Research Article

Identification of Promising Groundnut Genotypes Using Stability Analysis

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Abstract | Nine groundnut genotypes were studied for their stability analysis under national uniform yield trials in different agro-climatic zones of Pakistan. The combined variance effects (Anova) based on AMMI model confirmed significant differences (P<0.01) among genotypes, environments, and the genotype by environmental (G x E) interactions. The environmental factors explained 81.29% of the total yield variation. Environment variations proved to be the main factor influencing the performance of groundnut-genotypes in most of the locations where the study was conducted. The initial two components (IPCA1 and IPCA2) clarified 83.2% of the variance because of genotype and GxE interactions. The interaction principal component axis scores of a genotype good indicators of a genotype stability across environments. Various stability methods were used for stable genotypes identification across environments. According to different stability measures groundnut genotype 11AK011 turned out to be the most stable entry as revealed by Wricke's ecovalence, mean square deviation, coefficient of determination, Shukla's stability variance and coefficient of variation. The GGE biplot analysis also confirmed that 11AK011 groundnut genotype and can be considered as adaptable to the environments of the experimental sites.

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Introduction

Groundnut (*Arachis hypogaea* L) is among cash crops in barani (rainfed) areas of Pakistan which is mostly grown in of upper Punjab and parts of Khyber Pakhtunkhwa. About 91 % of the total area grown to groundnut is situated in Punjab, while 8 % area under this crop in Khyber Pakhtunkhwa. A negligible share of the area grown to groundnut (0.7 %) is in Sindh but that is under irrigated conditions. During 2015-16, the total area under groundnut was 91900 hectares while the total production was 91700 tonnes with the national average yield of 998 kg/ha (Government of Pakistan, 2017). Annual groundnut production in the country has been fluctuating due to erratic rainfall patterns and sensitivity of the groundnut genotypes to variable environmental conditions. A stable crop variety is desirable for its successful commercial cultivation across diverse agroclimatic regions. It is needed to breed superior genotypes with good stability for consistent yield performance under varied environments. (Nawaz *et al*., 2009). The researchers predominantly think that in addition to high-yields, importance should also be given to genotype yield stability under various environmental conditions (Qari *et al*., 1990). The genotypes are viewed as steady if their yield performances show little or no variations over environments. To identify genotypes resilient to changing environment (G×E) for yield trait, an experiment was conducted on 52 genotypes of peanuts for two years under two levels of phosphorous. The combined analysis of variance confirmed the significant variability due to genotypic, environmental, G×E interaction effects. The selection for yield and stability based on the IPCAS (SSI) works with 12 stability (AMMI) parameters model. The selection of genotypes for yield stability is based on the MASI, SIPC and MASV (Ajay *et al*., 2020).

A steady genotype doesn't change or if it does, the change across different environmental conditions should be the least (Baker, 1988). Thirty Bambara groundnut accessions were evaluated for G×E interaction and yield stability in Malaysia under four varied climatic zones. The locations and seasons were the great source variability for yield performance of the groundnut accessions. While seasons and localities contributed 31.13% and 14.02% variability among accessions respectively. The AMMI model and GGE biplot was to used to select best accessions on the base of performance rank (Khan *et al*., 2021).

A number of researchers have studied stability performance in different crops such as Kaya *et al*. (2002); Qari *et al*. (1990); Ahmad *et al*. (1996); Masood *et al*. (2003); Shah *et al*. (2009) in wheat, Ali *et al*. (2012) in lentil, Bakhsh *et al*. (1995) and Farshadfar *et al*. (2012) in chickpea, Mahalingam *et al*. (2006) in rice; and Sadeghi *et al*. (2011) in tobacco. Ashraf *et al*. (2016) compared two statistical models for studying stability in Flax, Ngozi et al. (2013) in aromatic pepper and Hidayatullah *et al*. (2017) in tomato , Javed *et al*. (2006); Kabir (2009); Khalil *et al*. (2011); Khalil *et al*. (2013); Munawar *et al*. (2013); Rahman *et al*. (2010); Munawar *et al*. (2013); Banik *et al*. (2010); Solomon *et al*. (2008) and Abid and Zahid (2018) in maize crop. The present research was designed with the objective to identify the promising genotypes of groundnut crops high level of stability under different agro-climatic conditions in Pakistan which would consequently lead to sustainable groundnut production in the country over years and environments.

