Journal of Environmental Biology
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July 2010, 31, 489-495 (2010)
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Stability of some quality traits in bread wheat (*Triticum aestivum*) genotypes

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(Received: November 11, 2008; Revised received: March 27, 2009; Accepted: April 30, 2009)

Abstract: *This study was carried out in order to determine some quality traits such as thousand grain weight (TGW), hectoliter weight (HW), grain protein content (GPC), Zeleny sedimentation volume (ZSV) and stability of quality traits of 25 bread wheat genotypes. The experiment was conducted at seven environmental conditions during 2 growing periods (2003-2004 and 2004-2005) using randomized complete block design with four replicates. The ANOVA showed that out of the total sum of squares, 48.4, 28.0 and 23.6% for TGW, 71.4, 14.9 and 13.7% for HW, 54.4, 23.0 and 22.6% for GPC, 44.7, 41.7 and 13.6% for ZSV was attributable to E, G and G x E interaction effects, respectively. Thousand grain weight, hectoliter weight, grain protein content and Zeleny sedimentasyon volume of genotypes changed from 34.5 to 41.4 g, from 76.5 to 80.4 Kg, from 11.49 to 13.37% and from 22.1 to 46.0 ml, respectively. Seven stability parameters, covering a wide range of statistical approaches, were used so as to predict the genotypes. The study of genotypic stability showed that Bezostaya and advanced lines numbered 11 and 24 had high stability for quality traits and proved to be the best within the pool of the studied genotypes. Also, 8 and 17 numbered genotypes demonstrated high stability for TGW, HW, GPC and HW, GPC and ZSV, respectively.*

Key words: *Genotype x environment interaction, Stability, Bread wheat, Quality traits*
PDF of full length paper is available online

Introduction

It's known that genotypes, environments and their interaction (G x E) have influence on the quality traits of wheat grain. Wheat quality is affected by environmental conditions such as temperature in the growing season, humidity during grain fill, duration of grain fill, fertilization, amount and distribution of precipitation, sowing time and rate (Blumenthal *et al.,* 1993; Salinger *et al.,* 1995; Anderson *et al.,* 1998; Peterson *et al.,* 1998; Smith and Gooding, 1999; Stone and Savin, 1999; Grausgruber *et al.,* 2000; Monaghan *et al.,* 2001; Evrendik *et al.,* 2008). Stability of quality characteristics is becoming an important need for the milling industries.

Thousand grain weight and test weight traits, which can be used to determine potential flour yield in wheat grain, are accepted as main quality factors by the milling industry (Unver and Kinacl, 1980; Schuler *et al.,* 1995). Grain protein content and Zeleny sedimentation value also are the most important indirect quality characteristics used in early generation selection of quality wheat (Atli, 1999; Grausgruber *et al.,* 2000). Zanetti *et al.* (2001) investigated the genetic analysis of bread-making quality of wheat and they used Zeleny sedimentation value, protein content and thousand grain weight as important quality traits.

For breeders, stability of quality attributes is important in terms of changing ranks of genotypes across environments and affects selection efficiency (Rharrabti *et al.,* 2003a; Korkut *et al.,* 2007). For end users, such as millers and bakers, consistency in quality performance of genotypes is very important, regardless of changing genotype ranks (Korkut *et al.,* 2007). As stated by Grausgruber *et al.* (2000), the quality of a genotype usually reacts like other quantitative characters to varying environmental conditions. A genotype is therefore considered to be economically stable if its contribution to the genotype x environment interaction (GEI) is low (Rharrabti *et al.,* 2003a). Stability of raw material quality is a desirable feature, since it guarantees consistent procedures and reduces product loss during processing (Grausgruber *et al.,* 2000). Moreover, stability of quality characters is also important in increasing variety selection efficiency for breeders in breeding programmes (Korkut *et al.,* 2007).

