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Genotype x Environment Interaction and Phenotypic Stability Analysis for Grain Yield and several Quality Traits of Durum Wheat in the South-Eastern Anatolia Region

Hasan KILIÇ[1)], Tacettin YAĞBASANLAR[2)]

[1)] *Bingöl University, Faculty of Agriculture, Department of Field Crops, 12000, Bingöl, Turkey; hkilic@bingol.edu.tr*

[2)] *Çukurova University, Faculty of Agriculture, Department of Field Crops, Adana, Turkey; tacettin@mail.cu.edu.tr*

Abstract

The objectives of this study were to assess genotype x environment (GEI) interaction and to determine stability of 14 durum wheat (*Triticum turgidum* var. *durum* Desf.) cultivars for grain yield, test weight, thousand grain weight (TGW), vitreousness, protein content, ash content and SDS sedimentation volume. Cultivars tested in a randomized complete block design with four replications across 8 environments of South-Eastern Anatolia Region of Turkey, were analyzed using four parametric stability measures (b_i, S^2_{di}, R^2 and a). A high GEI was determined for all traits. According to the stability analysis, 'Balcali-2000', 'Firat-93' and 'Altintoprak-98' were the most stable for grain yield. These cultivars had high mean grain yield and were non significant regression coefficient different from unity (b_i = 1.0), coefficient of determination (R_i^2) as high as possible. Although some cultivars were stable for one quality trait and unstable for another, the study of genotypic stability showed that 'Balcali-2000' cultivar had high stability for quality characteristics and determined to be the best within the pool of the studied cultivars. Furthermore, the estimated values of broad-sense heritability (H^2) were found between 30.3% and 94.3%. H^2 was low for vitreousness (30.3%) and ash contents (36.0%) while found high for thousand grain weight (94.3%), SDS volume (83.0%) and protein contents (75.2%). Grain yield (62.6%) and test weight (54.6%) were as moderate.

Keywords: durum wheat, grain yield, heritability, quality traits and stability

Introduction

The significance of durum wheat has increased worldwide due to shortages of good quality material utilized in the food industry, and food shortages occurring in many developing countries (Karagöz and Zencirci, 2005). Durum wheat (*Triticum durum* L. Desf.) is an important and popular crop in the Mediterranean Basin and used for food products as couscous, bulgur, and pasta (Korkut *et al.*, 2007).

In Turkey, durum wheat occupies second place after bread wheat and is sown over an area of 1.1 million hectares, producing 4 million tons (Çetin and Budak, 1999). Durum wheat has been cultivated for many years and has a significant role in South-Eastern Anatolia. This region is known as primary gene center of wheat diversification as well as the area of first wheat domestication around 10.000 BP (Harlan, 1950; Diamond, 1997; Nesbit and Samuel, 1998; Lev-Yadun *et al.*, 2000; Karagöz and Zencirci, 2005). Mediterranean climate generally dominates this region with cool and rainy winters, dry and hot summers.

Cultivars to be considered at inconsistent and unpredictable climatic conditions should be evaluated in multilocation trials and proved by stability tests. Durum wheat varieties have shown narrower adaptation and yield fluctuations over varying environments (Saini and Gautam , 1990) compared with bread wheat. Therefore, breeding of high yield, good quality and stable varieties are very important. Moreover, stability of quality parameters is becoming an important requirement for the milling and pasta industries, because of potentially high annual variation in both grain yield and quality, particularly under Mediterranean conditions (Rharrabti *et al.*, 2003). Some authors claimed that quality parameters were a static concept of stability, meaning that a stable genotype is defined as one having an unchanged performance regardless of any variation in environmental conditions (Becker and Leon, 1988). Peterson *et al.* (1992) reported that the concept of optimal genotype stability and response for quality parameters differs somewhat from the conventionally used to define the yield stability. For breeders, stability of quality attributes is important in terms of changing ranks of genotypes across environment and affects environments and affects selection efficiency. For end-users, such as millers and bakers, consistency in quality characteristics of cultivars is very important regardless of changing varieties ranks (Letta *et al.*, 2008). Several statistical methods have been developed for stability analysis with a view of explaining the information comprised in the GEI data matrix. Between these methods, the most widely used are (b_i) the regression coefficient (Finlay and Wilkinson, 1963), (S^2_{di}) deviation from regression (Eberhart and Russel, 1966), (a) regression line intercept (Smith, 1982) and (R_i^2) coefficient of determination (Pinthus, 1973). The stability of varieties was defined

