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Analysis of Yield Stability in Rainfed Wheat of Pakistan Using GGE Biplot

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Abstract

The aim of this paper is to discuss the stability of grain yield varieties of rainfed wheat using the GGE (genotype main effect plus genotype by environment interaction). New varieties have to be determined by the plant breeders that are responsive for grain yield in the environmental change. In the current study, Nineteen wheat varieties in twelve different environments during 2009-10 with four replications in each environment using the RCBD (randomized completely block design) as the experimental layout. From the combined (ANOVA), the "environment (E), Genotype (G) and genotype × environment interaction (GEI) effects" were much significant (P<0.01). From the polygon view it is obvious that there were three

winning genotypes which performed best in maximum environments for the rainfed wheat genotypes. G6 performed well in first mega-environment that contained 6 environments, G4 in second mega-environment and G7 performed best in the third mega-environments respectively among all environments. G10 was the most desirable genotype from the graph of genotype comparison and E9 was the desirable environment from the graph environments comparison.

Keywords: GGE biplot analysis, GEI (genotype by environments interaction), METs (multi environments data)

INTRODUCTION:

One of the most important crop is wheat that 99% of Pakistani use as their daily diet. It is cultivated about nearly twenty million hectors of land in Pakistan. Pakistan falls in those top ten countries that produces wheat in a larger quantity. About 10% wheat consuming in seed, 18% in feed for animal use and 72% in flour in Pakistan. According to FAO not only in Pakistan but throughout the world the production of wheat is 240 million ha, is more than any other crop. As a source of protein, calories and vitamins of a body wheat is the crucial crop all over the world.In the cultivable land of Pakistan farmers grow wheat in the land fed by rain and naturally irrigated with the proportion of 30% and 70% respectively .Around 10% to 20% of GDP in agriculture in achieved by wheat in Pakistan statement taken from (PES, 2015-2016).

Wheat production in any area depends upon many factors such as the variety of moisture situation and climate of a region that varies provincially in Pakistan. Environmental factors such as soil humidity and temperature develop a direct relation between genotype stability and environment. That's why genotype environments interaction (GEI) plays crucial role and also a stumbling block for the breeds, as it effect the genotype's relative performance.

In the field of applied technology the GGE biplot analysis has outstanding potential rate to agronomists, physiologists, nutritionists and plant breeders. GGE biplot was proposed by (Yan et al., 2000) for the purpose of graphically display of the (MET) data. In a "GGE biplot

technique "both the genotypes and environments shows in a biplot among the tested environments will define the longest vector optimal environmental. On the basis of distance from the origin of biplot to identify a best genotype between them and optimal environment. It is also possible to rank the visual suitability of tested environment.

In all the complex analysis cases about METs the GGE biplot approach is used to analyse the data. In such cases the data presents graphically is in the scatter plot form that are based on two way means table. GGE biplot provides the best genotypes among all the tested genotypes and best environments among all the testes environments in a simple graphs.

GGE bi-plot is an information visualization device which shows graphical (G x E) interaction (Yan, 2000). GGE bi-plot evaluation is an increasing number of being used in (G x E) interaction of agriculture analysis (Butron, 2004; Crossa, 2002; Dehghani et al., 2006; Hunt, 2002; Kaya et al., 2006; Samonte et al., 2005; Tinker, 2005; Yan, 2002; Yan, 2003; Yan, 2006). But there was no report of this software to forestry so far. As a case study, the purposes of this paper were to use the methodology to diagnose the styles of (G x E) interaction.

Materials and methods:

A GGE biplot analysis is applied on 12 rainfed wheat genotypes taken from 19 different environments of Pakistan. This data was taken from National Uniformity Wheat Yield Trials (NUWYT) coordinated by National Agriculture Centre (NARC) Islamabad. Randomized Complete Block Design with four replications in each environment were implemented for the year 2009-10. The names and their codes of the 19 wheat genotypes that were developed in different research institutions/stations are given in (Table 1, 2). To guesstimate the importance of main effects 'Genotype (G)', 'Environment (E)' and 'GE', combined ANOVA was performed. The stability analysis of genotypes and environments using GGE Biplot methods. All the computational work was done on data analysis by using the different Statistical Software i.e. Minitab SPSS and R package

(Table: 1) 12 genotypes of Rainfed wheat in Pakistan

Code	Genotype	Institute/Station
G1	QS-III	QAARI-Larkana
G2	V-05BT006	AARI Faisalabad
G3	NR-356	NARC-Islamabad
G4	V-076377	RARI-Bahawalpur
G5	PR-102	CCRI Pirsabak
G6	DN-62	ARI-D.I.Khan
G7	V-05082	AARI Faisalabad
G8	V-15	NIFA-Peshawar
G9	V-076309	RARI-Bahawalpur
G10	V-10	ARI-Quetta
G11	CT-04192	NIFA-Peshawar
G12	ESW-9525	NIA-Tandojam