Several stability measures including univariate and multivariate ones have been developed to assess the stability and adaptability of varieties. The most widely used is the joint regression including regression coefficient (b_i) (Finlay and Wilkinson, 1963) and variance of deviations from regression (S^2_{di}) (Eberhart and Russell, 1966). Some other univariate stability parameters are the environmental variance (S^2_{xi}) (Lin *et al.,* 1986; Becker and Leon, 1988), the Shukla stability variance (s_i^2) (Shukla, 1972) and Wricke's ecovalence (W_i^2) (Wricke, 1962). More recently, Purchase *et al.* (2000) developed the AMMI (The additive main effects and multiplicative interaction) Stability Value (ASV) based on the AMMI model's IPCA1 and IPCA2 (Interaction Principle Components axes 1 and 2, respectively) scores for each genotype. ASV is in effect the distance from the coordinate point to the origin in a two-dimensional scattergram of IPCA1 scores against IPCA2 scores. This statistical method can be used to evaluate stability after reduction of

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noise from the GEI effects. Non-parametric procedures proposed by Nassar and Huehn (1987) and Huehn (1990), Kang (1988) and Fox *et al.* (1990) are based on the ranks of genotypes in each environment, and the genotypes with similar ranking across environments are classified as stable. Non-parametric methods have some advantages over parametric stability methods.

Haile *et al*. (2007) indicated that it is critical to improve adaptable and stable genotypes with good processing quality to carry out the current aim of the government. Stable performance is a desirable attribute of genotypes, for countries such as Turkey, where environmental variations are very high and unpredictable. Thus, in this investigation, 25 bread wheat genotypes were used to evaluate their stability for thousand grain weight, hectoliter weight, grain protein content and Zeleny sedimentation volume across different environments and growing seasons by using seven stability parameters.

Materials and Methods

Plant material and environment: Twenty-five bread wheat (5 Turkish commercial varieties and 20 advanced lines from the bread wheat breeding programme of CIMMYT-ICARDA) (Table 1) were grown under rainfed conditions during the growing season of 2003–2004 in four environmental sites Samsun (E1), Amasya (E2), Amasya-Suluova (E3) and Tokat (E4) and during the growing season of 2004-2005 in three environmental sites [Samsun (E5), Amasya (E6) and Tokat (E7)] in the Central Black Sea Region of Turkey. Table 2 shows the detailed description of environmental sites. All experiments across the years were arranged in accordance with randomized complete-block design with four replicates. The experimental plots consisted of six rows of 6 m length and 20 cm row space. Seeding rate was 550 seeds m^{-2} for each location. All trial plots in E1, E4, E5 and E7 sites were fertilized with 60 kg N ha^{-1} and 60 kg P_2O_5 during sowing and 60 kg N ha^{-1} was applied at the beginning of stem elongation stage. Plots in the sites of E2, E3 and E6 were fertilized with 40 kg N ha^{-1} and 60 kg P_2O_5 at planting and 60 kg N ha^{-1} was applied at the beginning of stem elongation stage.

Quality traits: Data were recorded for thousand grain weight (TGW), hectoliter weight (HW), grain protein content (GPC) and Zeleny sedimentation volume (ZSV). All of the tests on the samples were performed in twice samples taken at harvest from each plot using standard procedures and the average values reported. The hectoliter weight was determined by using an Ohaus test weight apparatus and reported on an "as is" moisture basis. The thousand kernel weight was determined by counting the number of seeds in 20 grams of grain and reported on a dry basis. Samples of raw wheat were ground in a laboratory mill (Falling Number, Type-KT 30). Nitrogen percent was determined to AACC Approved Methods (Anonymous, 1995). The total N% was converted into grain protein content by the formula: protein content (%) (PC)= N (%) x 5.7. Zeleny sedimentation volume (ZSV) was determined to ICC standard method (ICC, 2002).

Statistical analysis: Combined analysis of variance on quality traits data from trials in seven environments was computed according to the method given by Comstock and Moll (1963). Seven stability parameters were applied to assess stability performance of genotypes and to identify superior genotypes; bi, the linear regression of the phenotypic values on environmental index (Finlay and Wilkinson, 1963), S^2_d, the deviation mean square from regression (Eberhart and Russell, 1966), the stability variance d^2_i (Shukla, 1972), W_i, the ecovalance stability index (Wricke, 1964), $S_i^{(1)}$ (statistic measures the mean absolute rank difference of a genotype over environments) and $S_i^{(2)}$ (the variance among the ranks over environments), two non-parametric stability statistics based on corrected x_{ij}-values (Nassar and Huehn, 1987) and ASV, AMMI Stability Value (Purchase *et al.,* 2000). The ASV is the distance from the coordinate point to the origin in a two-dimensional scatter gram of the first principal axis scores (IPCA1) against the second principal axis scores (IPCA2) in the AMMI model (Purchase *et al.,* 2000). The genotypes with the lowest ASV values are considered the most stable.

