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GENOTYPE X ENVIRONMENT INTERACTION ON BREAD WHEAT GROWN OVER MULTIPLE SITES AND YEARS IN PAKISTAN

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Abstract

The stability for yield performance and genotype x environment (GxE) interaction was studied in 12 wheat genotypes grown at 13 contrasting sites (12 in Sindh and one in NWFP) over two years. The combined analysis of variance over all environments revealed a highly significant ($P \leq 0.01$) difference for genotypes, environments and genotype x environment interaction. An adaptation analysis was applied to estimate the b, s.e. (b) and deviation from regression coefficients (S^2d) for each genotype. The genotype SI90157 produced the highest mean yield over all the environments showing wide adaptation and stability. Genotypes PN90111; Anmol 91, SP89126 and SH8921 gave the lower mean yield over all environments with high value of s.e (b) and s^2d. The line SI88126 gave higher yield particularly in high yielding environments showing weak stability. The utilization of stable genotype SI90157 in the breeding programme for the evolution of new high yielding variety has been suggested.

Introduction

Bread wheat (*Triticum aestivum* L.) is the most important food crop of Pakistan. Although the country has produced a record production of 18.7 million tonnes in 1997-98 (Anon., 1999), yet the ever increasing population will continue to demand more wheat grains in years to come. Improvement for higher yield will therefore remain as an important wheat breeding objective. The yielding ability of a genotype is the result of its interaction with the environment. Environmental factors such as soil characteristics, moisture, sowing time, fertility, temperature, day length vary across years and locations. There is strong influence of environmental factors during various stages of crop growth (Bull *et al.*, 1992), thus genotypes differ widely in their response to environments. Some genotypes exhibit highly specific response to a particular environment, others are uniform in performance over a range of environments. Many workers are of the view that mean high yield should not be the only criterion for a genotype unless its superiority performance is confirmed over the varying environmental conditions (Qari *et al.*, 1990, Kinyua, 1992, Golmirzaie *et al.*, 1990, Liu *et al.*, 1992.).

Stability in performance of a genotype over a range of environments is a desirable attribute and depends on the magnitude of genotype x environment interactions (Ahmad *et al.*, 1996). A number of statistical methods are now available for estimating phenotypic stability but the joint regression analysis described by Yates & Cochran (1938), Finlay & Wilkinson(1963), Eberhart & Russell (1966), Perkins & Jinks (1968) and Arain & Siddiqui (1977) is one of the most commonly used methods for studying the yield stability. Recently new techniques have been developed to analyze GxE interaction in crop species. Since genotype responses are very complex, the multivariate techniques having more efficiency in explaining GxE interaction than linear regression (univariate) models (Gauch & Zobel 1988; Nachit *et al.*, 1992; van Oosterom *et al.*, 1993) have been used. Among the multivariate techniques, cluster analysis of GxE interaction provides a valid grouping of the environments for yield into regions and sub regions of high yield and low yield (Fox & Rosielle, 1982; Basford & Cooper, 1998). AMMI (Additive main effects and multiplicative interaction) model introduced by Gauch, 1988 has further splitted the GxE interaction into different components (μ_i, α_g, β_e) to obtain additive parts from ANOVA and λ_n, λ_{gn} and β_{en}) to get multiplicative parts from a principal component analysis (PCA). Applications of AMMI have led to more insight than ANOVA in the complicated patterns of genotypic responses to changed environmental conditions (Voltas *et al.*, 1999; Romagosa *et al.*, 1996). These methods have been effectively used to ascertain the importance of genotype x environment interaction. The objectives of this study was to evaluate newly developed wheat genotypes and to determine the yield performance of genotypes across two consecutive years over thirteen different environments.

Materials and Methods

Twelve wheat genotypes of different origin were evaluated in zonal varietal trials across thirteen contrasting locations viz; Tando Jam, Thatta, Badin, Umerkot, Sanghar, Nawabshah, Naushahro Feroze, Khairpur, Sukkur, Jacobabad, Larkana, Dadu and Peshawar, having different agroclimatic conditions, during two seasons 1994-95 to 1995-96. These genotypes were: SI88126, SH8921, SP89126, SP89128, PN9005, SH9044, PN90111, SI90157, Sarsabz, Mehran 89, Soghat 90 and Anmol 91. At each site, the experimental design was randomized complete block (RCBD) with four replications. Each genotype was sown with six rows, 5 meter long and spaced 30 cm apart. The grain yield data (kg/plot) was collected from central 4 rows (6 m^2 plot size) at maturity and analysed by using analysis of variance method in which genotypes were considered as fix variable at each location. Two years and 13 locations were considered as 26 random environments for the analysis of stability parameters. The regression coefficient (b) and deviations from regression (S^2d) were obtained as parameters of stability. The joint regression analysis for grain yield was calculated as follows:

