Genetic variability and interrelationship among grain yield and some quality traits in Turkish winter durum wheat landraces

MEVLÜT AKÇURA

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Research Article

Genetic variability and interrelationship among grain yield and some quality traits in Turkish winter durum wheat landraces

Mevlüt AKÇURA

Department of Field Crops, Faculty of Agriculture, Bingöl University, P.O. Box: 42, 12000 Bingöl - TURKEY

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Abstract: Twenty durum wheat pure lines obtained from landraces collected from southwestern districts of Konya and 5 durum wheat cultivars were evaluated under rain fed conditions in Konya between 2005 and 2008 in a 3 replicates randomized complete block design to estimate genetic variation and heritability for grain yield and 6 quality traits. The overall goal of the study was to improve pure lines from durum wheat landraces for low input agricultural areas of the Central Anatolian region and similar environmental conditions. The broad sense heritability estimates ranged from 12.9% (particle size index) to 50.0% (semolina color). The highest expected genetic advance as a percentage of mean was recorded for grain yield (8.35%), followed by semolina color (5.50%). Mean grain yield values of the pure lines from landraces ranged from 1.85 to 2.85 t ha^{-1}. Out of 20 pure lines, 14 had above average grain yield of 4 standard cultivars. Based on mean performance, pure line 4 was superior with respect to grain yield; pure line 5 was superior with respect to mini SDS sedimentation and grain yield. Comparisons between the pure lines and the modern cultivars led to the conclusion that grain yield, protein content, mini SDS sedimentation, and semolina color of some pure lines were usually higher than those of modern cultivars. According to the results, some pure lines could be tested in winter durum wheat registration trials, and some lines could be used as genetic material to broaden the genetic basis of durum wheat breeding programs all over the world.

Key words: Genetic variation, grain yield, quality traits, pure lines, Turkish durum wheat landraces

Türkiye kışlık yerel makarnalık buğday çeşitlerinin tane verimi ve bazı kalite karakterleri arasındaki ilişkiler ve genetik çeşitlilik

Özet: Konya ilinin Güney Doğu ilçelerinden toplanan yerel makarnalık buğdaylardan seçilen 20 saf hat, 5 modern makarnalık buğday çeşidi ile birlikte 2005-2008 yılları arasında Konya doğal koşullarında 3 tekerrürlü tesadüf blokları deneme desenine göre ekilmiştir. Denemede tane verimi ile 6 adet kalite karakterinin genotipik ve fenotipik çeşitlilikleri ile geniş anlamda kalıtım dereceleri değerlendirilmiştir. Bu araştırmanın genel amacı, yerel makarnalık buğday çeşitlerinden Orta Anadolu Bölgesinin düşük girdili arazileri ve benzer ekolojik koşullara uygun materyal geliştirmektir. İncelenen karakterlerde geniş anlamda kalıtım derecesi % 12.9 (particle size indeks) ile % 50.0 (irmik rengi) arasında değişmiştir. Ortalamaların yüzdesine göre hesaplanan beklenen genetik ilerleme değeri en yüksek tane veriminden (% 8.35) elde edilmiş, bu karakteri irmik rengi (% 5.50) takip etmiştir. Yerel çeşitlerden seçilen saf hatların tane verimleri 1.85 t ha^{-1} ile 2.85 t ha^{-1} arasında değişmiştir. 20 saf hattan 14 tanesi 4 standart çeşitten daha yüksek ortalama tane verimine

* E-mail: makcura@bingol.edu.tr

sahip olmuştur. Ortalama performanslar göz önüne alındığı zaman 4 nolu saf hat tane verimi bakımından, 5 nolu saf hat ise hem tane verimi hem de mini SDS sedimantasyon değeri bakımından öne çıkmıştır. Saf hatlar ile denemede yer alan standart çeşitleri incelenen tüm karakterler bakımından karşılaştırdığımızda, bazı saf hatlar tane verimi, protein içeriği, mini SDS sedimantasyon ve irmik rengi bakımından standart çeşitlerden üstün olmuştur. Araştırma sonuçlarına göre, bazı saf hatlar kuru makarnalık tescil denemelerinde, bazıları ise tüm dünyada kışlık makarnalık buğday ıslah programlarında genetik çeşitliliği artırmak için kullanılabilir.

