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BIOTECHNOLOGY

Stability Performance of Bread Wheat Genotype for Grain Yield, Zinc and Iron Concentrations

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ABSTRACT

The primary aim of plant breeding is to improve stability in yield and to obtain varieties with good quality. For this reason, a study of wheat genotypes was conducted at three different locations: Bathinda, Gurdaspur and Ludhiana during 2015-16 in Punjab (India). Grain yield and its components with quality traits were assessed in 21 wheat genotypes with 3 checks using analysis of variance and regression analysis. The combined analysis of variance for environment (E), genotype (G) and (G×E) interaction was highly significant for all studied traits, suggesting differential responses of the genotypes and the need to stability analysis. Results revealed that high yielding genotypes can also be stable. The check HD 3086 and PBW 725 and genotypes BWL 6003, BWL 6065, BWL 6066, BWL 6068 and BWL 6069 for grain yield/plot had desired performance in term of high mean, unit regression coefficient (bi) and least deviation from regression (S^2d), indicating the role of linear portion of GxE interaction and average stability in the performance of these genotype. The value of regression coefficient (bi) of genotypes BWL 6008, BWL 6011 and checks HD 3086, PBW 725 for grain Fe concentration; genotypes BWL 6006, BWL 6007, BWL 6013 and BWL 6062 for grain Zn concentration were have high mean, unit regression coefficient (bi) and least deviation from regression (S^2d), indicating that these genotypes were considered specially adopted to unfavorable environments

Highlights

- The check HD 3086 and PBW 725 and genotypes BWL 6003, BWL 6065, BWL 6066, BWL 6068 and BWL 6069 for grain yield/plot was stable across environment.
- BWL 1007 and BWL 1008 had significant grain Iron and Zinc concentrations across three environment.

Keywords: Wheat, stability, regression coefficient, Fe, Zn, grain yield

Wheat (*Triticum aestivum* L.) is one of the most important crops of India, and improvement in its productivity has played a key role in making the country self-sufficient in food production. It is grown on a fairly wide range of soil and climatic conditions. The area available for wheat cultivation is becoming increasingly limited, but the demand for wheat continues to grow. For this reason, wheat breeders have recently emphasized the planting of varieties at their optimum times and location for maximum yield production. Planting wheat in its optimum location and sowing date would realize optimum season length and achieve high grain yield as a result of suitable weather conditions prevailing through different growth stage (Ouda *et al.* 2005). The task of breeder is to screen out genotype planted at different location to enable selection of those varieties, which are suitable for different climatic areas. Information about phenotypic stability is useful for the selection of crop varieties as well as for breeding programs. The phenotypic performance of a genotype is not necessarily the same under diverse agro-ecological conditions (Ali *et al.* 2003). Some genotypes may perform well in certain environments, but, fail in several others. The basic cause of differences between genotypes in their yield stability is the wide occurrence of Genotype × Environment (GE) interactions. Genotype-environment interactions are extremely important in the development and evaluation of plant varieties because they reduce the genotypic-stability values under diverse environments (Hebert *et al.* 1995). Therefore, In the development of the cultivars, G×E interactions are the primary factors that concern plant breeders. For breeders, stability of quality attributes is also important in terms of changing ranks of genotypes across environments and affects selection efficiency. The principal objective of plant breeding is to improve stability in yield and to develop varieties of good quality. The concept of stability has been defined in several ways and several biometrical methods including univariate and multivariate ones have been developed to assess stability (Lin *et al.* 1986; Becker and Leon 1988; Crossa 1990). The most widely used one is the regression method, based on regressing mean value of each genotype on the environmental index or marginal means of environments (Romagosa and Fox 1993; Tesemma *et al.* 1998). A good method to measure stability was previously proposed (Finlay and Wilkinson, 1963) and was later improved (Eberhart and Russell, 1966). The stability of varieties was defined by high mean yield and regression coefficient ($b_i = 1.0$) and deviations from regression as small as possible ($s^2_{di} = 0$). The stability was defined as adaptation of varieties to unpredictable and transient environmental conditions and the technique has been used to select stable genotypes unaffected by environmental changes (Allard and Bradshaw 1964). The stability parameters are useful in characterizing genotypes according to their relative performance across locations.