by high mean yield and regression coefficient (b_i = 1.0) and deviations from regression (S^2_{di} = 0) as small as possible (Akçura *et al.*, 2005). A number of stability studies have been carried out on different cereal crops as well as on durum wheat (Korkut *et al.*, 2007; Koç *et al.*, 2000; Rharrabti *et al.*, 2003; Ülker *et al.*, 2006; Letta *et al.*, 2008).

However, no stability and heritability study have been performed for commercial durum wheat cultivars as regard both yield and quality traits in the South-Eastern Anatolia region of Turkey. The objectives of this study were to evaluate the grain yield and some quality traits of promising durum wheat cultivars in different environments and to determinate their stabilities using stability parameters.

Materials and methods

Plant material and field conditions

TThe experiments were carried out in the 1999-2000 and 2000-2001 growing seasons in 4 different locations in South-Eastern Anatolia region: Diyarbakir rainfed conditions, Diyarbakir irrigation conditions, Akçakale and Ceylanpinar. Grain yield was recorded in six locations due to hail damage while quality traits were assessed in all eight locations. Fourteen durum wheat cultivars (13 cultivars and 1 landraces) were analyzed by a randomized complete block design with four replications for grain yield, test weight, (TGW) and vitreousness while protein content, ash content and SDS sedimentation volume were analyzed with 3 replications. The names of cultivars and pedigrees are given in Tab. 1.

The seeds were sown using an experimental drill in 1.2 m x 6 m plots consisting of 6 rows with a 20 cm row space. The seeding rates were about 450 seeds m^{-2}. Plots 1.2 m x 5 m size were harvested by a combined harvester. The yield was determined and expressed in ton per hectare (t ha^{-1}). All field conditions such as growing seasons, environments, soil properties, fertilization, amount of rainfall, sowing and emergency date at each location during the growing period are summarized in Tab. 2. Quality determinations consisted of the following parameters: Test weight, TGW, vitreousness and SDS volume were fixed or analyzed according to procedure described of Williams *et al.* (1986). Grain protein content and ash content were determined using the near infrared reflectance (NIR. 6500) method (Williams *et al.*, 1982; Delwiche *et al.*, 1998).

Tab. 1. Pedigrees and other information related to genotypes used in 8 environments

Code	Cultivars	Pedigrees
1	'Altintoprak-98'	Altar84 / AOS "S" – CD67124.1Y - 503M - OY
2	'Aydin-93'	OMRABİA "S"
3	'Ceylan-95'	Stk "S" / Rabi "S"
4	'Dicle-74'	Cocorit 71 = RA_E-TC^4 x stw63 // AA "S" D.27617 - 18M - 6Y - OM
5	'Diyarbakir-81'	LD.393 x Belle-Tc^2Cit71. SE:0.364 - 1S - 4S - OS
6	'D.5456'	(hybridization) 100 D X Semolina
7	'Ege-88'	JO/ AA // FG CM9799 - 126M - 1M - 4Y - 0M
8	'Firat-93'	AA "S" / Vol "S" // Fg "S" / 3 / Shwa "s" CM:2798-6 - 1M - 2Y - 1Y - OM
9	'Gidara-II'	Stj / Mrb3 ICD90 – 0179 – ABL - 0AP - 2AP - 0AP - 3AP – 0AP
10	'Özberk'	Fg"s" / Gr"s"//CandealI/4/Grebe/3/Ctfn/ Fg"s"//Ptl"s"/5/Akb.073.44/Yerli/6/Car"s"
11	'Harran-95'	Korifla (D.S.15 Gieger) = Korifla CD523 - 3Y - 1Y - 2M. OY
12	'Sariçanak-98'	Daki "S"
13	'Sorgül'	Landraces
14	'Balcali 2000'	MAGH72/FG *s *//CR "S"/USA2299/3/ YAV*S*/4/DACK/RABI*S*//WIN *S*