All analysis were performed using the statistical package Genstat Release 7.1 (Genstat 7 Committee, 2004) for AMMI's ANOVA and SAS release 6.12 (SAS Institute, 1996) for stability statistics.

To predict stability, a genotype was considered stable for a given quality parameter if it appeared stable in more than four (out of seven) stability analysis. Genotypes that proved to be stable for most stability analysis were then selected as the best.

Results and Discussion

The combined analysis of variance for thousand grain weight, hectoliter weight, grain protein content and Zeleny sedimentation volume across environments is given in Table 3. The difference between environments and genotypes and all interactions for all of the traits investigated were statistically significant ($p<0.01$). The ANOVA also showed that out of the total sum of squares, 48.4, 28.0 and 23.6% for TGW, 71.4, 14.9 and 13.7% for HW, 54.4, 23.0 and 22.6% for GPC, 44.7, 41.7 and 13.6 % for ZSV was attributable to E, G and G x E interaction effects, respectively (Table 3). The environmental variance components were much larger than genotypic variance components for all of the traits investigated.

Quality parameters of tested wheat genotypes grown in seven environments are presented in Table 2. Wheat samples from the environment E6 are characterized by good milling quality as indicated by high hectoliter weight (82.2 kg), high protein content (13.80%), high Zeleny sedimentation value (46.6 ml) and medium thousand grain weight (34.9 g). Samples from the environment E1 are characterized by very poor quality traits in comparison with other environments (Table 2). The highest thousand grain weights were obtained from genotypes 5, 12, 20 and 25, and the lowest thousand grain weights were obtained from genotypes 14, 1, 10 and 23. However, the highest hectoliter weights were obtained from genotypes 18, 17, 5 and 9 genotypes, and the lowest hectoliter weights genotypes 23, 13, 6 and 22. Additionally, the highest grain protein content were obtained from genotypes 5, 15, 12 and 3, and the lowest grain protein content genotypes 1, 11, 2 and 9, respectively. Furthermore, the highest Zeleny sedimentation volume was obtained from genotypes 13, 5, 7 and 3, and the lowest Zeleny sedimentation volume genotypes 2, 1, 22 and 21, respectively.

Table - 1: Code genotype / pedigrees of 25 bread wheat studied in seven environments

Code	Genotype/pedigree
G1	TX62A4793-7/CB809//VEE/3/VEE"S"/LIRA"S
G2	MG.5262/4/HYS/NO//LV11.F1/3/F1.KVZ/HYS/5/VEE"S"/GH"S"
G3	ERYT1554.90(DONSKAYA POLUINTENSIVNAYA/OD83)
G4	ERYT1554.90(DONSKAYA POLUINTENSIVNAYA/OD83)
G5	BEZOSTAYA
G6	MIRONOVSKAYA OSTISTAYA(AWNED)
G7	VONA//KS75210/TAM101
G8	PLV/OD-51//COLT/CODY KS831936-3/NE86501
G9	JUP/4/CLLF/3/II14.53/ODIN//CI13431/WA00477
G10	KATE A-1
G11	407-1-7
G12	TIX53/89-2
G13	ERYT484.89
G14	RIO BLANCO/BAI QUAN#3039
G15	PANDAS
G16	UNKNOWN96.27
G17	8023.16.1.1/KAUZ
G18	PI/MZ//CN067/3/LFN/4/ANT/5/ATTILA
G19	SPN/NAC//ATTILA
G20	SAKIN 2002
G21	VORONA/KAUZ//1D13.1/MLT
G22	CARSTEN/GIGANT//FUND133
G23	DACHNAYA/ATTILA
G24	NA160/HN7//BUC/3/FALKE
G25	CANIK 2003

Regression analysis was unable to explain the GEI pattern. Therefore, other stability parameters and statistics were used in order to consolidate the results from regression analysis. However, AMMI model appeared to be able to extract a large part of the interaction and is thus more efficient in analyzing GEI pattern. AMMI analysis (Table 3) revealed the significance of five principal component analysis (PCA) for grain protein content and Zeleny sedimentation volume. However, four PCA were significant for thousand grain weight and hectoliter weight. The first two PC axes cumulatively accounted for more than 61% of the total G x E interaction, where the residual was not significant and of small magnitude. These results demonstrated the efficiency of the AMMI analysis, which extracted a large part of the G x E interaction.

