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Effect of genotype and environment on quality traits and grain yield of wheat

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Abstract

Field experiments with 20 bread wheat and durum varieties of different origin were conducted in seven environments during 2005-06. Data on 5 quality traits (grain protein content, sedimentation value, test weight, thousand kernel weight, and grain density) and grain yield per plot were used to investigate the effects of G, E and G × E on these traits. Highly significant differences were detected among the environments and varieties for each of the quality variable. Both variety (V) and environment (E) had a significant effect on the quality traits and grain yield. Significant V × E interaction indicated that quality trait evaluation must be undertaken for different environments. Highly significant positive correlation were observed for grain density and yield per plot, thousand kernel weight and yield per plot, grain density and thousand kernel weight, grain density and test weight (kg/hl), test weight and thousand kernel weight. Significant negative association was observed between grain protein content and thousand kernel weight. High heritability (broad sense) was observed for all the six traits under consideration with a moderate genetic advance and moderate to high genotypic and phenotypic coefficient of variation. These findings suggests that quality parameters could be greatly enhanced through genetic improvement for the targeted, well characterized production environments.

Key words: Spring wheat, grain quality, variety × environment interactions

Introduction

Wheat (*Triticum aestivum* L.) is the most important food crop of the world. It provides food to 36% of the global population contributing 20% of the food calories to it. The area under cultivation of wheat crop in India is 26.6 M ha with the production of 72.1 M tonnes [1]. Given the reliance on wheat production in the country, breeding efforts aimed at market diversification, have led to develop wheat cultivars with diverse end-use properties. Recent cropping diversification has further prompted development and deployment of wheat varieties with better quality attributes suited for making specific end-use products. The lack of environmental predictability and to a certain extent, market conditions, has made the idea of dual purpose wheats for different product specific use. That is, if the grain does not meet quality specifications for one use, there is potential for placement of the grain in the alternative market.

Improvement of end-use quality in bread wheat depends on a thorough understanding of current wheat quality and the influence of genotypes, environments and genotype × environment interactions on quality traits [2]. Wheat varieties differ significantly as to their grain quality. However, environmental factors play a major role in the expression of genotype characteristics [3, 4]. Their impact however, is rarely optimal, one or more of them will always limit the yield and quality of the product.

The effect of genotype, environment and their interaction on wheat quality, determined using multilocation trials have been used to enhance wheat, breeding for quality [5, 6]. Therefore, in the present study twenty wheat genotypes were grown at seven environments for understanding the effect of genotype, environments and their interactions on major quality traits.

Materials and methods

Field studies were conducted at Field Experimentation Station, Indian Agricultural Research Institute, New Delhi during 2005-06. The studies included twenty wheat cultivars and advance generation material (HD 2935, C 306, HD 2851, WR 1511, RS 907, RS 916, HD 2865, HI 8498, HD 2923, RS 901, PBW 175, WR 1522, RD 1055, Kundan, RS 912, RS 902, RD 950, PBW 343, HD 2934, and WR 1508). The material was evaluated at seven diverse environments/locations *viz.*, Deoria, Pusa, New Delhi (timely and late sowing), Dehradun, Indore and Ujjain. In each trial, genotypes were sown in randomized complete block design with three replications. Test plots were managed following the recommended site specific standard agronomic practices. The plot size was 6 m, 6 rows with row spacing of 23 cms.

Harvested grain samples were cleaned prior to conditioning and quality testing. Quality tests were performed on the harvested grain of each variety for each location/environment and were calculated at 12% moisture. Protein content was measured as per Kjeldahl procedure (N × 5, 7; moisture basis), thousand kernel weight was determined as an average of three samples of 200 seeds multiplied by 5, test weight was determined by using a Schopper Chondrometer with a 1 L container, sedimentation value as per Zeleny sedimentation value in accordance with AACC method [7]. The grain density was measured as per Kharkwal and Chaudhary [8].