Statistical analysis

A combined analysis of variance was undertaken for the test environments. The four stability parameters were used in accordance with Eberhart and Russel's (1966) the regression coefficient (b_i) and deviation from regression (S^2_{di}), Pinthus's (1973) coefficients of determination (R_i^2) and Smith's (1982) regression line intercept (a). Broad sense heritability (H^2%) and variance components for grain yield and quality traits were computed as proposed by Demir and Turgut (1999); Sabanci (1992) and Akçura (2009). All statistical analyses were performed using the SAS (Statistical Analyses Systems) program (SAS Institute 1999).

Tab. 2. Site description and agronomic details

Code	Growing season	Environments	Soil properties	Fertilization kg ha^{-1}		Rain fall mm	Irrigation mm	Sowing date	Emergency date
				N	P_2O_5				
E1	1999 - 00	Diyarbakır^R	pH = 7.4 clay - silt	60^a + 60^b	60^a	245	-	01.11.99	16.01.2000
E2	1999 - 00	Diyarbakır^{Ir}	pH = 7.4 clay - silt	80 + 60	80	245	150	01.11.99	16.01.2000
E3	1999 - 00	Akçakale	Ph = 7.8 clay - silt	50 + 50	50	212	-	28.10.99	25.12.1999
E4	1999 - 00	Ceylanpınar	Ph = 7.8 clay- silt	50 + 50	50	156	-	11.11.99	14.12.1999
E5	2000 - 01	Diyarbakır^R	pH = 7.4 clay - silt	60 - 60	60	537	-	09.11.00	27.11.2000
E6	2000 - 01	Diyarbakır^{Ir}	pH = 7.4 clay - silt	80 + 60	80	537	100	09.11.00	27.11.2000
E7	2000 - 01	Akçakale	Ph = 7.8 clay - silt	50 + 50	50	319	-	27.11.00	16.12.2000

^{a} Seed-bed; ^{b} Stem elongation, ^{R}=Rainfed, ^{Ir}=Irrigation

Results and discussion

The analysis of variance of pooled data showed that grain yield, test weight, thousand kernel weight, vitreousness, SDS volume, protein and ash content were significantly affected by genotype, environment and the interaction of these factors (Tab. 3 and 4). The environmental effect on each trait was dominant, as demonstrated by the magnitude of the mean squares.

The four statistical parameters were used in this study to define genotypic stability. Means of yield, regression coefficient (b_i), deviations from regression (S^2_{di}), coefficient of determination (R_i^2) and regression line intercept (a) of each cultivar are given in Tab. 5.

To determine genotype stability, a genotype would be considered stable for grain yield and for any given quality parameter if it appeared to be stable as regard having high mean grain yield (X), a unit regression coefficient over the environment's (b_i = 1.00), a lower deviation from regression (S^2_{di}), maximum coefficient of determination (R_i^2) and having positive value of regression line intercept (a). The mean grain yield of the 14 durum wheat cultivars ranged from 2.40 t ha^{-1} to 3.42 t ha^{-1} and the highest grain yield was obtained from 'Sariçanak-98' and 'Gidara-II' (Tab. 5). Regression coefficient above 1.0 describes 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 for 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 0.703 to 1.122 for grain yield. This large variation in regression coefficients indicates different responses of genotypes to environmental changes (Tab. 5 and Tab. 6).

The regression coefficient of cultivars 'Firat-93', 'Balcali-2000' and 'Altintoprak-98' for grain yield were not significant (b_i = 1.0) and had higher yield values than the mean and their R_i^2 values were high as 96.1%, 98.9% and 98.7%, confirming their stability. Thus, these cultivars possessed good stability. Genotypes with high mean yield and a regression coefficient equal to the unity (b_i = 1) are considered stable (Finlay and Wilkinson, 1963). On the contrary, cultivars 'Gidara-II' and 'Sariçanak-98' had regression coefficients significantly greater than unity over the mean grain yield. Therefore, these genotypes are sensitive to environmental changes and can be recommended for cultivation under favorable conditions. 'Harran-95 'and Sorgül had significant regression coefficients, but they were less than unity (b_i = 1.0) and had low grain yields. These cultivars are, therefore, insensitive to environmental changes and have adaptation for poor environments.