The seven statistical stability parameters were used in our study to predict genotypic stability. Calculated stability parameters for thousand grain weight, hectoliter weight, grain protein content and Zeleny sedimentation volume are presented in Table 4 and 5. Bezostaya (genotype 5), 11 and 24 numbered genotypes can be regarded as the stable quality genotypes, demonstrating high stability for all of quality parameters. Further, Bezostaya shows not only stability but also a high level of performance. 8 and 17 numbered genotypes demonstrated high stability for TGW, HW, GPC and HW, GPC and ZSV, respectively. 15, 22 and 25 numbered genotypes were only stable for GPC and ZSV while 19 and 20 numbered genotypes were stable for TGW and ZSV. However, 14 numbered genotype shows high stability for HW and ZSV. Some genotypes were stable for only one trait (Table 4 and 5).

The genotype 24, which is among the stable genotypes for all quality parameters, was also the highest grain yield across

Table - 2: Agro-climatic characteristics of testing environments

Environment (Growing season)	Soil pH and type	Fertilization ($kg\ ha^{-1}$) Nitrogen	Phosphorus	Altitude (m)	Rain-fall (mm)	TGW (g)	HW (Kg)	GPC (%)	ZSV (ml)
Samsun/E1 (2003-2004)	pH=7.20 clayey	60[a] 60[b]	60[a]	7	829.0	32.4	65.2	10.00	22.1
Amasya/E2 (2003-2004)	pH=7.10 clayey loam	40 60	60	449	379.0	34.9	79.9	12.80	35.3
Suluova/E3 (2003-2004)	pH=7.65 clayey loam	40 60	60	490	477.3	38.9	78.0	12.80	35.5
Tokat/E4 (2003-2004)	pH=7.85 clayey loam	60 60	60	623	421.9	39.7	81.6	12.83	34.5
Samsun/E5 (2004-2005)	pH=7.30 clayey	60 60	60	7	745.1	41.1	80.9	11.40	31.0
Amasya/E6 (2004-2005)	pH=7.45 clayey loam	40 60	60	449	506.1	33.9	82.2	13.80	46.0
Tokat/E7 (2004-2005)	pH=7.92 clayey loam	60 60	60	623	508.9	41.7	80.2	12.90	37.0

[a] = Seed-bed, [b] = Stem elongation, TGW = Thousand grain weight, HW = Hectoliter weight, GPC = Grain protein content and ZSV = Zeleny sedimentation volume

Table - 3: Combined analysis of variance and AMMI analysis for selected quality of 25 bread wheat tested across seven environments

		TGW		HW		GPC		ZSV	
Source	**d.f.**	**MS**	**% of total**	**MS**	**% of total**	**MS**	**% of total**	**MS**	**% of total**
Environments	6	1057.8**	48.4	2690.2**	71.4	107.1**	54.4	5113.7**	44.7
Reps (E)	21	26.5**		10.4**		0.1		1.73	
Genotypes (G)	24	154.0**	28.0	131.4**	14.9	11.2**	23.0	1131.6**	41.7
G × E	144	21.5**	23.6	21.4**	13.7	1.9**	22.6	50.4**	13.6
Error 504	3.5		1.4		0.1		1.10		
CV%	4.96		2.80		2.09		3.04		
Interactions	144	14.56**	% ofG x E	4.08**	% of G x E	0.82**	% ofG x E	45.38**	% of GxE
IPCA 1	29	38.43**	53.14	7.03**	40.36	1.50**	34.56	99.86**	59.11
IPCA 2	27	14.03**	18.06	4.04**	21.62	1.17**	26.80	45.67**	17.00
IPCA 3	25	11.70**	13.95	3.30**	16.33	0.77**	16.43	25.35**	7.70
IPCA 4	23	6.81*	7.46	2.86*	13.03	0.62**	12.09	20.86**	6.00
IPCA 5	21	5.76	5.77	1.20	5.00	0.51**	9.11	19.06**	5.52
Residual	19	1.79		0.97		0.27		2.35	
Error	504	3.46		1.39		0.05		1.10	

** = Significant at the 0.01 probability level, Where MS = Mean squares, TGW = Thousand grain weight, HW = Hectoliter weight, GPC = Grain protein content and ZSV = Zeleny sedimentation volume, GxE = Genotype x environment interaction, CV = Coefficient of variation