$$Y_{ijk} = \mu_i + b_i I_j + b_{ij} + e_{ijk}$$

where,

Y_{ijk} = Yield of genotype (i) at site (j) and replicate (k).
μ_i = Mean of the ith genotype over all environments.
b_i = Regression coefficient of the ith genotype.
I_j = Environmental index.
b_{ij} = Regression coefficient of the ith genotype at jth environment.
e_{ijk} = Residual error of genotype (i) at site (j) and in replicate (k).

Results and Discussion

The combined analysis of variance for grain yield showed highly significant differences between locations (L), genotypes (G) and genotype x environment (GxE) interaction (Table 1). The year x location (Y x L) and year x location x genotype (Y x

Table 1. Pooled analysis of variance for grain yield (kg/plot) of wheat advanced lines in zonal trials during two years.

Source of variation	D.F	Mean square	Probability
Year (Y)	1	17.054***	.000
Locations (L)	12	28.514***	.000
Year x Location (Y x L)	12	11.379***	.000
Rep. (Location x Year)	78	0.349***	.000
Genotype (G)	11	1.047***	.000
Year x Genotype (Y x G)	11	0.191***	.004
Location x Genotype (L x G)	132	0.250***	.000
Year x Location x Genotype (Y x L x G)	132	0.279***	.000
Error	858	0.076	

L x G) interactions were aiso highly significant for grain yield. Significantly higher mean yield (2.23 kg) was obtained in 1994-95 as compared to 1995-96 (1.99 kg). Location means over individual years as well as combined over two years revealed highly significant differences (Table 2). Significant Y x L interaction meansquare further indicated that location means were inconsistent in both the years. For instance, location mean of Khairpur was the highest (3.54 kg) in 1994-95; whereas, it was the highest at Naushahro Feroze (3.32 kg) in 1995-96. Jacobabad was the poorest yielding location, where the lowest mean yield over two years was 1.41 kg.

Table 2. Site mean yield (kg/plot) of wheat genotypes tested over two years.

Locations	1994-95	1995-96	Mean	Rank
Tando Jam	2.82 C	2.69 B	2.75 B	3
Thatta	2.16 EFG	1.26 GH	1.71 EF	10
Badin	2.09 FG	1.80 EF	1.95 D	7
Umar Kot	3.17 B	2.00 DE	2.58 B	4
Sanghar	1.38 I	2.26 CD	1.82 DE	8
Nawabshah	1.98 G	2.26 CD	2.12 C	6
Naushahro Feroze	2.59 D	3.32 A	2.95 A	1
Khairpur	3.54 A	2.34 C	2.94 A	2
Sukkur	2.34 E	2.14 CD	2.24 C	5
Jacobabad	1.63 H	1.20.H	1.41 G	13
Larkana	1.58 H	1.52 FG	1.55 FG	11
Dadu	2.28 EF	1. 33 GH	1.80 DE	9
Peshawar	1.34 I	1.72 EF	1.53 FG	12
Mean	2.23	1.99	2.11	

Table 3. Genotypic mean yield (kg/plot) of wheat genotypes tested over two years.

Genotypes	1994-95	1995-96	Mean	Rank
SI88126	2.36 A	2.11 AB	2.23 A	2
SH8921	2.14 C	1.98 BC	2.06 CDE	7
SP89126	2.21 BC	1.89 CD	2.05 DE	8
SP89128	2.22 BC	2.06 AB	2.13 BCD	4
PN 9005	1.15 C	2.07 AB	2.11 BCD	5
SH 9044	2.29 AB	1.98 BC	2.13 BCD	4
PN 90111	2.02 D	1.76 E	1.89 F	10
SI90157	2.34 A	2.18 A	2.26 A	1
Sarsabz	2.31 AB	2.05 AB	2.18 AB	3
Mehran 89	2.22 BC	1.98 BC	2.10 CD	6
Soghat 90	2.22 BC	1.99 BC	2.10 CD	6
Anmol 91	2.20 BC	1.80 DE	2.00 E	9
Mean	**2.23**	**1.99**	**2.11**	