Anahtar sözcükler: Genetik çeşitlilik, tane verimi, kalite karakterleri, saf hat, Türkiye yerel makarnalık buğday çeşitleri

Introduction

Turkey is the center of origin of many crop species, possibly also that of plant domestication (Davis 1985). Variation in Turkish wheat has received great attention since the beginning of the 20th century (Karagöz and Zencirci 2005). Exploration and collection missions were mounted and the collected germplasm evaluated in different countries (Gökgöl 1939; Harlan 1950; Zhukovsky et al. 1951).

Landraces of wheat generally tolerant to biotic and abiotic stress have been grown under low-input or sustainable farming conditions where they produce reasonable yield. A landrace, being composed a mixture of homozygous genotypes, usually exhibits considerable genetic variation for developmental, qualitative, and quantitative characters (Moghaddam et al. 1997). Landraces have not been used under modern farming conditions mainly due to low productivity. Landraces are mainly cropped in remote rural areas for local use because of their high end-product quality and recently in the framework of organic farming. These landraces are expected to be mixtures of pure line and some of them seem to have encouraging performance under modern cropping conditions regarding both grain yield and end-product quality traits although they were tall and thus susceptible to lodging (Brush 1995). Grain quality of some wheat landraces should be of special interest because much broader diversity can be found here compared to presently grown cultivars. Keller et al. (1991) referred to the very high protein content in kernels of some landraces of common wheat. Dotlacil et al. (2003) expressed that the selected landraces had not only high protein content but also convenient parameters of some other traits of quality.

Such data can provide evidence that these landraces could be worth a direct breeding effort following pure line selection programs aiming to develop cultivars adapted to modern cropping conditions as has been often done in the past (Agorastos and Goulas 2005). It is worth mentioning that pure line selection does not develop new genotypes and the improvement is limited to the gentrification and isolation of the best genotypes (pure lines) already existing in the original landrace, which could be utilized either as monogenotypic or few line mixture (Poehlman and Sleper 1995). Such efforts are also consistent with 'organic plant breeding' aiming to serve variety development for organic agriculture (van Lammerts Bueren et al. 2003; Agorastos and Goulas 2005). Belay et al. (1993) concluded that it may be possible to improve Ethiopian wheat landraces by indirect selection for increased number of tillers and kernel weight or direct selection for grain yield per se.

In the present study, we used a set of different pure lines selected from durum wheat landraces from a mountain village in Konya province to measure the amount of genetic variation for grain yield and some quality traits, and the possibility of improving them through durum wheat breeding programs. The goal of this program is to breed improved landraces and/or modern cultivars for rain-fed areas of the Central Anatolian region of Turkey. Phenotypic and genotypic correlation coefficients between pairs of traits were also determined. Mean values of grain yield and 6 quality characters were also compared between pure lines and modern durum wheat cultivars.

Materials and methods

The durum wheat selection and improvement program was initiated by screening landrace populations collected from different localities. In 2002, at least 77 populations were collected from the villages of Bozkır, Ahırlı, Hadim, Taşkent, and Seydişehir, where durum wheat landraces were still grown in small fields (0.005-0.05 ha) and where farmers had been using their own seed for generations. In the 2002-2003 growing season all collected populations were sown in Konya's rain-fed conditions to select single spikes for head rows. In the second growing season 1800 spikes were sown in Konya province to select pure lines with respect to grain yield, some yield, quality traits, and yellow rust tolerance. In the 2004-2005 growing season 20 selected pure lines were grown in Konya province for seed multiplication.

