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Variation and Heritability for Some Semolina Characteristics and Grain Yield and Their Relations in Durum Wheat (*Triticum Durum* Desf.)

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Abstract: The study were carried out to estimate variation, heritability and correlation for milling characteristics of 25 durum wheat (*Triticum durum* Desf.) genotypes under rainfed conditions in three environments of North West Turkey. The genetic material showed relative large variations in which all traits except test weight. The variance component due to genotype explained most of the total variation, ranging 55.94 to 0.01% of the variability associated with grain yield and each of semolina traits. Effects of G x E interaction ranged from a low of 0.09 of total variance for grain yield to a high of 65.56% of total variance for vitreous grain. Broad sense heritability estimates ranged between 89.4% (semolina colour) and 23.1% (wet gluten content) for all traits. Whereas protein content showed positive significant correlations with wet gluten content (0.708**), semolina colour (0.492**) and vitreous grain (0.445**), negative significant relationships of protein content were determined with 1000 - grain weight (-0.773**), test weight (-0.539**) and ash content (-0.446**). Vitreous grain was positively correlated with semolina colour (0.392**) and both traits showed significant correlations with wet gluten content (0.388-0.462) and protein content (0.445-0.492), respectively. The significant and negative correlation coefficient (-0.288) was observed between protein content and grain yield.

Key words: Durum wheat · Semolina value · Variance component · Heritability · Correlation

INTRODUCTION

Thrace and Marmara Region of Turkey are suitable for durum wheat production the point of view climatic conditions. Whereas the proportion of durum wheat was 60 % in 1960's, in 1980's this rate decreased to 5 % [1] and today, rate is in the level to be no. The main reasons have not improved new genotypes with high yielding and quality competing with bread wheat and wrong price policies. So, durum wheat breeding programs should be designed to ensure that any new released cultivar has acceptable agronomic characteristics to meet the demand of the farmers and the quality traits required by the processing industry.

The chief aim of a durum wheat breeding program is to obtain new cultivar with a high yielding potential and better quality. There is genetic potential to improve the nutritional quality of durum wheat through convectional breeding techniques [2]. Durum wheat quality criteria are continually evolving in response to technological advances in durum wheat milling and secondary processing. The durum wheat physical condition is the most important factor determining wheat milling potential and end-use quality [3]. A high yield of highly refined semolina is the basic quality criteria valid today [4]. The semolina milling value can be defined as the capacity of a durum wheat to give high yields of semolina of a defined purity under industrial conditions [5] and it is of great importance regarding the physical quality character and complex because it is dependent on different factors. But, it is considered closely related with grain characteristics such as 1000 - grain weight and test

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weight characters which are the best predictors of grain size, shape and volume [6] and it is affected depending on a degree of vitreousness of endosperm [7]. Protein content, which is one of the most important traits in quality evaluation and breeding of durum wheat, are required to process semolina into a suitable final pasta product [8]. Wet gluten content of genotypes gives a good indication of protein content and because gluten strength can be judged by its extensibility and elasticity [9]. Additionally, ash content has been linked to semolina colour where it is used to assess the cleanliness of semolina [10]. Wheat quality is influenced by genotype, environment and their interaction [11-13], but relative magnitude of them on quality is unclear [14].

Quality improvement is to be possible via evaluation and selection [15], since wide variation exists in breeding material. Response to selection for quality depends on the heritability and genetic variance of quality traits and unfavourable correlated response with other important characteristics, in particular grain yield [16]. Correlations, although reliable only for the range of material tested, may point to relationships that can be utilised in making a selection programme more effective [17]. The objectives of this work were: (a) to determine the magnitude of variation present in a set of durum wheat genotypes; (b) to estimate variance components, heritability and genetic advance of the traits; (c) to investigate the relationships among the traits used with emphasis on protein content.

MATERIALS AND METHODS

Plant Material and Experimental Procedure: The genetic material of durum wheat (25 genotypes), which was comprised of 13 advanced lines, 8 mutant lines and 4 commercial varieties (Checks) were evaluated in the study.

Cite Characteristics and Agronomic Details: The study was carried out at Edirne (26°35' E, 41°38' N and elev. 32 m), Tekirdağ (27°34' E, 40°59' N and elev. 10 m) and Lüleburgaz (27°16' E, 41°22' N and elev. 41 m) locations of the Thrace Region during 2001-2002 growing year.

