-11160	**G12**	2744.53	2245.55	2709.32	2195.27	2702.65	2186.24	2962.09	2553.71
SAWSN-02-102	**G13**	2564.12	2006.18	2564.99	2007.42	2517.10	1939.58	2877.07	2449.46
NN-Gandum1	**G14**	2328.35	1827.95	2213.39	1665.12	2287.36	1769.89	2636.35	2264.22
TD-1	**G15**	2341.05	1835.28	2335.78	1827.83	2298.45	1774.95	2542.46	2120.56
TW 96010	**G16**	2926.17	2535.97	2566.13	2026.01	2903.83	2504.33	3203.35	2928.57
Sehar-06	**G17**	2856.16	2371.87	2770.49	2250.53	2816.26	2315.07	3091.95	2705.84
GALAXY 13	**G18**	2605.60	2107.68	2535.98	2009.08	2564.13	2048.95	2857.22	2464.09
NIA-MN-08	**G19**	2587.69	2018.30	2516.18	1917.01	2540.16	1950.98	3013.62	2621.60
NARC-11	**G20**	2599.26	2023.24	2752.98	2240.96	2552.05	1956.36	2781.57	2281.46

Table: 6 Rank Correlation of (Parametric Stability Statistics) 20 Genotypes in 16 Environments.

	$\bar{X}_{i.}$	S_i^2	CV_i	GAI	P_i	W_i^2	σ_i^2	b_i	S_{di}^2	$EV^{(1)}$	$EV^{(2)}$	$SH^{(1)}$	$SH^{(2)}$	$ER^{(1)}$	$ER^{(2)}$	$FW^{(1)}$	$FW^{(2)}$
$\bar{X}_{i.}$	1.000																
S_i^2	-0.162	1.000															
CV_i	0.069	0.953	1.000														
GAI	0.974	-0.003	0.226	1.000													
P_i	-0.185	0.741	0.690	-0.045	1.000												
W_i^2	-0.292	0.367	0.307	-0.257	0.559	1.000											
σ_i^2	-0.292	0.367	0.307	- 0.257	0.559	1.000	1.000										
b_i	-0.056	0.880	0.893	0.098	0.480	0.017	0.017	1.000									
S_{di}^2	-0.182	0.998	0.947	-0.023	0.731	0.350	0.350	0.889	1.000								
$EV^{(1)}$	0.499	0.686	0.817	0.639	0.577	0.203	0.203	0.639	0.668	1.000							
$EV^{(2)}$	0.368	0.802	0.911	0.516	0.636	0.256	0.256	0.752	0.785	0.962	1.000						
$SH^{(1)}$	0.726	0.054	0.238	0.744	0.250	0.296	0.296	-0.059	0.032	0.647	0.501	1.000					
$SH^{(2)}$	0.635	0.146	0.298	0.668	0.385	0.397	0.397	-0.024	0.123	0.678	0.550	0.980	1.000				
$ER^{(1)}$	0.499	0.686	0.817	0.639	0.577	0.203	0.203	0.639	0.668	1.000	0.962	0.647	0.678	1.000			
$ER^{(2)}$	0.368	0.802	0.911	0.516	0.636	0.256	0.256	0.752	0.785	0.962	1.000	0.501	0.550	0.962	1.000		
$FW^{(1)}$	0.544	0.632	0.768	0.667	0.359	-0.159	-0.159	0.732	0.618	0.904	0.901	0.414	0.411	0.904	0.901	1.000	
$FW^{(2)}$	0.438	0.731	0.848	0.580	0.426	-0.069	-0.069	0.818	0.720	0.908	0.932	0.373	0.382	0.908	0.932	0.938	1.000

Significant at a level of 5%

CONCLUSION

Simultaneous selection of mean yield and stable genotypes are mostly preferred by agronomists and plant breeders due to the high mean yield with stable performance of genotypes across environments. Numerous stability statistics and graphical approach were evaluated to deal the influence of GE interaction and to achieve the simultaneous identification of genotypes more precisely. *Safety first index/rule* (decision making tool) approach and most of the other stability measures specified the genotypes G16 and G17 be the most stable genotypes so can be recommended to plant breeders for cultivation widely while genotypes G14 and G15 to be the poorest and unstable genotypes so they must be replaced by alternative genotypes.

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