These 20 pure lines and 5 modern durum wheat cultivars (Kunduru, Kızıltan-91, Mirzabey, Altın, and Altıntaş-95) were used as experimental material in this research. The origins of the selected pure lines, history of selection, and standard cultivars are given in Table 1. The experiments were performed under rain-fed conditions in the 2005-2006, 2006-2007, and 2007-2008 growing seasons in Konya. A randomized complete block design with 3 replicates was laid out. The seeds were planted using an experimental drill in 1.2 m × 7 m plots consisting of 6 rows with 20 cm row spacing. The seeding rates were 550 seeds m^{-2} for rain-fed conditions. The plots were fertilized with 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} at planting and 40 kg N ha^{-1} in spring at stem elongation. Plots 1.2 m × 5 m in size were harvested with a combine harvester. The yield was determined and expressed as tons per hectare (t ha^{-1}). All field conditions such as the growing seasons, soil properties, and the rainfall during the growing periods, sowing date, and harvesting date are summarized in Table 2.

Different commercial and technological traits other than grain yield were considered: thousand kernel weight, protein content, ash content, mini SDS (sodium dodecyl sulfate) sedimentation test, particle size index, and semolina color (designated also as pigment content). Thousand kernel weight was calculated as mean weight of 4 sets of 100 kernels. Protein content, ash content, and particle size index were determined using the near infrared reflectance (NIR) method (Williams et al. 1982; Delwiche et al. 1998). The mini-SDS sedimentation test was performed according to Pena et al. (1990). Semolina color was assessed using a color quality control system and retaining the parameter b as an indicator of pigment content (Clarke et al. 2000; Şahin et al. 2006).

Data obtained from 20 pure lines and 5 standard cultivars were applied to variance analysis. In pooled analysis of experiments, years were considered random effect with genotypes as fixed. The significance of differences among genotypes was determined by LSD test (SAS Institute 1999). The genotypic coefficient of variation and genetic advance were calculated according to Johnson et al. (1955) using the following equations:

$$Vp = Vg + \frac{Vgy}{year} + \frac{Ve}{block \times year}$$

Vp = Phenotypic variance, Vg = Genotypic variance, Vgy = Genotype × year interaction variance, Ve = Error variance

$$Vg = \frac{\text{MS for Genotype - MS for genotype} \times \text{year interaction}}{year \times block}$$

$$Vgy = \frac{\text{MS for Genotype} \times \text{year interaction - MS for error}}{block}$$

MS = Mean square

Genotypic variability coefficient (GCV)

$$= \frac{\sqrt{Vg}}{\bar{x}} \times 100$$

Phenotypic variability coefficient (PCV)

$$= \frac{\sqrt{Vp}}{\bar{x}} \times 100$$

$\bar{X}$ = Mean of the traits

Broad sense heritability (H^2) = Vg/Vp

Response to selection or expected genetic advance after one generation of selection was calculated at 5% selection intensity using the following formula:

$$GA = k\sqrt{Vp}\, H^2$$

where

GA = The expected genetic advance, k = selection intensity (2.06), $\sqrt{Vp}$ = the phenotypic standard deviation

Table 1. Standard cultivars, durum wheat landraces origin and selection history.