Analysis of variance was done as per Panse and Sukhatme [9]. The stability analysis was carried out with model proposed by Eberhart and Russell [10]. Heritability in broad sense was calculated as per Allard [11]; genetic advance as per Robinson *et al.*, [12]; phenotypic and genotypic correlation as given by Al-Jibouri *et al.* [13]

Results and discussion

The analysis of variance for all the characters indicated significant differences among the genotypes over all the seven environments except grain protein content and yield per plot. Pooled analysis of variance for stability is presented in Table 1, revealed the presence of significant differences among the genotypes and environments for the all the characters. Mean squares due to genotype × environment interaction were highly significant for all the traits when tested against pooled error. For estimating the genotype × environment interaction, multilocation testing of varieties is essential. Further, environment + (V × E) interaction was also significantly different in pooled analysis of variance for stability for all the quality traits. The environment linear component for studied characters, was also significant. The genotype × environment (linear) was not significant for grain protein content and yield per plot when tested against pooled deviation. Pooled deviation significantly differed with respect to all the tested characters. Highly significant pooled deviation suggested that the genotype differed considerably with respect to stability of all the six traits over the seven locations. The environment (linear) component for all the traits were significant indicating that variation among the environment is linear. The genotype × environment interaction was further partitioned in to linear and non linear components. Since G × E (linear) component was significant for all the traits except grain protein content and yield per plot, this indicates the practical utility of prediction would depend on relative magnitude of the two variance. For other characters i.e., protein content and yield per plot, it indicates unpredictable performance of genotypes over the environments. The linear genotypes and S^2di could be considered as better measure of stability.

Primary requisite for sustainable crop production is the requirement of a genotype with high yield and stable performance over different environments. The stability parameters are presented in the Table 2. The best variety was categorized by regression coefficient (bi) equal or close to one and mean square deviation (S^2di) equal or close to zero and having high mean performance. For grain protein content Kundan revealed significant regression coefficient (bi). Among the non significant genotypes HD 2935, HD 2851, RS 916, PBW 175, WR 1522 recorded regression coefficient around 1 and non significant S^2di. For sedimentation value, only RS 902 showed significant bi value with significant S^2di, RD 950 was other genotype with non-significant S^2di close to zero and high mean performance. For test weight, none of the genotypes exhibited significant bi values. However, RS 907, C 306 and HD 2865 were considered stable depending on bi and S^2di values. For thousand kernel weight, no genotype could express significant values for regression coefficient. But RS 907, HD 2865, HD 2923, RS 912 and RS 902 were found to be relatively stable depending on the values of bi and S^2di. For grain density, Kundan and WR 1508 showed significant values of bi and were found to be stable in their performance when compared with the other genotypes for grain density. RS 907, HD 2935, PBW 175, RS 912, PBW 343 and WR 1508 were found to be stable depending on the values of

Table 1. Analysis of variance of six quality traits under different environments

Source of variation	df	Quality traits					
		Protein content	Sedimentation value	Hectoliter weight	1000 kernel weight	Grain density	Yield per plot
Varieties (V)	19	9.150366**	142.91549**	11.505224**	39.161618**	16.106330**	0.23671680
Environments (E)	6	27.976772**	252.89840**	71.551725**	493.09237**	790.87906**	14.093540**
V × E	114	4.311715*	16.411102**	5.6276775**	9.8622876**	19.631985**	3.13635481*
Pooled error	266	3.339973*	2.4627839	1.467637	1.3423285	0.96672932	3.13124734*
Env + (V × E)	120	3.6949686*	28.235467**	8.923879**	34.023792**	58.194339**	3.83421410*
Env (linear)	1	167.85551**	1517.27540**	429.4288**	2958.5727**	4744.1061**	84.561491**
V × E (linear)	19	0.671868	17.642423**	7.7920059**	7.0784215**	40.874288**	0.50376081
Pooled deviation	100	22.775220	15.357745	4.932745	9.8979233	14.626030	0.14587055