A significant GxE interaction may be either i) a non cross-over GxE interaction, in which case the ranking of genotypes remains constant across environments and the interaction is significant because of changes in the magnitude of response (Baker, 1988; Blum, 1983; Matus *et al.*, 1997) or ii) a crossover GxE interaction, in which case a significant change in rank occurs from one environment to another (Matus *et al.*, 1997). Genotypes differ significantly in their mean yield performance. Three genotypes SI90157, SI88126 and Sarsabz having statistically similar grain yield produced significantly higher yield than rest of the entries, when the means were pooled over two years (Table 3). Significant meansquares for Y x G and Y x L x G indicated inconsistency of performance of genotypes in different years. This was reflected by the change in the ranking order of genotypes under different environments (Tables 2 and 3). Statistically, GxE interactions are detected as a significantly different pattern of response among the genotypes across environments i.e., there is significant difference in the relative performance of genotypes when they are grown in different environments. Biologically, this will occur when the contributions (or level of expression) of the genes regulating the trait differ among environments (Basford & Cooper, 1998).

The stability analysis results are presented in Table 4. The regression coefficients (b) ranged from 0.878 in SP89128 to 1.084 in Sarsabz. Finlay & Wilkinson (1963) used linear regression as a measure of stability and suggested that the ideal variety having general adaptability is the one with maximum yield potential in the most favourable environments and maximum phenotypic stability. SI90157 had highest mean yield with regression value b=1.012 and low value of S.e (b) and S^2d. These results suggests that this genotype is high yielding as well as generally adapted to all the environments. Genotypes with a regression coefficient (b) approaching 1.0 would be stable over a range of environments. However, Eberhart & Russell (1966) proposed that `b' should be the parameter of response and deviation from regression coefficient ($S^2d$) as a parameter of stability. Accordingly `b' around 1.00 means less responsive to environmental changes, hence more adaptive. Thus a genotype is said to be stable over different environments, if it shows unit regression coefficient (b) with low deviation (non-significant) from the linear regression (S^2d).

Table 4. Stability parameters for grain yield of 12 wheat genotypes tested over 13 locations.

Genotypes	Mean yield (kg/plot)	Regression coefficient b+S.e (b)	Variance due to deviation from regression (s^2d)
SI88126	2.23	0.984±0.132	0.184
SH8921	2.06	1.024±0.064	0.043
SP89126	2.05	0.991±0.066	0.047
SP89128	2.13	0.878±0.068	0.047
PN9005	2.11	0.959±0.098	0.093
SH9044	2.13	1.067±0.069	0.054
PN90111	1.89	0.919±0.076	0.065
SI90157	2.26	1.012±0.077	0.059
Sarsabz	2.18	1.084±0.059	0.034
Mehran89	2.10	1.043±0.067	0.044
Soghat90	2.10	0.989±0.070	0.048
Anmol91	2.00	1.020±0.079	0.066

The year 1994-95 had higher yield than year 1995-96. Many investigators concluded that the year interaction effects are often the most important environmental factors affecting the yield and major components of G x E interactions (Lin & Binns, 1988, 1989; Yang & Baker, 1991). In the present study, the regression coefficient are close to unity in all the genotypes. However, SI88126 gave more average yield but had high value of S.e (b) and S^2d (Table 4) than the remaining genotypes, which makes its performance unpredictable under varying environments and thus it is less stable according to stability definition suggested by Eberhart & Russell (1966). PN90111, SH8921, SP89126 and Anmol 91 had comparatively low yield over all the environments with high value of S.e. (b) and S^2d and were specifically adapted to poor environments. Sarsabz had high yield (2.18 kg) with lowest values of S.e. (b) and S^2d which indicates that this variety had the highest stability than other genotypes. Stability analysis have also been carried out in many crops, such as chick pea (Khan *et al.*, 1988), barley (Voltas *et al.*, 1999), bermuda grass (Chakroun *et al.*, 1990), oat (Helms,1993), cotton (Abou-El-Fittouh *et al.*, 1969) and oil seed rape (Brandle & Mcvetty, 1988). The genotype SI90157 had the highest yield (2.26 kg) and unit regression coefficient (b=1.01) with low value of S.e. (b) and deviation from regression (S^2d), hence, it has a wide adaptability over a range of environments and may be considered as a future wheat variety for wide range cultivation in Sindh Province of Pakistan.

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