The chosen locations also differed, for instance, in the height above sea level, chemical composition of the soil and climate conditions. The height above sea level of Tekirdağ is H = 10 m which is a low-lying area, while Lüleburgaz's height above sea level is H = 41 m. The other location's altitude (Edirne) is H = 32 m. Soils characteristics of experiments were determined in soil analyses. Soils of the experiments were loamy clay, fine loamy and silty clay textured, neutral pH and low salt concentrations in Tekirdağ, Lüleburgaz and Edirne, respectively. Contents of phosphorus, potassium, calcium, magnesium, iron, copper, manganese and zinc were higher than the required. Organic matter also was quite higher than 1%.

The Thrace Region is a peninsula and the central parts of Thrace Region is under effect of continental climate, along with Mediterranean climate and Black Sea climate, with lower temperatures during winters and hot, dry summers. The total cumulative precipitation recorded during growth season (November-July) for Tekirdağ, Lüleburgaz and Edirne were 513.4 mm, 486.2 mm, 380.4 mm in experiment year [18].

The plots were fertilized with 36 kg N (20-20-0) ha^{-1} and 36 kg P_2O_5 ha^{-1} at sowing, 87 kg N (Urea) ha^{-1} at tillering and 41 kg N (NH_4NO_3) ha^{-1} at pre-heading. Standard cultural practices were followed for raising the crop.

Methods: The experiments were designed in a random completed block design with three replications. Each experimental unit consisted of 6 rows, 5 m long and with 20-cm spaces between two rows. Standard cultural practices were followed for raising the crop.

The traits studied were protein content (PC), 1000 grain weight (TGW), test weight (TW), percentage of vitreous grain (VG), wet gluten content (WGC), ash content (AC), semolina colour b (SC) and grain yield (GY). Quality tests were performed on the harvested grains of each genotype for each location and traits were calculated at 14% moisture level and 100% purity. Protein content was determined as process by ICC Standard Method 105 [19]. Test weight was weighted using the Approved AACC Method 55-10 [20] using portable hectolitre test weight kit; results were reported in kilograms/hectolitre. Thousand grain weight was calculated from the weight (g) of 4 lots of 100 seeds, multiplying by 10. The percentage of vitreous grain was determined using the ICC Standard Method 129 [21]. A scalpel was used for cutting grains transversely. Vitreous grains (those completely free of starchy or speckled appearance) were separated from a 20 g clean grain sample and weighed. Vitreousness was calculated visually as a percentage of vitreous grains (w/w) in the sample. Ash content was fixed using the ICC Standard Method 104/1 [22]. The ICC Standard Method 106/2 [23] was used for wet gluten content and semolina colour b values of the genotypes were obtained using the ICC Standard Method 152 [24]. Grain yields obtained from each plot were adjusted to ton per hectare for biometrical evaluation.

Statistical Analysis: Estimates of broad sense heritability (h^2_{BS}) for different traits were computed using the variance components method based on the combined analyses over the three test locations.

Initial the data were subjected to randomised complete block design analyses of variance. Appropriate transformations (logarithmic, square root) were performed when necessary. Entry means were used in the combined analyses across environments. Variance components were estimated according to Snedecor and Cochran [25] as follows:

$$V_g = (MS_g\text{-}MS_{gl})/rl,$$
$$V_{gl} = (MS_{gl}\text{-}MS_e)/r,$$
$$V_e = MS_e \text{ and}$$
$$V_{ph} = V_g + V_{gl} / r + V_e / rl$$

Where V_g, V_{gl}, V_e and V_{ph} are the variances due to genotypes (lines), genotype x location (G x L) interaction, experimental error and phenotypes, respectively. Ms_g, Ms_{gl} and MS_e are the mean squares of genotypes (i.e. lines), genotype x location (G x L) interaction and pooled error and l denotes the number of environments (i.e. locations) and r the number of replications.

$$\text{Broad sense heritability } (h^2_{BS}) = [V_g / V_{ph}] \times 100$$

Genetic advance (GA), expressed as a percentage of the mean was calculated as:

$$GA = k \times (\text{Phenotypic variance})^{0.5} \times h^2_{BS} (100/\bar{x}) \text{ [26]},$$

where 'k' was the selection intensity at 5 % level (value = 2.06)

Simple correlation coefficients were determined among traits studied.