(Table: 2) 19 test location of the rainfed wheat in Pakistan

Code	Province	District/location
E1	SINDH	QAARI-Larkana
E2	PUNJAB	AARI Faisalabad
E3	PUNJAB	NARC-Islamabad
E4	SINDH	NIA-Tandojam
E5	PUNJAB	AARI-Faisalabad
E6	SINDH	WRI-Sakrand
E7	PUNAB	RARI-Bahawalpur
E8	PUNJAB	CCRI Pirsabak
E9	KPK	ARI-D.I.Khan
E10	PUNJAB	AARI Faisalabad
E11	KPK	NIFA-Peshawar
E12	PUNJAB	RARI-Bahawalpur
E13	KPK	KPK A.U. Peshawar
E14	BALOCHISTAN	ARI-Quetta
E15	KPK	NIFA-Peshawar
E16	PUNJAB	AARI Faisalabad
E17	SINDH	NIA-Tandojam
E18	KPK	KPK A.U. Peshawar
E19	PUNJAB	UA-Faisalabad

Analysis of combined ANOVA

Combined ANOVA for the 12 rainfed genotypes of grain yield presented in the (Table 3). Highly significant ($p<0.01$) interaction was observed among the environment (E), Genotype

(G) and genotype × environment interaction (GEI), which inarguably showed that G, E and GEI effects substantial for every traits. It portrays genotype × environment interaction (GEI) is a substantial source of variation (Samonte et al., 2005).The explained

SS % for the rainfed wheat has shown (87.18) for environment (0.56) and (3.78) for their interaction.

(Table: 3) analysis of variance for a GGE biplot analysis of rainfed wheat

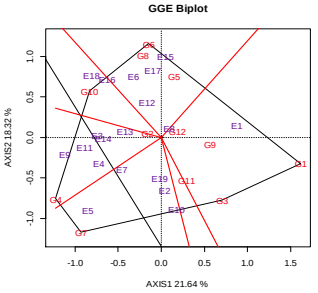
Source	DF	Seq SS	Adj SS	Adj MS	F	P	Explained SS (%)
Environment	18	2338473321	2338473321	129915184	478.19	0.000	87.18
Replicate(Environment)	57	56667652	56667652	994169	3.66	0.000	2.11
Genotype	11	15244459	15244459	1385860	5.1	0.000	0.56
Environment * Genotype	198	101518804	101518804	512721	1.89	0.000	3.78
Error	627	170342954	170342954	271679			
Total	911	2682247189					

"Which-won-where" pattern in GGE biplot analysis

Most importantly GGE biplot which can show the polygon view of a MET data set. It is the best and effective means of visualizing and interaction pattern between the cultivars and environments (Yan and Kang, 2003) .The polygon is drawn on those genotypes that have longest distance from the biplot origin and according to the (Yan and Tinker, 2005) genotypes that are placed on the vertex are the most responsive genotypes among all.

The polygon is used to compare the vertex genotypes and a perpendicular line has drawn (Fig 1). The perpendicular strains divide the polygon sectors, each having its very own triumphing cultivar i.e. vertex genotype (Yan et al., 2000). In this bi-plot .In the current study , based on the longest distance from the biplot origin genotypes G1, G6, G10, G4, G7, G3 are the vertex genotypes which indicates that these are genotypes that are best or worst among few or all the environments (Yan and Kang, 2003). From (Fig 1) it is obvious that the biplot has six sections and all the sections have the genotypes but tested environments are in five sections .Three genotypes come into first section i.e. G1, G9 and G11 among these G1 was the vertex genotype suggesting that G1 gave best performance in the environments E1 followed by G9 and G12.The second section having three genotypes and G6 was vertex genotype among them. Further it suggested that G6 was high yielding in the environments E15, E17, E6 and E12 followed by G8 and G5. In the third section it is obvious that G10 was the vertex genotype and it has yielded highly in the environments E18 and E16. In the fourth section G4 was the vertex genotype which means it gave the best performance among the environments E9, E11, E4, E14, E3 and E13. In the fifth section G7

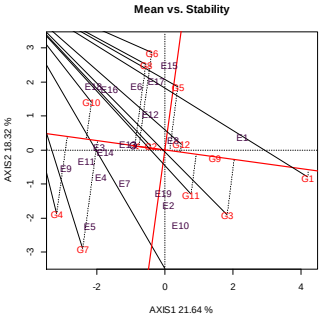
was the vertex genotype that gave the best performance in the environments E5, E7, E19 and E10 and in the last section G3 was the vertex genotype followed by G11 and they did not perform well in any of the environments. The sum of square for the GGE biplot analysis accounted for the both the PC1 (Axis1) and PC2 (Axis2) were 21.64% and 18.32% respectively while 39.96 % is the total explained variation. (Fig 1).



(Figure: 1) Which won where pattern of the 12 rainfed wheat genotypes tested in the 19 environments.