According to results, 'Balcali-2000' demonstrated a high stability between genotypes for the TGW, protein content and SDS volume (Tab. 5 and Tab. 6). Also, 'Firat-93', 'Özberk' and 'Altintoprak-98' displayed stability for the two of quality parameters. SDS sedimentation volume is a commercial trait that is highly valued in the pasta industry. Therefore, 'Balcali-2000', 'Gidara-II', 'D-5456' and 'Altintoprak-98' cultivars that have been determined stable as regard SDS sedimentation should be evaluated for this aim. The other cultivars showed some variation in their degree of stability from one quality trait to another. 'Balcali-2000' showed higher stability both grain yield and quality. This cultivar not only looks to have a specific adaptation to

Tab. 3. Analysis of variance for stability parameter for 14 durum wheat genotypes

		Grain yield		Test weight		TGW		Vitreousness	
Source of variation	DF	SS	MS	DF	MS	SS	MS	SS	MS	SS
Genotype (G)	13	18.00	1.38**	13	387.08	29.78**	3653.99	281.08**	7813.81	601.06 **
Environments E + (G x E)	70	644.57	9.21**	98	1284.44	13.11**	12095.19	123.42**	43548.58	444.38**
E (linear)	1	624.79	624.79**	1	1023.57	1023.57**	11252.48	11252.48**	34213.91	34213.91**
G x E (linear)	13	16.50	1.27**	13	204.50	15.73**	663.16	51.01**	9031.19	694.76**
Pooled Deviations	56	3.27	0.06	84	56.37	0.67	179.54	2.14	303.80	3.62
Pooled Error	234	34.60	0.15	312	203.55	0.65	899.26	2.88	3161.45	10.13

* P < 0.05, ** P < 0.01

Tab. 4. Analysis of variance for stability parameter for 14 durum wheat genotypes

		SDS volume		Protein content		Ash content	
Source of variation	DF	SS	MS	SS	MS	SS	MS
Genotype (G)	13	4777.69	68.08 **	73.55	5.66**	1.824	0.140**
Environments E + (G x E)	98	16600.23	169.39 **	1961.50	20.01**	21.547	0.220**
E (linear)	1	15194.94	15194.94**	1893.46	1893.46**	20.411	20.411**
G x E (linear)	13	1154.73	88.83 **	54.20	4.17**	0.8901	0.068**
Pooled Deviations	84	250.56	2.98	13.84	0.16	0.24616	0.00293
Pooled Error	208	1122.77	5.40	84.56	0.41	2.02672	0.00974