RESULTS AND DISCUSSION

Variations in Traits: The results of combined variance analysis made on data obtained from 3 locations are given in Table 1. Highly significant differences were detected among environments and genotypes for each of investigated traits. In general G x E interactions were significant, but relatively small than genotype and environment. While it was assumed that if the mean square for the genotype-environment interaction is solely determined by random reasons, CV is lower or equal to 5%, whilst the presence of this interaction increases values of the coefficient [27]. In addition, Dotlacil *et al.* [28] considered a minimum 10% CV is a sign of wide diversity in wheat. Thus, the genetic material used are amendable to selection for improving grain yield and semolina characters for relative large variations in which all traits except test weight (Table 1).

There was a wide range between the minimum and maximum values of most traits, but test weight had low ranges (14% of the means) (Table 2). In contrast, wet gluten content showed the highest range of variation (112% of the means). The remaining traits exhibited wide variation (>55%). Wide phenotypic variations have been reported by Lerner *et al.* [29] and Paul *et al.* [30].

Component of variance for each trait expressed as percentage illustrates the relative contribution of each source to total variance in Table 2. The variance component due to genotype explained most of the total variation, ranging 55.94 to 0.01% of the variability associated with grain yield and each of semolina characters. Genotypic variance is a parameter which represents the magnitude of heritable effects. High degree of it indicates that selection can be successfully applied in this population [31]. The availability of significant genetic variability concerning SC, TGW, VG, AC and PC in population points out that selection might be conducted taking into consideration these traits in direction of increases or reductions.

Effects of G x E interaction ranged from a low of 0.09 of total variance for GY to a high of 65.56% of total variance for VG. Relatively large G x E interaction for the traits except SC and GY indicates that selection should be carried out in range of environments and it is compulsory to breed different genotypes for every specific environment [32]. Taking into account these results, it is recommended to develop of new genotype/cultivar for different environments regarding important semolina traits and grain yield which is considered as a major aim in durum wheat breeding studies. The main effects of genotype environment and their interaction, were statistically significant source of variation for all traits. Of greater interest was the relative magnitude of variation attributable to these effects, which were compared using variance component ratios [14] (Table 2). The σ^2_g/σ^2_{ge} ratio differed among the traits. A ratio > 1.0 indicates greater influence and stability of genetic factors relative to the variability associated with the interaction G x E. The ratios for all traits ranged from 10.0 (SC) to 0.41 WGC). The highest value calculated signifies a larger influence on variability by the genotype than the G x E interaction for SC. The ratios for WGC (0.41), PC (0.50) and AC (0.77) were < 1.0, indicating the important

Table 1: Mean square value of grain yield and semolina traits of 25 durum wheat genotypes over three environments

	Source of variation					
Traits	Environment	Genotype	G x E	Error	CV%	S.E.(±)
TGW (g)	2886.14**	100.39**	28.61**	2.69	13.90	0.407
TW ($kg*hl^{-1}$)	136.52**	12.25**	4.22**	1.06	2.59	0.137
VG (%)	4126.72**	701.83**	198.37**	21.80	13.15	0.727
AC (%)	1.71**	0.13**	0.04**	0.004	10.46	0.013
SC	73.85**	40.09**	1.37**	0.07	13.48	0.154
WGC (%)	3034.15**	129.93**	61.87**	4.99	26.23	0.531
PC (%)	552.91**	10.42**	3.61**	0.06	18.37	0.164
GY ($t*ha^{-1}$)	46.75**	2.93**	0.52**	0.24	16.33	0.062

TGW: Thousand grain weight, TW: Test weight, VG: Vitreous grain percent, AC: Ash content, SC: Semolina colour (b), WGC: Wet gluten content, PC: Protein content and GY: Grain yield

Table 2: Range, means, estimates of components of variance, broad-sense heritability (h^2_{BS}) and genetic advance for the characters of 25 durum wheat genotypes

	Range			Estimates of components of variance*					
	Min-Max	% of mean	Mean	σ^2_{ph}	σ^2_{g}	σ^2_{gl}	$\sigma^2_g / \sigma^2_{gl}$	h^2_{BS} (%)	GA as % of mean
TGW	33.5-62.0	65	43.9	19.30	7.98	8.65	0.92	41.3	8.52
TW	73.0-84.0	14	79.1	3.04	0.89	1.03	0.86	29.3	1.33
VG	42.0-98.0	68	82.9	143.19	55.94	65.56	0.85	39.1	11.63
AC	1.25-2.24	55	1.81	0.028	0.010	0.013	0.77	35.7	6.63
SC	12.1-23.6	67	17.1	4.81	4.30	0.43	10.0	89.4	23.63
WGC	14.0-48.0	112	30.4	32.78	7.56	18.33	0.41	23.1	8.98
PC	8.3-17.5	69	13.4	1.84	0.59	1.18	0.50	32.1	6.64
GY	3.11-7.50	77	5.7	0.61	0.27	0.09	3.00	44.3	12.46