Grain yield stability is one of the most important needs of agriculture. The ideal wheat (*Triticum aestivum* L.) genotype should be high yielding under any environmental conditions. But as genetic effects are not independent of environmental effects, most genotypes do not perform satisfactorily in all environments (Carvalho *et al.* 1983). When interaction between genotype and environment occurs, the relative ranking of cultivars for yield often differs when genotypes are compared over a series of environments and/or years. This poses a serious problem for selecting genotypes significantly superior in grain yield (Stafford 1982).

Various statistical techniques have been developed to identify systematic variation in individual genotypic responses. Among these, Eberhart and Russell (1966) model has been widely used in studies of adaptability and stability of plant materials (Carvalho *et al.* 1983, and Espitia-Rangel *et al.* 1999). The effectiveness of each method depends on the proportion of the genotype by environment interaction that each analysis can explain (Shorter *et al.* 1991). Therefore, the choice of an adequate model to measure the stability of different genotypes is a question to be resolved by researchers. According to Crossa *et al.* (1988), the selection of superior genotypes in a plant-breeding program is based mainly on their yield potential and stable performance over a range of environmental conditions.

The objectives of this study were to estimate genotype × environment (GE) interaction effects and testing stability of their performance and range of adaptations to determine the stable bread wheat (*Triticum aestivum* L.) genotypes for grain yield and its components with reference to Fe and Zn in different areas of Punjab (India). Where, development of any crop genotypes with wider adaptation is one of most important goal of breeding program.

MATERIALS AND METHODS

Plant material

Twenty one genotypes of bread wheat (*Triticum aestivum* var. aestivum) including three control cultivar namely, HD 3086, WH 1105, and PBW 725 were grown in the field of Punjab Agricultural University, Ludhiana as state trial during 2015-16 crop season. The experiment was conducted at three sites in northern western plan zone, Punjab, India (Ludhiana, Bathinda, Gurdaspur). Each genotype was sown in three replication and plot sizes were 1.2 × 6m at planting spaced at distance of 20 cm. The grain yield was measured as per plot. Recommended package of practices was followed to raise a good crop. Observations were recorded on plant height (cm), days to heading, grain Fe and

Zn concentration, 1000 grain weight (gm) and grain yield (kg/plot).

Grain analysis

The concentration of elements Fe and Zn in wheat grains was determined using a bench-top, non-destructive, energy-dispersive X-ray fluorescence spectrometry (EDXRF) instrument (model X-Supreme 8000, Oxford Instruments plc, Abingdon, UK), previously standardized for high throughput screening of Zn and Fe in whole wheat grain (Paltridge *et al.* 2012).

Data analysis

Combined analysis of variance (ANOVA) was calculated by Randomized Block Design analysis on multiple environment trials to evaluate the significance of the differences between genotypes. Two stability parameters were applied to assess stability performance of genotypes and to identify superior genotypes; b_i, the linear regression of the phenotypic values on environmental index (Finlay and Wilkinson, 1963) and S^2d, the deviation mean square from regression (Eberhart and Russell, 1966), all analysis were performed using the statistical software OPSTAT for ANOVA and for stability statistics. To predict stability, a genotype was considered stable for grain yield if it appeared stable in two (out of three) stability analysis. Genotypes that proved to be stable for most stability analysis were then selected as the best. One way analysis of variance was used to evaluate the significant difference for the studied genotypes and the genotype and environment interaction. The differences in the means of yield of the genotypes were determined for each location based on the overall average. Stability values were estimated from the quadratic mean of the regression deviation (Eberhart and Russell 1966). To define genotypic stability, a genotype which had higher or equal mean grain yield than grand mean yield as a precondition was considered stable for grain yield.

RESULTS AND DISCUSSION

Effects of environments, genotypes and their interaction on grain yield

The results of the combined analysis of variance are given in Table 1. An analysis of variance revealed significant ($p<0.01$) differences for grain yield among genotypes and environments. This reveals not only the amount of variability that existed among environments but also the presence of genetic variability among the genotypes. For genotype × environment and genotype × environment (linear) interaction significant difference were observed. Thus it signifies unit change in environmental index for each unit change in the environmental conditions. These results also reported in many previous studies on bread and durum wheat (Marti and Slafer 2014) and (Menshawy 2007). The mean grain yield was observed from 21 wheat genotypes with 3 checks across three environments and ranged from 2.92 kg to 3.73 kg/plot and the highest grain yield was obtained from genotypes BWL 6003 and BWL 6066, which is at par as compare to checks