** significant at P < 0.01

Tab. 5. Stability parameters for the considered grain yield and quality traits

	[a]$\overline{X}$	[b]b_i	[c]s^2_{di}	[d]R^2_i	[e]a	[a]$\overline{X}$	[b]b_i	[c]s^2_{di}	[d]R^2_i	[e]a
	Grain yield					Test weight				
1. 'Altintoprak-98'	***3.24***	***1.05***	***0.04***	***98.7***	-0.04	81.6	0.88	***0.18***	***0.93***	***9.88***
2. 'Aydin-93'	3.18	***0.99***	***0.02***	***99.1***	***0.08***	***82.7***	1.15	***0.32***	***0.93***	-11.53
3. 'Ceylan-95'	3.10	***1.00***	***0.06***	***97.8***	-0.17	***82.5***	***1.10***	0.73	***0.84***	-7.66
4. 'Dicle-74'	3.08	***0.98***	***0.05***	***98.1***	***0.02***	80.3	0.59	2.20	*0.32*	***32.49***
5. Dyb.-81	3.10	***0.98***	***0.06***	***97.8***	***0.04***	82.1	***1.11***	0.61	***0.84***	-8.25
6. 'D.5456'	2.94	***0.96***	***0.03***	***99.0***	-0.05	80.9	***0.97***	0.36	***0.89***	***1.53***
6. 'Ege-88'	3.19	1.10	***0.05***	***98.5***	-0.23	81.8	***0.98***	0.50	***0.85***	***2.11***
8. 'Firat-93'	***3.26***	***1.06***	0.12	***96.1***	-0.02	***82.3***	***0.99***	1.11	0.73	***1.07***
9. 'Özberk'	3.07	***0.99***	***0.01***	***99.6***	***0.00***	81.7	1.22	***0.18***	***0.96***	-18.00
10. 'Gidara-II'	***3.35***	1.12	0.13	***96.4***	-0.13	***82.3***	0.73	***0.32***	***0.84***	***22.47***
11. 'Harran-95'	2.99	0.90	**0.02**	***99.0***	***0.18***	80.6	***1.03***	***0.21***	***0.94***	-3.54
12. 'Sarıçanak-98'	***3.42***	1.14	***0.05***	***99.7***	-0.12	***82.9***	***0.91***	0.94	0.73	***8.39***
13. 'Sorgül'	2.40	0.70	***0.03***	88.3	***0.23***	79.8	1.35	0.96	***0.85***	-30.34
14. 'Balcali-2000'	***3.24***	***1.02***	0.13	***98.9***	***0.05***	82.1	***0.99***	0.79	0.790	***1.36***
Means	3.11	1.01				81.7	1.00			
	TGW					Vitreousness				
1. 'Altintoprak-98'	***42.0***	1.11	1.57	***0.96***	-4.29	89.53	***1.22***	***2.29***	***0.99***	-20.22
2. 'Aydin-93'	37.1	***0,95***	1.90	***0.96***	-2.17	***95.18***	0.42	***1.03***	***0.95***	***56.91***
3. 'Ceylan-95'	***41.7***	0.79	2.28	***0.90***	***8.69***	89.31	***1.09***	***0.81***	***0.99***	-8.90
4. 'Dicle-74'	***41.9***	0.90	***1.51***	***0.95***	***4.51***	80.40	2.04	8.91	***0.98***	-103.89
5. Dyb.-81	***42.5***	***1.05***	***0.54***	***0.99***	-1.21	85.94	1.49	***3.65***	***0.98***	-48.32
6. 'D.5456'	38.1	***0.97***	***1.52***	***0.95***	-2.30	88.09	1.30	***2.05***	***0.99***	-29.67
6. 'Ege-88'	41.5	1.27	2.04	***0.96***	-11.42	88.77	***1.11***	***2.15***	***0.98***	-11.78
8. 'Firat-93'	***48.0***	***0.90***	***1.48***	***0.95***	***10.47***	***94.40***	0.53	***3.22***	***0.90***	***46.72***
9. 'Özberk'	***44.9***	***1.06***	2.09	***0.95***	***0.81***	***92.21***	***0.71***	***1.37***	***0.97***	***28.31***
10. 'Gidara-II'	38.1	0.89	4.18	***0.87***	***0.96***	87.82	1.31	***1.76***	***0.99***	-30.05
11. 'Harran-95'	***42.9***	0.90	3.66	***0.88***	***5.59***	87.97	1.40	9.77	***0.96***	-30.61
12. 'Sariçanak-98'	38.8	***1.03***	2.17	***0.94***	***3.94***	***95.05***	0.41	6.94	0.71	***58.41***
13. 'Sorgül'	40.6	1.13	2.28	***0.95***	***6.45***	***93.14***	0.67	***1.52***	***0.97***	***32.46***
14. 'Balcali-2000'	***43.9***	***1.04***	***1.19***	***0.97***	***0.75***	***95.94***	0.30	***4.93***	0.65	***68.64***
Means	41.6	1.00				90.26	1.00			
	Protein content					Ash content				
1. 'Altintoprak-98'	***13.8***	***0.99***	***0.03***	***0.9 9***	***0.19***	1.46	***1.01***	***0.001***	***0.99***	***-0.04***
2. 'Aydin-93'	***14.1***	***0.92***	***0.12***	***0.98***	***1.64***	1.63	***1.09***	***0.002***	***0.97***	***-0.00***
3. 'Ceylan-95'	13.1	***1.02***	***0.11***	***0.99***	-0.48	***1.39***	0.75	***0.004***	***0.92***	0.26
4. 'Dicle-74'	12.7	***1.05***	***0.09***	***0.99***	-1.38	***1.40***	***1.01***	***0.003***	***0.97***	***-0.14***
5. Dyb.-81	12.9	1.15	***0.10***	***0.99***	-2.29	***1.42***	***0.93***	***0.002***	***0.97***	0.03
6. 'D.5456'	13.2	1.15	***0.12***	***0.99***	-2.24	1.50	***1.10***	***0.005***	***0.95***	***-0.13***
6. 'Ege-88'	13.0	1.05	***0.05***	***0.99***	-1.32	1.43	1.16	***0.002***	***0.98***	***-0.31***
8. 'Firat-93'	***14.1***	0.85	***0.10***	***0.98***	***2.67***	1.53	0.81	***0.005***	***0.91***	0.32
9. 'Özberk'	***13.9***	1.11	***0.21***	***0.98***	-1.01	1.56	1.18	***0.001***	***0.99***	***-0.20***
10. 'Gidara-II'	13.4	0.83	***0.21***	***0.96***	***2.19***	1.52	***0.89***	0.005	***0.93***	0.20
11. 'Harran-95'	13.3	***1.07***	***0.27***	***0.97***	-1.15	1.59	1.22	***0.003***	***0.98***	***-0.24***
12. 'Sariçanak-98'	13.3	0.74	***0.15***	***0.96***	***3.35***	***1.42***	0.83	***0.003***	***0.96***	0.18
13. 'Sorgül'	13.6	1.07	0.47	***0.95***	-0.83	1.53	***1.01***	***0.004***	***0.96***	0.03
14. 'Balcali-2000'	***14.4***	***1.02***	0.28	***0.96***	***0.67***	1.57	***0.99***	***0.002***	***0.98***	0.08
Means	13.5	1.00				1.50	1.000			