Pure Line Code	Site (Province-Town-Village)	Altitute (m)	Local Name	Selection History
1	Konya-Bozkır-Bayboğan	1200	Koca Buğday	BDKMYÇ 02-03 BS 18-6
2	Konya-Bozkır-Bayboğan	1200	Koca Buğday	BDKMYÇ 02-03 BS 18-12
3	Konya-Bozkır-Karabayır	1150	Koca Buğday	BDKMYÇ 02-03 BS 20-8
4	Konya-Bozkır-Karabayır	1150	Koca Buğday	BDKMYÇ 02-03 BS 21-6
5	Konya-Bozkır-Soğucak	1300	Koca Buğday	BDKMYÇ 02-03 BS 31-14
6	Konya-Bozkır-Soğucak	1300	Koca Buğday	BDKMYÇ 02-03 BS 32-4
7	Konya-Bozkır-Soğucak	1300	Koca Buğday	BDKMYÇ 02-03 BS 32-14
8	Konya-Bozkır-Soğucak	1300	Koca Buğday	BDKMYÇ 02-03 BS 32-15
9	Konya-Bozkır-Soğucak	1300	Sarı Buğday	BDKMYÇ 02-03 BS 35-17
10	Konya-Bozkır-Yalnızca	1100	Koca Buğday	BDKMYÇ 02-03 BS 51-1
11	Konya-Bozkır-Yalnızca	1150	Koca Buğday	BDKMYÇ 02-03 BS 52-8
12	Konya-Bozkır-Söğüt	1300	Koca Buğday	BDKMYÇ 02-03 BS 54-1
13	Konya-Bozkır-Söğüt	1300	Koca Buğday	BDKMYÇ 02-03 BS 54-13
14	Konya-Bozkır-Söğüt	1300	Koca Buğday	BDKMYÇ 02-03 BS 54-14
15	Konya-Bozkır-Tarlabaşı	1200	Koca Buğday	BDKMYÇ 02-03 BS 81-18
16	Konya-Bozkır-Yazıdamı	1100	Koca Buğday	BDKMYÇ 02-03 BS 89-12
17	Konya-Ahırlı-Kuruçay	1150	Bolavadin	BDKMYÇ 02-03 BS 91-4
18	Konya-Ahırlı-Kuruçay	1150	Bolavadin	BDKMYÇ 02-03 BS 94-7
19	Konya-Ahırlı-Kuruçay	1150	Bolavadin	BDKMYÇ 02-03 BS 95-4
20	Konya-Bozkır- Karacaardıç	1150	Bolavadin	BDKMYÇ 02-03 BS 103-2
Modern Durum Wheat Cultivars				
21	Kızıltan-91			
22	Kunduru-1149			
23	Mirzabey-2000			
24	Altın-40/98			
25	Altıntaş-95			

Table 2. Growing seasons, soil properties, rainfall, sowing date and harvesting date.

Growing seasons	Soil properties	Rainfall (mm)	Sowing date	Harvesting Date
2005-2006	pH = 7.7, clayey, loam	283	14.10.2005	17.07.2006
2006-2007	pH = 8.2, clayey, alluvial	248	11.10.2006	13.07.2007
2007-2008	pH = 7.8, clayey, silty	311	19.10.2007	21.07.2008

GA expressed as percentage of mean was calculated with the following formula:

$$\text{GA expressed as percentage of mean} = \frac{GA}{\bar{x}} \times 100$$

Phenotypic and genotypic correlation coefficients and their standard errors were estimated by multivariate restricted maximum likelihood estimation method (REML) with SAS Proc MIXED procedure as described by Holland (2006).

Results

Analyses of variance and genotypic performance

The analysis of variance revealed that the mean squares for genotypes and year were significant for all the traits studied except particle size index (Table 3). This indicates the existence of a high degree of genetic variability in the material to be exploited in breeding programs that was also reflected in the broad ranges observed for each trait (Table 3). Genotype year interactions for grain yield, 1000-kernel weight, protein content, mini-SDS sedimentation, and semolina color (b value) were significant, indicating that differences among mean values of genotypes varied with years.

Mean values and ranges of grain yield and 6 quality traits for the pure lines derived from each durum wheat landraces population, along with mean values of the five modern durum wheat cultivars, across growing seasons are given in Table 4. It was found that there were significant differences for grain yield among pure lines across growing seasons.

Out of 20 pure lines, 14 pure lines had higher grain yield than the mean of 4 standard cultivars. Mean grain yield values of the pure lines from landraces ranged from 1.85 to 2.85 t ha^{-1} with pure line 9 showing the lowest grain yield. The highest grain yield was shown by pure line 4 (2.85 t ha^{-1}), followed by pure line 5 (2.80 t ha^{-1}), pure line 1 (2.75 t ha^{-1}), and pure line 14 (2.64 t ha^{-1}). These genotypes also showed better performance for some of the quality traits than others. Based on mean performance, pure line 4 was the superior with respect to grain yield; pure line 5 was superior with respect to mini SDS sedimentation and grain yield, followed pure lines 14 and 18, whereas pure line 11 recorded the highest semolina color and above grain yield (Table 4). Mean grain yield of the modern durum wheat cultivars ranged from 2.00 (Altın 40/98) to 2.94 t ha^{-1} (Kızıltan-91) over growing seasons. When evaluated against the modern durum wheat cultivars (except Kızıltan-91), some pure lines showed higher grain yield (Table 4).