*,**Significant at 5% and 1% level, respectively

Table 2. Stability parameters of wheat genotypes for quality traits and yield per plot

Genotype	Protein content			Sedimentation value			Test weight			1000 kernel weight			Grain density			Yield per plot (Kg/plot)		
	Mean	bi	S2di	Mean	bi	S2di	Mean	bi	S2di	Mean	bi	S2di	Mean	bi	S2di	Mean	bi	S2di
HD 2935	12.62	0.94	0.24	43.38	20.70	3.87	81.62	1.29	7.19*	43.95	0.68	2.49	134.24	0.82	6.51*	2.57	0.88	0.03
C 306	12.43	1.34	0.19	42.29	1.31	12.70**	81.57	0.73	3.33	42.81	1.30	6.23*	136.10	1.62	5.07*	2.72	1.08	0.11
HD 2851	11.90	0.88	–0.08	45.57	1.34	4.47*	79.81	0.61	3.17	41.33	0.70	6.14*	136.95	0.99	19.87**	2.29	0.88	0.33
WR 1511	12.10	0.65	–0.09	44.17	0.72	8.50*	80.19	0.53	1.95	43.95	0.73	6.92*	137.95	1.03	12.07**	2.65	1.02	0.07
RS 907	11.24	0.69	–0.03	38.33	0.98	16.99**	81.52	0.93	1.87	41.62	0.84	0.04	135.48	0.79	18.12**	2.42	0.96	0.03
RS 916	12.19	0.85	0.52	40.29	1.18	4.32	81.19	0.65	1.79	43.87	1.11	1.00	135.81	0.79	9.57**	2.90	1.21	–0.01
HD 2865	11.81	1.18	–0.02	44.57	0.82	10.85**	80.38	0.71	–0.13	45.10	0.94	8.99*	139.00	1.33	7.31*	2.73	0.84	0.73
HI 8498	12.33	1.07	0.02	35.29	0.32*	14.79**	79.48	2.63	7.92*	46.11	1.22	10.00**	137.90	0.92	6.04*	2.74	1.13	0.00
HD 2923	12.33	0.60	–0.05	43.48	0.61	5.76*	80.00	0.79	0.40	45.43	0.91	3.34	137.19	1.37	12.63**	2.92	1.04	0.11
RS 901	12.48	1.14	0.44	39.67	0.78	16.32**	78.62	2.20	4.27	44.33	1.26	32.80**	133.95	0.64	36.66**	2.57	1.09	0.06
PBW 175	11.86	0.89	0.02	41.90	1.26	16.92**	80.29	0.26	0.58	46.48	0.79	10.88**	137.62	1.38	14.37**	2.89	1.06	0.03
WR 1522	11.90	0.66	0.25	45.52	1.62	10.48**	78.10	0.67	4.23	42.14	1.06	15.97**	133.62	1.05	9.26**	2.67	0.98	–0.01
RD 1055	12.29	1.17	–0.02	35.57	1.41	51.34**	79.76	1.17	4.73*	44.86	1.29	18.07**	136.05	1.47	17.51**	2.42	1.12	–0.01
Kundan	12.48	0.48*	0.17	50.14	0.86	33.97**	79.57	1.39	20.72**	50.38	1.02	10.45**	135.76	0.39	10.49**	2.64	0.84	0.03
RS 912	12.10	1.07	0.37	52.13	1.04	42.66**	79.33	1.34	2.34	43.57	0.84	8.69*	137.49	1.10	8.11*	2.54	0.98	–0.01
RS 902	12.24	1.23	0.10	39.48	0.03*	15.54**	80.48	0.12	0.59	40.95	0.89	0.70	135.19	0.79	7.54*	2.44	1.01	0.21
RD 950	12.86	1.63	0.12	37.43	*0.75	0.77	79.24	0.69	3.88	41.24	1.15	8.49*	133.67	0.81	13.53**	2.47	0.93	–0.02
PBW 343	12.14	1.08	0.18	36.10	0.91	10.92**	77.43	0.63	8.76	43.05	1.33	7.44*	135.67	1.75	4.81*	2.95	0.96	0.17
HD 2934	11.71	1.34	–0.03	43.24	0.52*	5.47*	79.67	1.40	3.68	44.81	1.17	6.10*	137.86	0.97	16.19**	2.62	1.13	0.12
WR 1508	12.33	0.82	0.01	41.38	1.52	1.07	82.26	1.05	7.60*	40.52	0.76	24.25**	135.38	0.05*	50.45**	2.56	0.86	0.04
Population mean	12.67			42.01			80.05			43.85			136.29			2.63		
SEbi±	0.19			0.16			0.90			0.26			0.25			0.19		
SEm±	0.16			0.16			0.48			0.13			0.16			0.15		