Materials and Methods

Nine groundnut genotypes were tested during 2017-18 at a range of different environments under national uniform yield trials (NUYT) and the experimental sites included Agriculture Research Institute Bahawalpur; Groundnut Research Station Attock, (Punjab); Barani Agricultural Research Institute Chakwal; Arid Zone Research Institute *Umerkot (Sindh);* Agricultural Research Institute Quetta (Baluchistan) and National Agricultural Research Centre Islamabad. The experimental data of National Uniform Groundnut Yield Trials were used in this study for stable genotypes identification. The data were analyzed by using various statistical procedures such as Genotype Mean, Standard Deviation (S_i); Coefficient of Variation (CV); Regression Coefficient (b_i); Mean Square Deviation (S^2_{di}); Shukla's Stability Variance (σ_t^2); Coefficient of Determination (R_i^2); Wricke's Ecovalence (W_i^2); Additive effects along with Multiplicative Interaction (AMMI), genotype and genotype x environment (GGE) analysis were used as parameters for assessing genotypes stability. Several of these stability procedures were used by different scholars such as Kaya *et al*. (2002); Banik *et al*. (2010); Sadeghi *et al*. (2011); Ali *et al*. (2012); Munawar *et al*. (2013); Shah *et al*. (2009), Khan *et al*. (2014); Kilic (2014), Masood *et al*. (2003), Hidayatullah *et al*. (2017) and Abid and Zahid (2018).

Results and Discussion

AMMI Analysis

Combined variance effects (ANOVA) for nine groundnut genotypes evaluated across six different locations, based on AMMI model are presented in Table 1. The ANOVA revealed statistically highly significant differences (P < 0.001) for variation caused by the genotypes (G), environments (E) and GxE interaction. The F-test turned out to be highly statistically significant (P<0.001) for the entire interaction principal component axis. The environments explained for 81.29% of variation followed by the GxE interaction (11.25%). Genotypes contributed to total variation by 7.45% which indicated that in the multi -environment trails genotypic contribution to the total variation is the lowest of all factors. Environmental variation proved to be main factor influencing yield performance of groundnut genotypes across most of the experimental sites. The first

Table 1: *AMMI analysis of variance of groundnut yield over six environments.*

Sources of Variation	DF	SS	MS	F-Value	Total variation explained (%)	G x E explained (%)	Cumulative (%)
Environment (E)	5	167123654.3	33424730.9	189.8**	81.29		81.29
Genotype (G)	8	15326350.2	1915793.8	10.88**	7.45		88.75
G x E	40	23135169.3	578379.2	3.29**	11.25		100.00
IPC1	12	12941381.5	1078448.5	6.23**		55.94	55.94
IPC2	10	6316123.3	631612.3	3.65**		27.30	83.24
IPC3	8	3208098.0	401012.2	2.32*		13.87	97.11
IPC4	6	393469.9	65578.3	0.38		1.70	98.81
IPC5	4	276096.6	69024.2	0.40		1.19	100.00
IPC6	2	0.0	0.0	0.00		0.00	100.00
Residuals	108	19012778.7	176044.2			0.00	0.00

***P < 0.01; *P < 0.05; IPC= Interaction principal component axis.*

five interaction principal component axes were highly significant and explained for 100% of the GxE interaction in the study.

The first Interaction principal component axis (IPCA) explained 55.94% of interaction sum of squares while IPCA2 described 27.3% of the interaction sum of squares (Table 1). The IPCA 1 and IPCA 2 mean squares cumulatively contributed 83.24% to the total genotype × environment interaction (GEI). The model was good enough to explain maximum of the total genotype x environment interaction component.