Genetic variation

The phenotypic coefficient of variation (PCV) and genetic coefficient of variation (GCV), estimates of the components of variance, broad-sense heritability, and genetic advance are shown in Table 5. In this study the heritability estimate ranged from 12.9% to 50.0%. The heritabilities were small for most of the characters due to larger phenotypic variances,

Table 3. Mean squares from the combined analysis of variance across years for studied characteristics of durum wheat landraces.

SV	DF	GY	TKW	PC	AC	PSI	SDS	SC
Year (Y)	2	22.31**	297.7**	122.90**	1.89**	2232.21	120.45**	1.09**
Rep (Year)	6	1.44	230.2	19.75	0.37	245.86	8.22	20.00
Genotype (G)	24	0.86**	34.2**	2.66**	0.07**	76.31	3.13**	7.55**
G × Y	48	0.60**	22.1**	1.60**	0.04	66.45	2.26**	3.81**
Error	144	0.12	7.3	0.35	0.01	49.57	0.64	2.18
R^2		0.86	0.79	0.91	0.85	0.61	0.84	0.61
CV		14.32	6.99	3.82	7.29	13.84	11.16	8.63
Mean		2.38	38.63	15.39	1.48	50.89	7.14	17.13

** P < 0.01, GY: Grain yield, TKW: Thousand kernel weight, PC: Protein content, AC: Ash content, PSI: Particle size index, SDS: Mini SDS sedimentation test, SC: Semolina color (b value)

Table 4. Mean performance of genotypes across growing seasons.

Code	Genotypes	GY (t ha^{-1})	TKW (g)	PC (%)	AC (%)	PSI	SDS (mL)	SC
				Pure Lines				
1	Pure Line-1	2.75(4)#	39.54(9)	14.98(19)	1.40(23)	46.22(25)	6.67(20)	17.33(11)
2	Pure Line-2	2.35(14)	37.31(20)	15.24(13)	1.46(13)	49.95(15)	6.72(19)	16.87(17)
3	Pure Line-3	2.49(11)	41.68(1)	14.76(24)	1.59(4)	50.87(10)	6.89(15)	16.67(19)
4	Pure Line-4	2.85(2)	40.59(4)	15.3(11)	1.55(6)	49.72(16)	6.83(17)	17.06(14)
5	Pure Line-5	2.80(3)	36.96(21)	14.98(20)	1.31(25)	51.42(8)	8.44(1)	16.86(18)
6	Pure Line-6	2.60(6)	39.99(7)	15.02(17)	1.62(2)	48.12(22)	7.44(8)	16.90(15)
7	Pure Line-7	2.53(9)	38.73(13)	15.13(15)	1.42(18)	56.66(2)	6.56(22)	16.24(23)
8	Pure Line-8	2.35(15)	38.58(15)	15.41(9)	1.65(1)	50.74(11)	6.61(21)	17.46(9)
9	Pure Line-9	1.85(25)	38.59(14)	14.92(22)	1.47(12)	51.30(9)	7.50(6)	17.18(13)
10	Pure Line-10	2.51(10)	40.04(6)	15.34(10)	1.41(20)	49.71(17)	7.06(13)	16.58(20)
11	Pure Line-11	2.54(8)	39.38(11)	14.68(25)	1.46(14)	52.59(6)	7.17(11)	18.83(1)
12	Pure Line-12	2.21(18)	40.64(3)	15.80(6)	1.55(7)	54.08(4)	8.06(2)	16.47(21)
13	Pure Line-13	1.94(23)	40.47(5)	16.82(1)	1.42(19)	49.12(20)	6.89(16)	17.21(12)
14	Pure Line-14	2.64(5)	38.41(16)	15.78(7)	1.50(11)	53.56(5)	7.94(4)	17.90(5)
15	Pure Line-15	1.93(24)	36.19(23)	16.06(5)	1.41(21)	52.01(7)	7.22(10)	16.9(16)
16	Pure Line-16	2.41(13)	37.64(19)	14.83(23)	1.51(8)	57.96(1)	8.06(3)	16.32(22)
17	Pure Line-17	2.05 (20)	39.51(10)	15.25(12)	1.51(9)	47.41(23)	6.94(14)	17.50(7)
18	Pure Line-18	2.57(7)	39.58(8)	15.60(8)	1.43(17)	49.37(19)	7.50(7)	17.35(10)
19	Pure Line-19	2.46(12)	41.36(2)	14.98(21)	1.60(3)	48.80(21)	6.50(23)	18.35(3)
20	Pure Line-20	1.95(22)	33.34(25)	16.25(2)	1.41(22)	50.49(13)	6.83(18)	17.94(4)
Means	(Pure Lines)	2.39	38.93	15.36	1.47	51.01	7.19	17.19
				Cultivars				
21	Kızıltan-91	2.94(1)	38.18(17)	15.24(14)	1.45(15)	49.50(18)	7.39(9)	15.87(24)
22	Kunduru-1149	2.10(19)	38.14(18)	15.01(18)	1.58(5)	50.54(12)	6.11(25)	17.57(6)
23	Mirzabey-2000	2.32(17)	39.19(12)	16.14(3)	1.45(16)	46.53(24)	6.33(24)	14.52(25)
24	Altın-40/98	2.00(21)	35.43(24)	16.07(4)	1.51(10)	55.50(3)	7.78(5)	17.48(8)
25	Altıntaş-95	2.33(16)	36.21(22)	15.1(16)	1.36(24)	49.99(14)	7.11(12)	18.80(2)
Means (cultivars)		2.34	37.43	15.51	1.52	50.41	6.94	16.85
Mean of Genotypes		2.38	38.63	15.39	1.48	50.89	7.14	17.13
LSD (0.05)		0.32	2.52	0.54	0.11	ns	0.74	1.64