* σ^2_{ph} , σ^2_{g} and σ^2_{gl} are phenotypic, genotypic and genotype x environment interaction, respectively. $\sigma^2_g / \sigma^2_{gl}$ is ratio of variances estimated for cultivar main effect and interaction.

influence of G x E interaction on these traits. The genotype and G x E interaction effects were almost similar for TGW, TW and VG due to their ratios ≅ 1.0. Grain semolina value is a complex character that depends on numbers of traits and the individual contribution of each trait varies depending on the specific reaction to environmental conditions.

Heritability and Genetic Advance: The processing quality of durum wheat and our understanding of the factors that determine quality, has improved recently. This was accomplished despite limited knowledge of the mode of inheritance and heritability of the traits [2]. Heritability is often used by plant breeders and geneticists as a measure of precision of a trial or a series of trials for standardization of their selection units. Its main use is for computing the response to selection [33]. The magnitude of heritability was affected by the type of genetic material and yield level of the environment [34]. It has emphasized that heritability alone is not enough to make sufficient improvement through selection unless accompanied by substantial amount of genetic advance [35]. Broad sense heritability estimated on the basis of genotypic and phenotypic variances ranged between 89.4 and 23.1% for all traits. WGC had the lowest heritability value (23.1%) followed by TW (29.3%). The heritability estimates were small for most of the characters due to larger phenotypic variances, indicating the growing areas effect. Only heritability of SC was greater than that of GY. In the present study SC had the highest (89.4%) broad sense heritability. The heritabilities for TGW, VG, AC and PC were 41.3%, 39.1%, 35.7% and 32.1%, respectively. The heritability estimate was 44.3% for GY (Table 2). The highest heritability (89.4%) coupled with high genetic advance (23.6%) of SC suggested that selection could be practised for this trait. Low heritability and low genetic advance were observed for WGC and TW indicating low transfer of these traits in the subsequent generations.

Table 3: Coefficients of correlation among traits studied of durum wheat grown in 3 sites of Northwest Region of Turkey during 2001-2002 growing season (n = 25)

	TW	VG	AC	SC	WGC	PC	GY
TGW	0.545**	-0.437**	0.463**	-0.409**	-0.680**	-0.773**	0.339**
TW		-0.336**	0.282**	-0.391**	-0.431**	-0.539**	0.381**
VG			-0.334**	0.392**	0.388**	0.445**	-0.377**
AC				0.033	-0.343**	-0.446**	0.391**
SC					0.462**	0.492**	-0.203**
WGC						0.708**	-0.324**
PC							-0.288**
GY							

Moderate heritability and high genetic advance estimates for TGW and VG reflect the possibility of effective selection for these traits. Moreover moderate heritability and genetic advance for AC and PC recommended that selection should be delayed to more advanced generations for those traits. But, selection for PC in wheat is complicated due to the negative relationship with GY and the influence of environmental conditions on PC. Our findings are in agreement with Clarke *et al.* [36] who stated that heritability for PC ranged from 29% to 53%. Bilgin *et al.* [37] determined the heritability and genetic advance of 71.7-32.5%, 49.3-11.7% and 62.4-10.1% for TGW, TW and VG, respectively. Johnston *et al.* [38] notified broad sense heritability of 31 to 69% for semolina colour and also they stated that it was a highly heritable trait and improvement of colour should be possible through early generation selection. Budak [39] determined the heritability of 29% for TW. Akçura [40] found heritability values of 35.4%, 39.9%, 32.6% and 50.0% for TGW, PC, AC and SC, respectively. The heritability estimates in present study were much lower than these ones exhibited differences from these findings. But, Yağdı and Sözen [41] estimated lower heritability values for TGW, GC, PC and TW than that of ours.