the three parameters used for studying the stability performance of the genotypes. Genotype x environment interaction has important effect on quality parameters. Therefore, efforts to understand GE interaction need to be included in the breeding programmes. The responses of the cultivars to the production environments need to be well characterized. A thorough understanding of the variations among cultivars in their response to environment would further improve the probability of predicting and identifying cultivars with superior quality attributes. Industrial grain quality could be substantially improved through integration of knowledge of geographic cultivar distribution with key environmental variables that relate to end use quality. Also suitable selection strategies to accommodate the significant G × E interactions need to be developed.

Correlation between traits depends upon genetic and environmental factors. Pleiotropic gene effects and gene linkages are the main reasons for the existence of genetic correlations between traits. When several traits are involved in evaluation of quality, it is desirable to determine correlations among these traits. In the present investigation, 15 possible pairs of traits were examined for interrelationships. The correlations among the various traits are presented in the Table 4. Significant high positive correlations were observed between sedimentation value and protein content, hectoliter weight and thousand kernel weight, grain density and thousand kernel weight, grain density and hectoliter weight, yield per plot and hectoliter weight, yield per plot and thousand kernel weight which is in agreement with most of the studies. The high positive correlation between sedimentation value and grain protein content is also in close agreement with that reported by Gaile and Kopmanis [14].

The results obtained on heritability (broad sense), genetic advance, phenotypic and genotypic coefficients of variation, have been presented in Table 3. High heritability (broad sense) was observed for all the six traits under consideration with a moderate genetic advance and moderate to high genotypic and phenotypic

Table 3. Estimation of selection parameters for different quantitative traits in wheat

Quality characters	Heritability	Genetic advance (K=2.06)	GCV (%)	PCV (%)
Protein content	78.1	2.19	9.91	11.21
Sedimentation value	94.5	13.15	15.62	16.07
Hectoliter weight	85.5	5.64	3.70	4.00
1000 kernel weight	95.6	11.78	13.34	13.64
Grain density	98.1	14.73	5.30	5.35
Yield per plot	82.5	1.57	31.81	35.03

Table 4. Phenotypic and genotypic correlation coefficients between different quality traits and grain yield

Quality characters	Protein content	Sedimentation value	Hectoliter weight	1000 kernel weight	Grain density	Yield per plot
Protein content	**1.000**	0.482**(0.473**)	–0.031(-0.038)	–0.346*(-0.312*)	–0.043(-0.045)	0.250(0.232)
Sedimentation value		**1.000**	–0.187(-0.173)	–0.144(-0.132)	–0.048(-0.045)	0.136(0.124)
Hectoliter weight			**1.000**	0.403**(0.367**)	0.253*(0.230*)	0.388*(0.317*)
1000 kernel weight				**1.000**	0.568**(0.552**)	0.490**(0.444**)
Grain density					**1.000**	0.603**(0.547**)
Yield per plot						**1.000**

*,** Significant at 5% and 1% level of probability; Figure in parenthesis is phenotypic correlation

coefficient of variation. This finding suggests that quality parameters could be greatly enhanced through genetic improvement for the targeted well characterized production environments.

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