Groundnut Genotypes Stability assessment

The results showed that the mean groundnut yield over six environments varied from the lowest of 1966 kg ha^{-1} recorded in Korean-1 to the highest of 2848 kg ha^{-1}given by 11AK011 with a grand mean of 2376 kg ha^{-1}. Entry 11AK011out-yielded all the other genotype by giving the mean yield of 2848 kg ha^{-1} followed by 10AK003 (2762 kg ha^{-1}), ICG-11855 (2684 kg ha^{-1}) and 13CG063 (2456 kg ha^{-1}) whereas Korean-1 (1966 kg ha^{-1}) produced the lowest average yield combined along all the environments. According to Francis and Kannenberg (1978), the smaller numerical value of coefficient of variation (CV) indicates more stable genotypes across the environments in terms of their agronomic performance. So according to logic given by Francis and Kannenberg (1978), entry 11AK011can be considered as comparatively more stable over the environments given its smallest value of coefficient of variation (Table 2).

The values for coefficient of regression (b_i) ranged from 0.90 to 1.16, absolute values of Mean Square Deviation (S^2_{di}) ranged from 27929 to 656065. A stable variety is the one which has the highest mean performance, b_i closest to the unity (1.0) and $S^2_{di} = 0$ (Eberhart and Russel, 1966). The results showed that entry 11AK011 having highest yield average (kg ha^{-1}), regression coefficient (b_i) close to one and having the lowest value of deviation from regression (S^2_{di}) corroborated the stability and adaptability of this genotype to a wide range of environments (Table 2). Furthermore, the genotypes having regression coefficient (b_i) value greater than unity (1.0) show adaptability to the favorable or high-yielding environments and on the other hand, genotypes having b_i value smaller than one possess adaptability to low-yielding or adverse environments (Petersen, 1989). The results showed that entries 1, 4, 7 and 8 had values of regression slope (b_i) less than one, which indicates that these genotypes would perform better in low yielding or poor environments. Similarly the entries 2, 3 and 5 having regression coefficient (b_i) greater than unity may be suggested for farming in high yielding or more favorable environments (Table 2). A larger value of coefficient of determination (R_i^2) is desirable because a higher R_i^2 values shows favorable reactions to environmental variations (Sayar *et al*., 2013). The highest value of coefficient of determination (R_i^2) (0.96) for entry 11AK011 also confirms its higher level of stability as compared to other genotypes (Table 2).

According to the concept of ecovalence as defined by Wricke (1962) the genotypes with a minimum ecovalence (W_i^2) value have comparatively smaller deviations from the grand mean across locations/environments and are consequently considered stable as compared to others genotypes with larger values for

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Table 2: *Stability statistics for 9 groundnut yield (kg ha^{-1}) across 6 environments in Pakistan.*

E.#	Entry Name	Stability Statistics*							
		Mean	S_i	*CV (%)*	b_i	S^2_{di}	R_i^2	σ_i^2	W_i^2
1	10AK003	2762	1119.4	40.5	0.98	35464	0.96	41570	268767
2	ICG-6590	2220	1242.3	56.0	1.05	204672	0.88	218598	957211
3	ICG-11855	2684	1486.2	55.4	1.16	656065	0.75	719059	2903447
4	ICG-2271	2086	1112.6	53.3	0.95	109902	0.91	121232	578566
5	ICG-156	2065	1226.8	59.4	1.05	129343	0.91	142474	661173
6	11AK011	2848	1092.5	38.4	0.99	27929	0.96	35710	245981
7	Korean-1	1966	1110.9	56.5	0.94	138140	0.89	152150	698802
8	13CG063	2456	1090.5	44.4	0.90	189698	0.85	214406	940909
9	Bari-11	2299	1148.4	50.0	1.00	82837	0.93	89938	456867

**Mean= Groundnut yield mean (kgs ha^{-1}); S_i = Standard deviation; b_i = Regression Coefficient; CV= Coefficient of Variation; S^2_{di} = mean square deviation; R_i^2= Coefficient of determination; W_i^2 = Wricke's Ecovalence; and σ_i^2= Shukla's stability variance.*