[a:] Values in italics and bolds are significantly higher than the mean at P<0.05. Cultivars with higher values than the mean are regarded as stables;[b] Values in italics and bolds are non significantly different from the unity at P<0.05. Cultivars with values in italics and bolds are considered as stables; [c] Values in italics and bolds are non-significantly different from 0 at P<0.05. Cultivars with values in italics are considered as stables; [d]: Values in italics and bolds are as high as possible. Cultivars which have high values are regarded as stables; [e:] Values in italics and bolds are positive. Cultivars which have positive values are regarded as desired except ash content

Tab. 5. Stability parameters for the considered grain yield and quality traits (Continuous)

SDS volume	[a]$\overline{X}$	[b]b_i	[c]s^2_{di}	[d]R^2_i	[e]a
1. 'Altintoprak-98'	***22.54***	***1.12***	***1.150***	***0.98***	***0.19***
2. 'Aydin-93'	21.04	1.36	***1.44***	***0.99***	-5.22
3. 'Ceylan-95'	16.56	0.89	5.56	***0.88***	***0.20***
4. 'Dicle-74'	***23.08***	0.85	***1.57***	***0.97***	***6.71***
5. Dyb.-81	13.52	0,73	***0.80***	***0.97***	***0.39***
6. 'D.5456'	***21.25***	***1.11***	4.71	***0.84***	-0.19
6. 'Ege-88'	15.47	0.84	5.08	***0.89***	-0.72
8. 'Firat-93'	18.35	1.09	6,73	***0.91***	-2.63
9. 'Özberk'	14.89	0.76	4.45	***0.89***	***0.33***
10. 'Gidara-II'	***22.54***	***0.91***	***3.21***	***0.94***	***4.91***
11. 'Harran-95'	20.66	1.34	***2.23***	***0.98***	-5.25
12. 'Sariçanak-98'	15.16	0.81	***0.15***	***0.99***	-0.55
13. 'Sorgül'	17.91	***1.07***	4.11	***0.94***	-2.65
14. 'Balcali-2000'	***27.06***	***1.12***	***0.57***	***0.99***	***4.49***
Means	19.29	1.00			

[a]: Values in italics and bolds are significantly higher than the mean at P<0.05. Cultivars with higher values than the mean are regarded as stables

[b] Values in italics and bolds are non significantly different from the unity at P<0.05. Cultivars with values in italics and bolds are considered as stables