Table - 4: Mean thousand grain weight, hectoliter weight and stability parameters of bread wheat genotypes tested over seven environments

	Thousand grain weight (TGW)								Hectoliter weight (HW)							
G	**m (g)**	**b_i**	**S^2_{di}**	**d^2_i**	**W_i**	**$S_i^{(1)}$**	**$S_i^{(2)}$**	**ASV**	**m (kg)**	**b_i**	**S^2_{di}**	**d^2_i**	**W_i**	**$S_i^{(1)}$**	**$S_i^{(2)}$**	**ASV**
1	34.9 (-)	0.740**	3.53*	4.07	23.33	11.05	82.57	2.962	77.4 (-)	1.031**	0.64	0.61	3.40	5.85	57.24	1.233
2	37.5 (-)	0.980	4.91*	4.30	24.59	8.76	55.95	2.059	77.3 (-)	1.007	0.53	0.43	2.71	0.10	46.15	1.730
3	36.1 (-)	1.146**	16.70**	15.29	85.28	13.14	142.95	3.230	78.9 (+)	0.931**	0.18	0.32	1.91	5.73	48.95	0.584
4	37.8 (-)	1.110**	3.53*	3.22	18.65	9.71	64.57	3.098	78.0 (-)	1.029**	0.32	0.34	1.82	0.15	56.57	0.927
5	41.4 (+)	1.002	1.26	0.98	6.28	5.33	20.33	0.710	79.9 (+)	1.067**	0.06	0.20	1.30	6.09	37.47	0.270
6	39.3 (-)	1.097**	4.20*	3.79	21.78	9.80	67.14	0.719	76.8 (-)	0.969**	2.67**	2.40	13.50	0.20	104.20	0.253
7	36.5 (-)	1.067	2.26	1.96	11.69	7.62	41.08	2.073	77.1 (-)	0.931**	1.74**	1.72	9.71	6.95	83.80	0.242
8	36.8 (+)	0.992	0.36	0.17	1.81	4.86	16.28	1.121	77.7 (-)	1.011	0.41	0.34	2.10	0.09	29.90	0.728
9	37.6 (-)	1.240**	3.80*	4.16	23.84	9.71	68.57	0.271	77.1 (-)	0.913**	0.50	0.72	4.12	5.33	63.95	0.128
10	34.9 (-)	0.814**	10.37**	9.76	54.74	12.09	110.39	0.982	77.8 (-)	1.055**	0.73*	0.72	4.30	0.20	110.30	0.681
11	37.0 (+)	1.259**	1.60	2.31	13.63	7.80	41.33	0.752	79.0 (+)	1.006	0.47	0.40	2.32	8.67	29.04	0.666
12	41.2 (-)	1.077*	10.16**	9.14	51.32	12.38	117.62	1.505	77.5 (-)	1.045**	2.40**	2.21	12.41	0.17	71.29	0.149
13	35.6 (-)	1.194**	1.29	1.58	9.62	7.81	41.54	1.220	76.7 (+)	1.005	0.44	0.41	2.22	7.95	39.06	0.837
14	34.5 (-)	0.878**	4.12**	3.80	21.85	8.00	44.90	1.565	78.1 (+)	1.001	0.52	0.42	2.60	0.08	28.00	0.941
15	37.9 (-)	0.900**	8.53**	7.60	42.82	11.71	94.62	1.131	77.3 (-)	1.059**	1.74**	1.70	9.40	4.47	106.70	0.645
16	39.3 (-)	0.953	3.54*	3.08	17.87	8.57	51.82	0.646	77.6 (-)	0.970**	1.35**	1.20	6.90	0.18	67.33	0.246
17	38.3 (-)	0.823**	0.66	0.92	5.94	7.90	43.14	1.844	80.1 (+)	0.989	0.18	0.18	0.93	7.33	15.62	0.175
18	36.9 (+)	0.954	1.15	1.04	6.59	4.76	18.48	0.977	80.4 (-)	0.981	2.12**	1.90	10.70	0.35	80.48	0.879
19	38.9 (+)	0.862**	1.25	1.26	7.86	8.28	45.82	0.737	78.4 (+)	0.960**	0.62	0.60	3.40	9.05	39.14	1.803
20	40.8 (+)	0.997	0.92	0.67	4.60	8.38	47.81	1.045	77.6 (-)	1.077**	2.03**	2.01	11.40	0.30	93.57	0.434
21	37.0 (+)	1.023	2.62*	2.22	13.12	9.47	66.06	0.961	78.3 (+)	0.992	1.13*	0.20	0.70	3.07	9.06	0.748
22	35.1 (-)	0.895**	1.61	1.47	8.99	6.86	32.81	1.530	76.8 (-)	0.989	0.68*	0.60	3.40	0.21	50.62	0.656
23	35.0 (-)	0.790**	4.19*	4.31	24.66	10.29	73.48	0.249	76.5 (-)	0.993	0.97*	0.80	4.81	7.19	92.00	1.144
24	38.1 (+)	0.824**	0.42	0.70	4.74	6.67	32.23	0.262	78.6 (+)	1.004	0.42	0.32	2.12	0.06	59.81	0.154
25	39.4 (-)	1.385**	1.79	3.71	21.34	10.00	74.14	0.557	78.0 (-)	0.983	0.86*	0.81	4.41	4.69	50.48	2.329