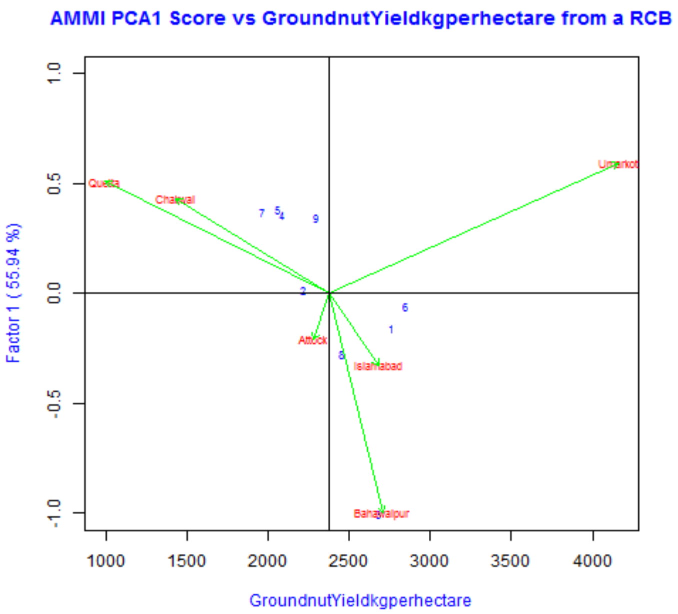

Figure 1: *Biplot analysis of PCA1 scores and yield of nine groundnut genotypes across six environments.*

the above mentioned statistical measure. The most stable genotype was 11AK01 according to the ecovalence method of Wricke (1962) given its smallest W_i^2 value of 245981. Shukla's (1972) stability variance revealed that entry11AK01 had the smallest variance value across the environments and so was the most stable genotype. The results of Shukla also confirmed the findings of Wricke (1962). All the statistical measures for stability given in the Table 2 indicate toward higher level of performance stability of genotype 11AK011acorss environments as compared to other genotypes.

Biplot analysis of Groundnut Genotypes

The biplot (AMMI) model dependent on IPCA1 and mean of genotypes for nine groundnut genotypes across six conditions was built to show the exhibition and relationship of the contemplated genotypes. (Figure 1). It is evident from Figure 1 that entry 11AK011 was the most elevated yielding followed by entry 10AK003 and entry ICG-11855. The genotype with least yielding potential was among nine passages was section 7 (Korean-1) situated at the upper left corner of the biplot. Section 6 (11AK011) was the most steady as it is the nearer to the IPCA1 axis and can be considered as versatile to every one of the conditions.

The genotype main effects and genotype-environment interaction (GGE) biplot analysis based on the performance of nine groundnut genotypes across six environments were constructed. First two IPC scores (PC1 & PC2) described 83.24% of variation in yield was due to genotype (G) and (G×E) genotype by environment interaction (Figure 2). The association of among different environments is presented in **Figure 2**. Locations/Environments with the smallest vector angles tend to have more likeness among the environments and those having wide vector angles showed least association. Chakwal and Bahawalpur was the most distinctive environment due to its lengthiest vectors of the biplot.

Conclusions and Recommendations

Several stability analysis techniques were used to identify the stable groundnut genotype across the environments. Comparison of various stability measures showed that 11AK011 groundnut genotype was the most stable entry identified by mean square deviation (S^2_{di}), Shukla's stability variance (σ_i^2), coefficient of variation, coefficient of determination (R_i^2) and Wricke's ecovalence (W_i^2). The GGE biplot analysis also confirmed the stability of 11AK011 genotype across diverse environmental conditions and can be recommended for cultivation in any of the environment under the study.

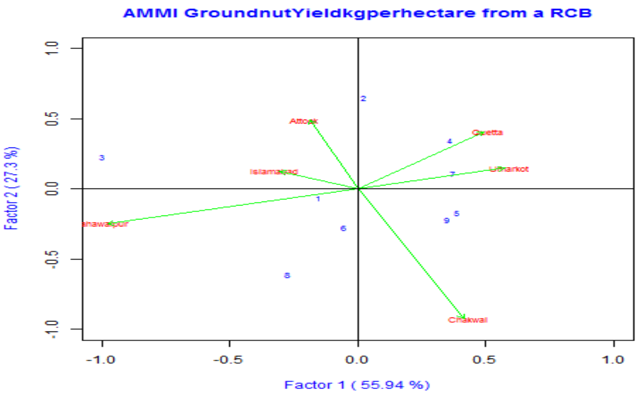

Figure 2: *Biplot analysis of GEI for the PC1 and PC2.*

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Novelty Statement

The newly developed advance line 11AK011 was the most elevated yielding and most steady as it is the nearer to the IPCA1 axis and can be considered as versatile to every one of the conditions.

Author's Contribution

Both authors contributed equally to the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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