Table 1: Pooled Analysis of variance of different characters in different genotypes of Bread Wheat

Source of Variation	DF	DTH	PH (cm)	Grain Fe	Grain Zn	1000 grain weight (g)	Yield/plot
Genotype	23	4.284**	11.44*	6.02*	17.67**	0.62	6.03*
Environment	2	2.93	114.60**	3.83	68.20**	27.51**	1.17**
Geno. × Envion.	46	14.68**	15.01**	23.21**	13.47**	1.74*	1.07*
Env+ Geno. × Env	48	14.19	19.16	22.41	15.75	2.82	0.12
Env (Linear)	1	5.86	229.19	7.65	136.39	55.03	2.35
Env × Geno. (Lin)	23	22.56**	24.15**	18.91	14.578**	2.017*	0.099**
Pooled Deviation	24	6.505**	5.63**	26.36**	11.86**	1.40**	0.04
Pooled Error	138	4.37	5.55	0.21	0.51	1.32	0.15

**, ** significant at P=0.05 and 0.01, respectively.*

DF = Degree of freedom, DTH = Days to heading, PH = Plant height

(Table 2). It was emphasized that both linear (b_i) and non-linear (s^2d_i) components of GE interactions are necessary for judging the stability of a genotype (Eberhart and Russell 1966). A regression coefficient (*bi*) approximating 1 coupled with an s^2d_i of zero indicates average stability (Eberhart and Russell 1966). Regression values above 1 describe genotypes with higher sensitivity to environmental change (below average stability) and greater specificity of adaptability to high yielding environments. A regression coefficient below 1.0 provides a measurement of greater resistance to environmental change (above average stability), and thus increases the specificity of adaptability to low yielding environments (Wachira *et al.* 2002). Linear regression for the average grain yield of a single genotype on the average yield of all genotypes in each environment resulted in regression coefficients (b_i values) ranging from -0.75 to 3.00 for grain yield. This large variation in regression coefficients indicates different responses of genotypes to environmental changes (Table 4, Fig. 1). As regard of grain yield genotypes and environment interaction was significant, indicating that adequate amount of genetic difference among genotypes for environmental response. Genotype BWL 6003, BWL 6065, BWL 6069 and checks HD3086, PBW 725 have regression coefficient (b_i) values close to unity (0.9 and 1.0, respectively) with small deviation from regression (s^2d_i) and above average yield and thus possessed fair stability and wider adaptation over different environment. Genotypes with high mean yield, a regression coefficient equal to the unity ($b_i = 1$) and small deviations from regression ($s^2d_i = 0$) are considered stable (Finlay and Wilkinson, 1963; Eberhart and Russell 1966). Similar findings reported by Mohtasham *et al.* (2012), Mohammadi *et al.* (2012) and Hamlabad (2012). In contrast, genotype BWL 6003, BWL 6002, BWL 6001 and check WH1105 had regression coefficients greater than 1, and so were regarded as sensitive to environmental changes for grain yield.

Table 2: Pooled mean DTH, PH, grain Fe, grain Zn, 1000 grain weight (g) and Seed yield/plot of bread wheat genotypes tested over three environments

Genotype	DTH	PH (cm)	Grain Fe	Grain Zn	1000 grain weight (g)	Yield/plot
BWL6001	100	111.67	34.0	25.0	36.00	3.84
BWL6002	100	111.33	37.0	31.0	36.22	4.45
BWL6003	101	112.33	41.0	32.0	36.43	4.96
BWL6004	99	108.00	40.0	32.0	37.00	4.70
BWL6005	98	107.67	36.0	30.0	37.22	4.58
BWL6006	99	108.67	41.0	35.0	37.43	4.04
BWL6007	98	96.00	41.0	35.0	38.67	4.66
BWL6008	98	95.67	42.0	30.0	38.88	4.15
BWL6009	99	96.67	41.0	33.0	38.22	4.45
BWL6010	99	104.33	37.0	31.0	38.00	4.45
BWL6011	98	104.00	42.0	32.0	39.43	4.22
BWL6012	99	105.00	34.0	34.0	38.43	4.25
BWL6013	97	100.67	41.0	35.0	36.00	4.26
BWL6062	97	100.33	39.0	35.0	36.43	4.38
BWL6063	98	101.33	40.0	32.0	36.00	4.46
BWL6064	97	107.33	39.0	30.0	39.43	4.37
BWL6065	96	107.00	34.0	29.0	36.22	4.72
BWL6066	97	108.00	36.0	27.0	36.43	4.83
BWL6067	99	108.00	38.0	33.0	39.00	4.42
BWL6068	99	107.67	34.0	31.0	39.22	4.76
BWL6069	100	108.67	37.0	32.0	39.00	4.78
HD3086	98	103.00	42.0	30.0	39.22	4.87
WH1105	98	102.67	37.0	27.0	36.22	4.71
PBW725	99	103.67	42.0	30.0	39.10	5.03