*,** Significant at p<0.05, and 0.01 respectively; where, G – genotypes, m - mean value, b_i – regression slope, S^2_{di} – deviation from regression, d^2_i – stability variance, W_i^2 - ecovalance stability index, $S_i^{(1)}$ and $S_i^{(2)}$ two non-parametric stability statistics, ASV - AMMI stability value, (+) – stable for more than four stability parameters, (-) – non-stable for less than four stability parameters

environments (data not shown). While the 12 genotypes have the highest quality traits, excepting HW, it was unstable for all of quality parameters. Thus, this genotype was high sensitive to change of environment.

Regression technique (Finlay and Wilkinson, 1963) confuses interaction and main effects (Wright, 1971) and is unable to predict non-linear genotypic response to the environments (Nachit *et al.,* 1992). However, AMMI model appeared to be able to extract

Table - 5: Mean grain protein content (GPC), Zeleny sedimentation volume (ZSV) and stability parameters of bread wheat genotypes tested over seven environments

	Grain protein content (GPC)								Zeleny sedimentation volume (ZSV)							
G	m (%)	b_i	S^2_{di}	d^2_i	W_i	$S_i^{(1)}$	$S_i^{(2)}$	ASV	m (ml)	b_i	S^2_{di}	d^2_i	W_i	$S_i^{(1)}$	$S_i^{(2)}$	ASV
1	11.49 (-)	0.894**	0.25**	0.22	1.24	10.38	73.57	0.535	24.0 (-)	0.485**	12.96**	25.94	146.21	9.47	65.37	3.968
2	11.90 (-)	0.923**	0.23**	0.21	1.22	6.95	39.65	0.449	22.1 (-)	0.517**	14.75**	25.77	145.25	11.04	88.14	3.399
3	12.85 (-)	0.821**	0.28**	0.30	1.72	10.29	74.29	0.781	40.8 (-)	1.282**	24.11**	25.72	144.97	11.52	93.95	1.784
4	12.18 (-)	0.933*	0.58**	0.52	2.93	11.24	101.95	0.214	38.8 (+)	1.210**	3.45	5.03	30.81	5.33	21.12	1.968
5	13.37 (+)	0.994	0.07	0.07	0.44	7.81	41.62	0.088	45.9 (+)	0.999	4.93	5.54	33.61	6.67	30.33	0.542
6	12.09 (+)	1.182**	0.07	0.11	0.66	7.76	41.75	0.599	39.5 (-)	1.462**	8.21*	18.77	106.65	11.43	96.24	3.320
7	12.32 (-)	0.951	0.19**	0.16	0.95	9.81	65.14	0.183	42.4 (-)	1.475**	5.50	16.98	96.76	9.52	61.24	2.282
8	12.24 (+)	1.031	0.11	0.09	0.56	7.52	42.57	0.557	38.2 (-)	1.346**	9.21*	14.47	82.88	10.00	70.81	2.724
9	11.91 (+)	1.057*	0.11	0.10	0.59	8.57	51.95	0.501	28.8 (-)	1.204**	13.90**	14.37	82.32	9.52	62.29	1.212
10	12.15 (-)	1.189**	0.07	0.12	0.70	9.04	62.95	0.603	34.8 (-)	1.502**	4.46	17.52	99.73	10.67	91.14	3.081
11	12.95 (+)	1.138**	0.11	0.13	0.75	8.28	49.95	0.175	37.4 (+)	1.423**	1.84	11.07	64.11	8.38	47.14	2.233
12	11.76 (-)	0.885**	0.24**	0.23	1.31	9.71	65.24	0.196	34.3 (-)	0.629**	6.85*	13.31	76.49	10.09	71.33	2.613
13	12.43 (-)	0.907**	0.23**	0.22	1.23	10.66	76.48	0.498	46.0 (-)	1.373**	2.61	9.57	55.84	8.67	53.99	2.194
14	12.61 (-)	1.077**	0.80**	0.72	4.03	12.19	110.00	0.305	37.8 (+)	1.055	1.74	1.20	9.63	3.90	10.90	1.666