GY: grain yield, TKW: thousand kernel weight, PC: Protein content, AC: Ash content, PSI: Particle size index, SDS: Mini SDS sedimentation test, SC: Semolina color (b value), #: Numbers in brackets are rank values of genotypes for each character

Table 5. Phenotypic coefficient of variation (PCV) and genetic coefficient of variation (GCV), components of variance, broad sense heritability (H), and genetics advance (GA) of 7 characters of durum wheat landraces genotypes from the Central Anatolian region.

Characters	Mean	PCV(%)	GCV(%)	Estimates of Components of variation*			H (%)	GA**	GA as % of mean
				σ^2ph	σ^2g	σ^2/r			
GY	2.38	13.03	7.27	0.10	0.03	0.79	31.10	0.20	8.35
TKW	38.63	5.05	3.00	3.80	1.35	12.88	35.40	1.42	3.68
PC	15.39	3.53	2.23	0.30	0.12	5.13	39.90	0.45	2.90
AC	1.48	5.77	3.30	0.01	0.00	0.49	32.60	0.06	3.87
PSI	50.89	5.72	2.06	8.48	1.10	16.96	12.90	0.78	1.52
SDS	7.14	8.26	4.36	0.35	0.10	2.38	27.80	0.34	4.73
SC	17.13	5.35	3.78	0.84	0.42	5.71	50.00	0.94	5.50

*σ^2ph, σ^2g, σ^2/r are phenotypic, genotypic, and error variance of genotype means, respectively

** The selection differential used was 2.06 at 5% selection intensity

GY: Grain yield, TKW: Thousand kernel weight, PC: Protein content, AC: Ash content, PSI: Particle size index, SDS: Mini SDS sedimentation test, SC: Semolina color (b value)

indicating the growing seasons effect. Heritability of semolina color (b values), protein content, 1000 kernel weight, and ash content were greater than that of grain yield. In the present study semolina color had the highest (50.0%) broad sense heritability. The heritabilities for protein content and thousand kernel weight were 39.9% and 35.4% respectively. Mini SDS sedimentation tests heritability was 27.8%. The heritability estimate was 31.1% for grain yield (Table 5).