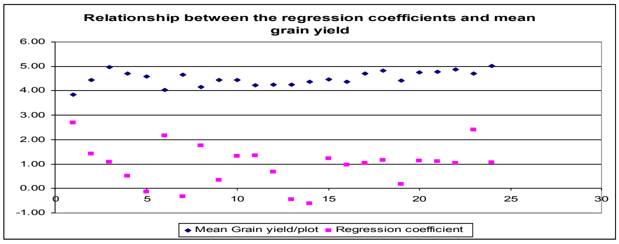

Fig. 1

Fig. 1 shows the genotype and regression coefficients plotted against the means of grain yield. Genotypes BWL 6001, BWL 6006, BWL 6008 and check WH1105 had regression coefficients greater than unity for grain yields with at par grain yield *i.e.* 3 kg/plot. Therefore, these genotypes are sensitive to environmental changes and can be recommended for cultivation under favorable conditions. Genotype BWL 6003, BWL 6065, BWL 6066, BWL 6068, BWL 6069 and checks HD3086, PBW 725 have regression coefficient (b_i) values close to unity. Therefore, these genotypes are resistant to environmental changes and can be recommended for cultivation under unfavorable conditions.

Effects of environments, genotypes and their interaction on grain iron and zinc concentration

The pooled analysis of variance (Table 1) was carried out after ascertaining the homogeneity of error variance using the Eberhart and Russell model. G × E interactions were found to be significant (at P≤0.01) for both the micronutrients. Grain Fe expressed higher G × E interaction in comparison to grain Zn concentration. Similar finding was reported in maize (Chakraborti *et al.* 2011). The ANOVA for stability using Eberhart Russel model revealed variation due to G × E (linear) non significant for grain Fe and significant for grain Zn concentration.

Table 3: Deviation from regression S^2d_i (Eberhart and Russell 1966), stability parameters for 21+3 checks in bread wheat genotypes across three environments

Genotype	DTH	PH (cm)	Grain Fe	Grain Zn	1000 grain weight (g)	Yield/plot
BWL6001	1.92	3.29	1.07	1.72	0.25	-0.71
BWL6002	-0.62	2.15	4.01	0.90	-0.95	0.51
BWL6003	-0.38	1.59	2.47	2.72	-0.16	-0.43
BWL6004	0.60	1.46	2.40	2.75	4.09	0.64
BWL6005	0.45	-0.24	0.55	5.96	4.09	0.86
BWL6006	1.25	-0.30	1.60	-0.43	0.19	0.28
BWL6007	0.96	2.20	0.72	0.28	-0.21	0.12
BWL6008	0.41	2.20	-0.60	1.18	0.25	0.54
BWL6009	0.75	1.15	1.85	1.28	0.85	-0.61
BWL6010	2.54	-0.24	2.28	2.10	2.10	0.85
BWL6011	0.22	-0.36	0.40	2.05	0.02	-0.53
BWL6012	1.53	3.97	0.52	0.19	2.10	0.34
BWL6013	-0.38	3.34	0.22	0.06	0.85	0.52
BWL6062	0.87	2.97	0.72	0.37	0.75	0.75
BWL6063	-0.12	3.59	0.15	1.52	0.85	-0.43
BWL6064	0.39	0.28	3.43	0.97	0.54	-0.61
BWL6065	1.82	-0.30	4.33	1.26	0.64	-0.51
BWL6066	2.46	2.06	2.30	1.80	0.84	0.12
BWL6067	0.40	0.02	2.73	2.05	0.16	-0.82
BWL6068	1.50	0.43	1.14	2.45	1.54	0.48
BWL6069	0.20	1.34	-0.29	3.06	0.96	0.62
HD3086	1.15	0.10	-0.55	0.45	0.18	0.11
WH1105	2.99	2.14	0.24	0.20	1.14	0.85
PBW725	0.99	2.38	0.36	0.42	0.15	-0.92

Despite various factors affecting grain micronutrient status including differential behavior of genotypes in locations, this study was successful in identifying promising wheat genotypes based on mean value of genotypes, regression values and deviations from regression. Thirteen wheat genotypes viz., BWL 6008, BWL 6011 and checks HD 3086, PBW 725 for grain Fe concentration; genotypes BWL 6006, BWL 6007, BWL 6013 and BWL 6062 were identified as stable genotype for grain Zn concentration (Table 4). The study indicated higher sensitivity of grain Fe to environmental fluctuations.