15	12.96 (+)	1.027	0.16	0.14	0.81	7.90	43.95	0.560	38.9 (+)	1.063	2.83	2.23	15.33	6.95	33.29	0.522
16	12.19 (-)	0.902**	0.46**	0.42	2.37	9.23	59.24	0.209	30.6 (-)	1.302**	7.79*	11.56	66.83	8.95	55.48	1.989
17	12.75 (+)	0.873**	0.12	0.13	0.75	9.80	66.48	0.152	34.7 (+)	0.654**	4.57	10.27	59.70	8.28	47.57	2.244
18	12.47 (-)	0.800**	0.10	0.15	0.87	9.80	67.57	0.563	32.3 (-)	0.397**	9.31*	28.12	158.22	12.57	112.57	3.569
19	12.79 (-)	1.030	0.43**	0.39	2.17	12.09	101.57	1.112	35.7 (+)	1.227**	6.72	6.77	40.41	8.38	47.45	1.652
20	12.18 (-)	1.158**	0.18*	0.19	1.11	8.48	51.90	0.887	29.0 (+)	0.974	8.06*	6.79	40.49	8.05	48.56	0.269
21	12.57 (-)	0.837**	0.12	0.15	0.86	6.57	29.62	0.327	28.6 (-)	0.574**	4.98	14.06	80.61	9.67	64.56	2.440
22	12.14 (+)	1.196**	0.08	0.13	0.78	9.52	65.67	0.261	24.9 (+)	0.701**	0.81	5.15	31.46	6.57	29.95	1.518
23	12.25 (+)	1.134**	0.08	0.10	0.58	5.24	30.91	0.257	30.8 (-)	0.718**	6.55	9.80	57.12	9.71	60.06	1.892
24	12.25 (+)	0.990	0.05	0.04	0.24	6.19	28.24	0.453	37.0 (+)	0.686**	3.19	7.83	46.22	8.00	49.49	1.903
25	12.27 (+)	1.069**	0.12	0.11	0.64	8.76	54.95	0.102	30.8 (+)	0.743**	4.41	7.13	42.40	9.24	59.57	1.608

*,**Significant at $p<0.05$, and 0.01 respectively; where, G = Genotypes, m = mean value, b_i = regression slope, S^2_{di} = deviation from regression, d^2_i = Shukla stability variance, W_i = ecovalance stability index, $S_i^{(1)}$ and $S_i^{(2)}$ two non-parametric stability statistics, ASV = AMMI stability value, (+) = Stable for more than four stability parameters, (-) = Non-stable for less than four stability parameters

a large part of the interaction and is thus more efficient in analysing GEI pattern, as demonstrated by Zobel *et al.* (1988). For all the traits investigated in this study, the component of variation due to environment was larger than the component of variation due to genotype and G x E interaction. These results are consistent with the results of previous studies (Baenziger *et al.,* 1985; Bassett *et al.,* 1989; Lukow and McVetty, 1991; Peterson *et al.,* 1992 and 1998; Robert and Denis, 1996; Robert, 2002; Rharrabti *et al.,* 2003a). Further, Grausgruber *et al.* (2000) reported that environmental effects were higher than genetic effect for PC and ZSV but smaller than for Farinogram and Extensogram traits. Altinbas *et al.* (2004) also reported that environmental effects were higher than genetic effect for sedimentation value and wet gluten content but smaller than for thousand grain weight. In addition, our results also are consistent with the results of Haile *et al.* (2007), who reported that protein content is more strongly influenced by environment. However, our results differ from other reports that protein content is more influenced by genotype (Yong *et al.,* 2004; Baric *et al.,* 2004).