Correlations among Traits: Nearly all correlations among traits except correlation between AC and SC were significant (Table 3). Whereas PC showed positive significant correlations with WGC (0.708), SC (0.492) and VG (0.445), negative significant relations of PC were determined with TGW (-0.773**), TW (-0.539**) and AC (-0.446**). Rharrabti *et al.* [42], Eslami *et al.* [43] and El-Khayat *et al.* [44] reported that positive correlations among PC, WGC, SC and VG. The degree of vitreousness of durum wheat grains are related to protein composition of the grains [45], this observation was to be expected. Grain physical quality of durum wheat, which depends on TGW and TW influence the semolina production [6]. Oak *et al.* [46] reported similar relations for PC, TGW and TW.

VG was positively correlated with SC (0.392**) and both traits showed significant correlations with WGC and PC. Thus, it appears that increasing for VG and SC could lead to increases in PC under the conditions of our study.

The significant and negative correlation coefficient (-0.288) was observed between PC and GY. This relationship had been encountered in barley [47], in spring wheat [48], in durum wheat [49] and in triticale [50]. This negative association between PC and GY mainly caused from dilution of protein by non-nitrogen compounds in the grain [51].

CONCLUSIONS

The availability of significant genetic variability concerning SC, TGW, VG, AC and PC in population points out that selection might be conducted taking into consideration these traits in direction of increases or reductions. Genotypic main effects were found to have a significant on semolina traits, but contributed a smaller proportion of variability as compared with either environment or genotype x environment interaction effects. The high variance ratio from 1.0, heritability (89.4%) coupled with high genetic advance (23.6%) of SC suggested that selection could be successfully practised for that trait. The results of our correlation analyses indicate that VG should be considered as a selection criterion for future durum wheat quality breeding programmes.

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REFERENCES

1. Ada, H., 1993. Durum Wheat (*Triticum durum* Desf.) Production under Thrace and Marmara Region Ecological Conditions. Ankara Univ., Graduate School of Natural and Applied Sciences. Master Thesis. pp: 140. (In Turkish)
2. Clarke, J.M., 2001. Improvement of durum wheat grain quality: Breeding. Durum wheat, semolina and pasta quality. Workshop, 27 November 2000, Montpellier, France, 99: 27-54.
3. Dexter, J.E. and N.M. Edwards, 1998. The implications of frequently encountered grading factors on the processing quality of durum wheat. Association of Operative Millers Bulletin, October, pp: 7165-7171.
4. Dexter, J.E. and B.A. Marchylo, 2000. Recent trends in durum wheat and pasta processing. Impact on Durum Wheat Quality Requirements. In: Durum wheat, semolina and pasta quality. Recent achievements and New Trends. Proceeding of the International Workshop, Montpellier 27 November 2000, Institute National of Research Agronomy, Montpellier, pp: 77-101.
5. Abecassis, J., 1991. Nouvelles possibilities d'apprecier la valeur meuniere et la valeur semouliere des bles. Ind. Cereales, 81: 25-37. (In French).
6. Novaro, P., F. Colucci, G. Venora and M.G. D'egidio, 2001. Image analysis of whole grains: a non-invasive method to predict semolina yield in durum wheat. Cereal Chem., 89: 217-221.
7. Dexter, J.E. and R.R. Matsuo, 1981. Effect of starchy kernels, immaturity and shrunken kernels on durum wheat quality. Cereal Chem., 58: 395-400.
8. D'Egidio, M.G., B.M. Mariani, S. Nardi, P. Novaro and R. Cubadda, 1990. Chemical and technological variables and their relationships: A predictive equation for pasta cooking quality. Cereal Chem., 67: 275-281.
9. Clarke, J.M., B.A. Marchylo, M.I.P. Kovacs, J.S. Noll, T.N. McCaig and N.K. Howes, 1998. Breeding durum wheat for pasta quality in Canada. Euphytica, 100: 163-170.
10. Pomeranz, Y., 1987. Grain Quality. In: Modern Cereal Science (ed. Y. Pomeranz). pp: 72-149. New York: VCH Publishers.
11. Kovacs, M.I.P., L.M. Poste and G. Butler, 1997. Durum wheat quality: Comparison of chemical and rheological screening tests with sensory analysis. J. of Cereal Sci., 25: 65-75.
12. Troccoli, A., G.M. Borreli, P. De Vita, C. Fares and N. Di Fonzo, 2000. Durum wheat quality: a multidisciplinary concept. Journal of Cereal Sci., 32: 99-113.
13. Sharma, R., M.J. Sissons, A.J. Rathjen and C.F. Jenner, 2002. The null-4A allele at the waxy locus in durum wheat affects pasta cooking quality. J. of Cereal Sci., 35: 287-297.
14. Peterson, C.J., R.A. Graybosch, P.S. Baenziger and A.W. Grombacher, 1992. Genotype and environment effects on quality characteristics of hard red winter wheat. Crop Sci., 32: 98-103.
15. Peterson, C.J, R.A. Graybosch, D.R. Shelton and P.S. Baenziger, 1998. Baking quality of hard winter wheat: Response of cultivars to environment in the Great Plains. Euphytica, 100: 157-162.
16. Fisher, R.A., L. O'brien and K.J. Quail, 1989. Early generation selection in wheat. II. Grain quality. Aust. J. Agric. Res., 40(6): 1133-1142.
17. Baker, R.J., K.H. Tipples and A.B. Campbell, 1971. Heritabilities of and correlations, among quality traits in wheat. Can. J. Plant Sci., 51: 441-448.
18. Anonymous, 2002. Turkish State Meteorolical Service Reports.
19. Anonymous, 1980a. ICC-Standart No: 105. Method for the determination of crude protein in cereals and cereal products for food and for feed.
20. Anonymous, 2000. Approved Methods of the AACC, 10th end. Methods 55-10. American Association of Cereal Chemistry. St Paul, MN:AACC.
21. Anonymous, 1980b. ICC Standart No: 129. Method for the Determination of the Vitreousness of Durum Wheat. Standard Methods of the International Association for Cereal Chemistry (ICC). Verlag Moritz Schafer. Detmold.
22. Anonymous, 1990a. ICC Standard Method No: 104/1. Determination of Ash in Cereals and Cereal Products. Standart Methods of the International Association for Cereal Chemistry (ICC). Verlag Moritz Schafer. Detmold.
23. Anonymous, 1984. ICC Standard No. 106/2. Working Method for the Determination of Wet Gluten in Wheat Flour. Standard Methods of the International Association for Cereal Chemistry (ICC). Verlag Moritz Schafer. Detmold.
24. Anonymous, 1990b. ICC Standard No. 152. Determination of the yellow pigment content of durum wheat semolina and flour. Standard Methods of the International Association for Cereal Chemistry (ICC). Verlag Moritz Schafer. Detmold.

25. Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 7th ed., Iowa State Univ. Press, pp: 593.
26. Johnson, H.W., H.F. Robinson and R.I. Comstock, 1955. Estimates of genetic and environmental variability in soybeans. Agron. J., 47: 314-318.
27. Wegrzyn, S., T. Wojas and T. Smialowski, 2002. Genetic conditioning and mutual relations between the yield and selected functional characters in winter wheat (*Triticum aestivum* L.). Biul. IHAR, 223/224, pp: 77-86 (In Polish).
28. Dotlacil, L., J. Hermuth, Z. Stehno and M. Manev, 2000. Diversity in European winter wheat landraces and obsolete cultivars. Czech. J. Genet. Plant Breed. 16: 29-36.
29. Lerner, S.E., M. Cogliatti, N.R. Ponzio, M.L. Seghezzo, E.R. Molfese and W.J. Rogers, 2004. Genetic variation for grain protein components and industrial quality of durum wheat cultivars sown in Argentina. J. of Cereal Sci., 40: 161-166.
30. Paul, A.K., M.A. Islam, M.J. Hasan, M.M.H. Chowdhury and A.Z.M.K.A. Chowdhury, 2006. Genetic variation of some morpho-physiological characters in *Triticum durum* Wheat. Int. J. Sustain. Agric. Tech., 2(8): 11-14.
31. Allard, R.W., 1960. Principles of Plant Breeding. John Wiley and Sons. Inc., New York.
32. Falconer, D.S., 1985. Introductions to Quantitative Genetics. Longman, London.
33. Falconer, D.S. and T.F.C. Mackay, 1996. Introduction to Quantitative Genetics. 4th Edn., Benjamin Cummings, England, ISBN-10: 0582243025.
34. Toker, C., 2004. Estimates of broad-sense heritability for seed yield and yield criteria in faba bean (*Vicia faba* L.). Hereditas, 140: 222-225.
35. Larik, A.S., H.M.I. Hafiz and A.M. Khushk, 1989. Estimation of genetic parameters in wheat populations derived from intercultivaral hybridization. Pakphyton, 1: 51-56.
36. Clarke, J.M., F.R. Clarke, N.P. Ames, T.N. Mccaig and R.E. Knox, 2000. Evaluation of predictors of quality for use in early generation selection. In: Durum Wheat Improvement in the Mediterranean Region: New Challenges, Eds. C Royo, MM Nanchit, N Di Fonzo, JL Araus. Serie A: Seminaires Mediterraneennes, No. 40. Zaragoza, Espana: Instituto Agronomico Mediterraneo de Zaragoza, pp: 439-446.
37. Bilgin, O., I. Baser, K.Z. Korkut, T. Genctan, A. Balkan and N. Sağlam, 2009. Variations for grain yield and milling value of durum wheat landraces and obsolete cultivars. Philipp. Agric. Scientist, 92(1): 25-32.
38. Johnston, R.A., J.S. Quick and J.J. Hammond, 1983. Inheritance of semolina colour in six durum wheat crosses. Crop Sci., 23: 607-610.
39. Budak, N., 2000. Heritability, correlation and genotype x year interactions of grain yield, test weight and protein content in durum wheats. Turk. J. Field Crops, 5(2): 35-41.
40. Akçura, M., 2009. Genetic variability and interrelationship among grain yield and some quality traits in Turkish winter durum wheat landraces. Turk. J. Agric. For., 33: 547-556.
41. Yağdi, K. and E. Sözen, 2009. Heritability, variance components and correlations of yield and quality traits in durum wheat (*Triticum durum* Desf.). Pak. J. Bot., 41(2): 753-759.
42. Rharrabti, Y., D. Villegas, C. Royo, V. Martos Nunez and L.F. Garcia Del Moral, 2003. Durum wheat quality in Mediterranean environments. II: Influence of climatic variables and relationships between quality parameters. Field Crops Res., 80: 133-140.
43. Eslami, M., S.A.M. Mirmohammady Maibody and A. Arzani, 2005. Evaluating grain quality traits and their heritabilities in durum wheat genotype. J. Sci. and Technol. Agric. and Natur. Resour., 9(3): 129. (In Persian).
44. El-Khayat, G.H., J. Samaan, F.A. Manthey, M.P. Fuller and C.S. Brennan, 2006. Durum wheat quality. I: Some physical and chemical characteristics of Syrian durum wheat genotypes. Int. J. Food Sci. Techn., 41(2): 22-29.
45. Dexter, J.E., B.A. Marchylo, A.W. Macgregor and R. Tkachuk, 1989. The structure and protein composition of vitreous, piebald and starchy durum wheat kernels. J. of Cereal Sci., 10: 19-32.
46. Oak, M.D., S.A. Tamhankar, V.S. Rao and S.B. Bhosale, 2004. Assessment of commercial, technological and kernel characteristics of Indian durum wheat (*Triticum durum*). Indian Journal of Agricultural Sci., 74(2): 68-72.
47. Yoshida, T., 1976. Relation between yield and protein content of barley. Barley Genetics Newsletter, II. Research Notes, 6: 87-89.