[c] Values in italics and bolds are non-significantly different from 0 at P<0.05. Cultivars with values in italics are considered as stables

[d]: Values in italics and bolds are as high as possible. Cultivars which have high values are regarded as stables

[e] Values in italics and bolds are positive. Cultivars which have positive values are regarded as desired except ash content

Tab. 6. Summary of the stability analyses of 14 durum wheat varieties grown during 1999/2000 and 2000/2001 seasons

Traits	Cultivar Code													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Grain yield	+[a]	-[b]	-	-	-	-	-	+	-	-	-	-	-	+
Test weight	-	-	+	+	-	-	-	+	-	-	-	+	-	-
TGW	-	-	-	-	+	-	-	+	+	-	-	-	-	+
Vitreousness	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Protein content	+	+	-	-	-	-	-	-	-	-	-	-	-	+
Ash content	-	-	-	-	+	-	+	-	-	-	-	-	-	-
SDS volume	+	-	-	-	-	+	-	-	-	+	-	-	-	+

[a]: stable, [b]: unstable

TGW, respectively. Budak (2000) stated that H^2 of grain yield, protein content and test weight were 67%, 64% and 29%, respectively. Pecetti and Anncchiarrico (2006) also, reported that the H^2 for grain yield and SDS volume were 59%, 89%, respectively. However, some researcher suggested that they obtained low heritability values for grain yield and quality traits of wheat. Likewise, Yağdi and Sözen (2009) found low level of heritability (between 0.725% and 30.43%) for grain yield and quality traits. Similarly, Akçura (2009) stated that H^2 values of grain yield, TGW, protein content, ash content and SDS values were 31.1%, 35%, 39.9%, 32.6% and 27.8% in Turkish durum wheat, respectively. H^2 for both grain yield and quality traits were

Tab. 7. Heritabilities and variance components for grain yield and some quality traits

	σ^2_g	σ^2_{gl}	σ^2_{gy}	σ^2_{gyl}	σ^2_e	σ^2_{ph}	H^2 (%)
Grain yield	0.0376	0.0050	0.022	0.024	0.1478	0.060	62.6
Test weight	0.646	0.0072	0.916	0.304	0.652	1.182	54.6
Thousand kernel weight	8.469	0.0411	0.059	1.507	2.882	8.975	94.3
Vitreousness rate	9.858	1.993	37.875	11.581	10.133	32.5	30.3
Grain protein content	0.202	0.028	0.048	0.148	0.406	0.267	75.2
Ash content	0.0107	0.0003	0.000	0.002	0.0097	0.0296	36.0
SDS sedimentation	13.651	0.1043	4.617	1.850	5.398	16.442	83.0

σ^2_g : genotypic variance; σ^2_{gl} variance for interaction of genotypes with locations; σ^2_{gy}: variance for genotypes with years; σ^2_{gyl}: variance for genotypes, locations and years; σ^2_e: variance for error; σ^2_{ph}: phenotypic variance; H^2 %: Broad sense heritability

Çukurova region but it can also be grown successfully in coastal areas of Turkey, under drought and supplementary irrigated conditions. Thus, this promising cultivar could be advised to farmers dealing with the production of good quality durum. Most of cultivars were stable for one trait and unstable for another, suggesting that the genetic factors involved in the GEI differed between traits (Grausgruber *et al.*, 2000). Likewise, some researchers (Rharrabti *et al.*, 2003 and Letta at al., 2008) also obtained similar results.

According to investigation, it could be explained by GEI that low heritability values were determined for vitreousness rate and ash content; moderate values for grain yield and test weight; high levels for TGW, grain protein content and SDS (Tab. 7). Zanetti *et al.* (2001) determined the heritability as 96% and 87% for protein and comparatively higher than findings of above mentioned researchers, because genotypic effects constituted a major portion of the total phenotype variation in these characters

Conclusions

According to genotypic stability, 'Balcali-2000' cultivar showed high stability for grain yield and three of the quality characteristics and proved to be the best within the pool of the studied genotypes. Besides, it can be concluded that cultivars performing better for quality traits have potential to be used as parents in breeding programs for production of cultivars having high quality for costal region.

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