Genotype evaluation based on stability and mean yield:

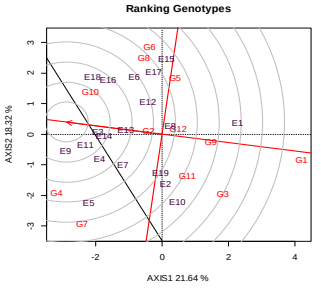
From Figure 2, two lines which examine stability and mean yield of the genotypes. average tester coordinate (ATC) the biplot origin and it has a point in the GGE biplot known as AEC (average environment coordinate), represents the mean yield and the other line stability of genotype is denoted by these lines which pass through origin and perpendicular to ATC. The best yielding genotypes among the tested environments are those that are closer to the (AEC). According to our study, above-average mean genotypes were G2 to G6 and below-average mean were G5 to G1. (Figure: 2). The genotypes that were close to the overall mean were G12 and G2. More ever, G5, G12 and G3 were the low-yielding and more unstable genotypes. The most stable genotypes were G2 and G9 followed by G12 and G10.



(Figure: 2) Mean vs. stability of rainfed wheat in Pakistan

Genotypes comparison relative to the perfect genotype

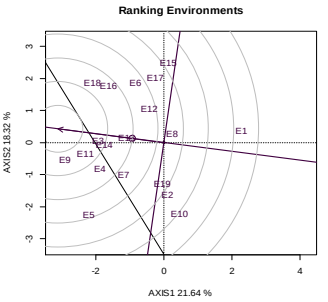
A genotype is considered to be ideal which has high stability and mean yield and that's placed in the middle of the concentric circles (Figure 3). A stable genotype must have zero (0) projection at the (ATC y-axis). Genotypes ranked on the bases of average is greater favourable if it is towards the ideal genotype. So according to the this criteria G10 was ideal genotypes regarding the high yield and stability as it falls in the middle of the concentric circles (a reliable genotype is characterised by means of always high yield and stability (Annicchiarico, 2002). The G2 and G4 are the second and third genotypes that fell nearest so the ideal genotypes and can be considered the second and third most desirable genotypes. Ranking of different genotype primarily based on appropriate genotypes (G8>G6>G7>G6>G12>G5>G11), while, the genotypes (G9>G3>G1) were considered unfavourable and lower yielding because they were at some distance from ideal genotype.



(Figure: 3) Genotypes Comparison with ideal genotype for the 12 rainfed wheat tested in the 19 environments.

Environments comparison relative to the perfect environment:

The two main properties for the ideal environment are the representativeness and discriminating ability (Yan, 200). A genotype that is highly differencing and representative to the desired genotype will be the perfect genotype (Yan and Kang, 2003).The ideal environment pointed out by the small circles and an arrow on it (Fig: 4). As compare to the others environments E9 was the ideal environment followed by the E11 and E3 among all. The selection of the ideal environment become more difficult in the presence of the genotype interaction (GE) (Yan et al., 2000) To observe the genotype interaction in (MET) most of the time it is compulsory to reveal the genotype interaction nature. In all such kind of interaction the GGE biplot methodology plays a vital role in the analysing of their PCs. In order to the discriminating ability a genotype must have large PC1 (AXIS1) and relatively less PC2 (AXIS2) scores (Yan & Rajcan, 2002).

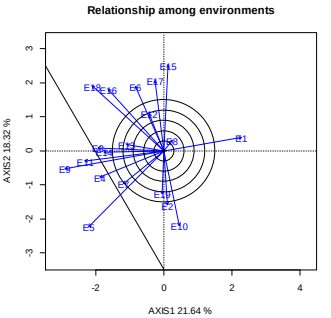


(Figure: 4) Comparison of the 19 environments with the ideal environment

Relationship between the test environments

The relationship between the test environments is graphically illustrated in (Fig 5). In the biplot vector view the angles between the tested environments will indicate the correlation among them. The acute angle among the environments indicated the positive correlation whereas obtuse angle will suggest the there is a negative correlation among the tested environments. So, from the Figure 5 the first 7 environments (E15, E17, E6, E12, E16, E18, E13) were positively correlated with each other and in the 2nd group the 7 environments (E3, E14, E11, E9, E4, E7, E5) were also positively correlated but both groups of environments were negatively correlated and the

environments (E19, E2, E10) were strongly correlated with each other but negatively correlated with all the environments of first group and with the environments (E13, E14) of second group. E10 and E1 were not correlated (a right angle).



(Figure: 5) Showing the relationship among 19 test environments.

CONCLUSION:

In the present study, the methodology of GGE biplot was very effective for the durum wheat in analysing the (MET) data (Mohammadi et al., 2011) as it gives the clear idea related to the genotype environment interaction and the exploring to relations between the tested genotypes and environments. Under low stress condition yield was the functional explicator (Cooper et al., 1997). Our testing was accordance that are directed by (Cooper et al., 1997), as the desirable environment (E9) was the more desirable for the discriminating genotypes and more representative among all the tested environments. According to the (Cooper et al., 1997) the grain yield breeding can be best in desirable environments by the combination of yield potential. This research paper is clearly indicating that for visualising the (MET) dataset GGE biplot analysis is an excellent tool. The main advantage of this methodology are graphical presentation that having the facility of mega environments identification and can be easily interpreted.

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