48. Campbell, C.A., H.R. Davidson and G.E. Winkelman, 1981. Effect of nitrogen, temperature, growth stage and duration of moisture stress on yield components and protein content of Manitou spring wheat. Can. J. Plant Sci., 61: 549-563.
49. Rharrabti, Y., S. Elhani, V. Martos Nunez and L.F. Garcia del Moral, 2000. Relationship between some quality traits and yield of durum wheat under Southern Spain conditions. In: Royo, C., Nachit, M., di Fonzo, N. and J.L. Araus (Eds.), Durum Wheat Improvement in the Mediterranean Region: New Challenges, 40, Options Mediterraneennes, pp: 529-531.
50. Garcia Del Moral, L.F., A. Boujenna, J.A. Yariez and J.M. Ramos, 1995. Forage production, grain yield and protein content in dual-purpose triticale grown for both and forage. Agron. J., 87: 902-908.
51. Pleijel, H., L. Mortensen, J. Fuhrer, K. Ojanpera and H. Danielsson, 1999. Grain protein accumulation in relation to grain yield of spring wheat (*Triticum aestivum* L.) grown in open-top chambers with different concentrations of ozone, carbon dioxide and water availability. Agric. Ecosys. Environ., 72: 265-270.
00. Matsuo, R.R., 1988. Evaluation of durum wheat, semolina and pasta in Canada. ln: *Durum Wheat: Chemistry and Technology,* Fabrini, *G.* and Lintas, C. (eds) AA", St. Paul, Minnesota.