The value of regression coefficient (bi) of genotypes BWL 6002, BWL 6003, BWL 60011 and BWL 6069 for days to heading; genotypes BWL 6005 and BWL 6010 for plant height: genotypes BWL 6006, BWL 6067 and HD 3086 for 1000 grain weight were close/ equal to unit indicating that these genotypes were considered specially adopted to unfavorable environments. Meanwhile, the value of regression coefficient of genotypes BWL 6001, BWL 6006, BWL 6065, BWL 6066 and check WH 1105 for days to heading; BWL 6001, BWL 6002, BWL 6064 and check HD 3086, WH 1105 for plant height; genotypes BWL 6005, BWL 6007, BWL 6067 and check PBW 725, WH 1105 for grain Fe concentration; BWL 6006, BWL 6010, BWL 6067, BWL 6069 and check HD 3086 for grain Zn concentration; BWL 6001, BWL 6002, BWL 6065, BWL 6066 and check WH 1105 for 1000 grain weight and genotypes BWL 6001, BWL 6002, BWL 6006, BWL 6008 and check WH 1105 had bi values more than unity (bi>1) and could be greater specificity of adaptability to optimum environment.

CONCLUSION

Only genotype BWL 6003 showed higher grain yield than both checks HD3086 and WH1105 and its regression coefficient was close to unity. This variety was considered the best in terms of adaptation to all environments with lowest deviations from

Table 4: Regression coefficient b_i (Eberhart and Russell 1966), stability parameters for 21+3 checks in bread wheat genotypes across three environments

Genotype	DTH	PH (cm)	Grain Fe	Grain Zn	1000 grain weight (g)	Yield/plot
BWL6001	2.74	3.53	-5.33	-0.52	1.88	2.68
BWL6002	1.10	2.69	-3.33	-0.40	2.42	1.41
BWL6003	1.05	1.44	-5.60	-0.48	1.62	1.08
BWL6004	-1.48	0.84	3.06	1.75	0.24	0.50
BWL6005	-5.52	1.02	1.06	4.45	-0.84	-0.14
BWL6006	1.82	2.35	5.16	1.02	1.02	2.17
BWL6007	-8.25	-1.66	4.32	1.08	-0.26	-0.32
BWL6008	-1.89	-1.52	-1.32	2.68	-0.52	1.75
BWL6009	-2.96	-1.81	3.46	0.38	0.26	0.34
BWL6010	-1.42	1.02	-5.75	3.17	1.64	1.32
BWL6011	1.10	1.21	-4.01	0.17	1.30	1.35
BWL6012	-0.51	1.88	-5.50	2.29	0.84	0.67
BWL6013	-4.95	-0.91	-9.55	1.10	-0.28	-0.46
BWL6062	-3.13	-1.88	-6.91	1.04	0.48	-0.61
BWL6063	-5.86	-1.61	-6.40	0.29	1.28	1.24
BWL6064	2.22	2.97	-2.62	1.65	2.68	0.96
BWL6065	2.58	2.35	-2.35	1.70	1.86	1.03
BWL6066	2.77	1.38	-2.26	1.92	4.03	1.15
BWL6067	1.30	2.67	2.23	4.09	0.98	0.18
BWL6068	0.73	2.53	1.92	2.44	1.30	1.13
BWL6069	1.09	2.02	1.07	2.56	-0.26	1.10
HD3086	0.23	2.23	0.97	3.86	1.06	1.03
WH1105	5.63	1.63	3.94	1.91	1.68	2.41
PBW725	0.95	-2.64	0.44	-1.64	-0.28	1.06

regression (s^2d_i = -0.43). Genotype BWL 6008, BWL 6011 for grain Fe concentration, BWL6006, 6007, 6013, 6062 for Zn concentration were suitable for unfavorable environments due to their regression coefficients equal to unity, above mean and low deviations from regression values.

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