The PCV was generally higher than the GCV for most of the characters, indicating the influence of the growing season. PCVs were the highest in grain yield (13.03%) and mini SDS (8.26%). The lowest PCVs were for protein content (3.53%) and semolina color (5.35%). The greatest GCV was for GY (7.27%); among the quality characters it was for mini SDS (4.36%) (Table 5).

To predict the selection effects precisely, heritability accompanied by genetic advance is more useful than heritability alone. Therefore, genetic advance was also computed as percentage of mean. The results indicated that maximum genetic advance was recorded for grain yield and semolina color: 8.35% and 5.50%, respectively.

Correlation between characters

Genotypic and phenotypic correlation coefficients along with their standard errors are presented in Table 6. Among the quality traits, 1000-kernel weight and mini SDS sedimentation showed a significantly positive correlation with grain yield at phenotypic level. The association of protein content with ash content was positive and significant both at genotypic and phenotypic levels. Particle size index was negatively correlated with protein content and positively correlated with mini SDS sedimentation. An interesting observation relates to the negative association exhibited by semolina color with other quality traits except particle size index. Grain yield was negatively correlated with protein content and ash content at both phenotypic and genotypic levels.

Discussion

Genotypic differences were highly significant for grain yield and all quality characters except particle size index. Despite the significant differences between the pure lines in terms of quality traits, e.g., 1000-kernel weight, protein content and ash content, the pure lines are usually better quality than the cultivars.

Table 6. Phenotypic and genotypic correlation coefficients among various pairs of grain yield and quality traits of durum wheat landraces over growing seasons.

Traits		GY	SE	TKW	SE	PC	SE	AC	SE	PSI	SE	SDS	SE
TKW	G	0.56	0.58	…	…	…	…	…	…	…	…	…	…
	F	0.28**	0.08	…	…	…	…	…	…	…	…	…	…
PC	G	-0.57	0.47	-0.12	0.58	…	…	…	…	…	…	…	…
	F	-0.33**	0.08	-0.28**	0.08	…	…	…	…	…	…	…	…
AC	G	-0.23	0.67	-0.11	4.02	0.86**	0.28	…	…	…	…	…	…
	F	-0.29**	0.08	-0.39	0.84	0.62**	0.05	…	…	…	…	…	…
PSI	G	-0.45	1.23	-0.27	0.99	-0.37**	1.10	-0.77	1.64	…	…	…	…
	F	0.00	0.07	-0.24**	0.07	0.00	0.07	0.10	0.64	…	…	…	…
SDS	G	0.06	0.77	-0.08	0.72	-0.07	0.68	-0.01	0.76	1.32	1.45	…	…
	F	0.18*	0.09	-0.16**	0.08	-0.03	0.09	-0.03	0.09	0.23*	0.07	…	…
SC	G	-0.26	0.55	-0.43	0.52	-0.46	0.49	-0.16	0.46	0.59	1.23	-0.05	0.60
	F	-0.05	0.08	-0.02	0.08	-0.06	0.08	-0.11	0.08	-0.01	0.07	0.04	0.08

* $P < 0.05$, ** $P < 0.01$ P: Phenotypic, G: Genotypic, SE: Standard error, GY: Grain yield, TKW: Thousand kernel weight, PC: Protein content, AC: Ash content, PSI: Particle size index, SDS: Mini SDS sedimentation test, SC: Semolina color (b value)

In particular, mini SDS sedimentation and semolina color of pure lines were higher than those of most of the modern cultivars. In this regard, it could be useful to stress that in previous studies Peterson et al. (1992), Pecetti and Annicchiarico (1993), and Novaro et al. (1997) found similar results in durum wheat.