Our results showed that thousand grain weights were affected by genotypes and environments (Table 3).The climatic conditions during grain filling period, cultivation practices and the status of nutrition elements effects thousand grain weight (Keser and Ekingen, 1994). But, it's known that thousand grain weight is a stable character least effected by environmental factors (Blue *et al.,* 1990). The hectoliter weight was also changed by both genotypes and environments (Table 2 and 4). Hectoliter weight, which effects flour yield in bread wheat, changes due to factors like genotype, environmental conditions, cultivation practices, lodging, diseases and pests (Atli, 1999).

Present work clearly showed that there are certain differences in grain protein content of genotypes among environments due to climatic conditions (Atli, 1999; Haile *et al.,* 2007). Grain protein contents are higher in low rainfall environments (Table 2, 5). As reported by many authors, moisture stress increases protein content in grain (Atli, 1999; Rharrabti *et al.,* 2003b; Haile *et al.,* 2007).

Zeleny sedimentation value depends more on the qualitative variation of storage proteins than on their quantity and is mainly affected by the genotypic and environmental effects (Grausgruber *et al.,* 2000). This statement confirms our results (Table 3). Moreover, it must be said that early generation selection of quality wheat is carried out almost entirely in an indirect manner, on the basis out of various technological criteria, *e.g.* protein content, Zeleny sedimentation (Grausgruber *et al.,* 2000).

Our results suggest that almost all quality traits measured changed substantially with environments (Table 2). Therefore, production of a cultivar conferring improved quality may require a growing environment that favors expression of this genetic potential, in order for this lead to the eventual production of high-quality grain.

The stability analysis showed high stability for Bezostaya (genotype 5), line 11 and line 24 with regard to all quality traits. Bezostaya, a Turkish commercial variety, showed high stable quality parameters and may still be of interested for growers in Turkey, although it has not high grain yield. From the advanced lines of the CIMMYT-ICARDA bread wheat breeding programme, line 11 and line 24 could be used successfully as progenitors in breeding programmes for the production of high grain quality bread wheat in the tested environments and similar ecology. Some variability measurement of stability within each genotype was observed in present study. Thus, some genotypes were stable for some traits and unstable for another, suggesting that the genetic factors involved in the G x E differed between traits (Grausgruber *et al.,* 2000; Rharrabti *et al.,* 2003a; Baric *et al.,* 2004).

The intensive lodging and disease epidemy occurred due to heavy rain effected all investigated quality characters negatively on significant level in environment (Table 2). Similar findings were published by Aydin *et al.* (2005). Several studies revealed significant reduction for yield, some yield components and quality traits in wheat due to waterlogging (Gardner and Flood, 1993; Musgrave and Ding, 1998; Olgun *et.al.,* 2008). Furthermore, winter wheat genotypes grown under Mediterranean conditions may be subjected to late drought especially during the grain-filling period (Calhoun *et al.,* 1994). Water deficit during the grain-filling period can adversely affect grain yield and quality traits such as 1000 grain weight and hectoliter weight (Genç *et al.,* 1987; Rharrabti *et al.,* 2003a). The cultivation of more unstable cultivars should be recommended only for specific regions where they can attain a high performance with regard to quality traits independent of seasonal effects.

Genotypes selected according to stability of quality in this study verified the possibility of combining both stable and high quality. However, breeders must be aware of the difficulties in selection. As reported by Grausgruber *et al.* (2000) and Rharrabti *et al.* (2003a), an integrated selection system designed to maximize the probability of producing stable quality wheat a high level of performance should be developed.

The important goal for breeders is to find genotypes with good and stable quality - not only to provide quality raw material for end users, but also to provide parents in the future breeding programmes. Breeding for separate sub-regions will definitely increase the cost. Therefore, a balance between selection gain and breeding cost must be made (Atlin *et al.,* 2000). Large GEI also complicates the design of an efficient field testing system. An efficient testing system is more important for quality traits than for other agronomic traits, because analysis of milling and baking quality attributes are more costly (Yong *et al.,* 2004). However, Robert and Dennis (1996) have pointed out that the breeder must keep in mind that the assessment of stability depends on the sets of genotypes and environments studied. In stability analysis, various statistics should be applied to characterize the genotypes for responsiveness to environments as much as possible and to be sure of the GEI effects.

Acknowledgment

We wish to thank Dr. F. Seyis for his technical assistance.

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