The genotypic correlation values were slightly higher than their corresponding phenotypic values, which might have been due to the modified effect of growing seasons on character association at genetic level. It was surprising that there were positive relationships between grain yield and mini SDS sedimentation in durum wheat landraces. The high yielding pure lines generally had values above the average for thousand kernel weight and mini SDS sedimentation. Some of pure lines could be useful in improving grain yield quality in breeding programs for winter durum wheat in the Central Anatolian region of Turkey. There were significant and negative correlations between grain yield and protein content at both phenotypic and genotypic levels as in the studies reported by Campbell et al. (1981) and Pleijel et al. (1999) in bread wheat, and Garcia del Moral et al. (1995) in triticale.

Heritability of a trait is important in so far as it determines response to selection (Sharma and Smith 1986). The magnitude of heritability was affected by the type of genetic material and yield level of the environment (Toker 2004) due to the fact that the studies characters are created by the effects of genes and growing seasons.

In the present study, examined traits of quality heritabilities varied from low to moderate. Semolina color heritability was moderate. Braaten et al. (1962) reported heritabilities of pigment concentration to be 0.79 to 0.94, with little evidence of genotype-year interaction. However, Lee et al. (1976) found heritability of a 10-parent diallel to be 0.11 in one environment and 0.79 in another. Elouafi et al. (2001) found a heritability range of 0.48 to 0.99 for a durum by *T. dicoccoides* cross grown in 16 environments. Johnston et al. (1983) reported realized broad sense heritability of 0.31 to 0.69 for semolina color, and observed genotype-environmental interactions.

Estimates of protein content heritability vary from low to moderate. Selection for protein in wheat is complicated by the negative relationship with grain yield, and the influence of environmental conditions on protein content. Our results were in agreement with those reported by Clarke et al. (2000), who expressed that heritability for grain protein content ranged from 29% to 53%. In addition, Kaltsikes and Lee (1971) found 19% broad sense heritability for thousand kernel weight. Although mini-SDS sedimentation is used widely in early generation selection parameters for bread wheat, heritability for mini-SDS sedimentation is low in Turkish winter durum wheat pure lines. Like our results, broad sense heritability for SDS-sedimentation varies from intermediate to high in wheat (Clarke et al. 2000).

In our study, the heritability of grain yield was low. Sharma and Smith (1986) reported that grain yield was highly influenced by the environment and is known to have low heritability. The most common justification for conducting selection in optimum environments, regardless of the nature of the target environment, was the lower heritability found by Ceccarelli (1994) in low yielding environments. Furthermore, Ceccarelli (1996) reported that lower heritability was expected in low input conditions. In addition, Atlin and Frey (1990) concluded that heritability in low yielding environments is lower than that in high yielding environments in oat (*Avena sativa* L.). Estimated values of the heritabilities in the study were low due to low yielding years. In this study, low estimates of heritability and expected genetic advance were observed for grain yield and quality traits. Pathak and Nema (1985) and Ehdaie and Waines (1989) also reported moderate to low values of heritability and genetic advance for grain yield in wheat. The fact that heritability estimates for both grain yield and quality traits are usually lower than for other characters in wheat suggests that environmental effects constitute a major portion of the total phenotype variation in these characters.

No studies were found in the literature dealing with the heritability, or phenotypic or genotypic correlations for grain yield and quality characters of pure lines from Turkish durum wheat landraces in Central Anatolian rain-fed conditions. There were only studies about genetic variation in Turkish durum wheat landraces at population level in rain-fed conditions of the Central Anatolian region (Zencirci and Kün 1996; Zencirci 2008), showing higher variation for grain yield and quality characters. In addition, Korkut et al. (2001) reported similar genetic coefficients of variation and phenotypic coefficients of variation for grain yield of bread wheat genotypes in the Thrace region of Turkey.

The data in this study showed the possibility of improving Turkish durum wheat landraces by selection for grain yield and quality traits in rain-fed conditions in the Central Anatolian region of Turkey. The pure lines from landraces could be used as a genetic material to broaden the genetic basis of durum wheat breeding programs all over the world; also some pure lines could be tested in winter durum wheat registration trials.

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