Pak. J. Bot., 43(1): 253-260, 2011.

GENETIC VARIATION AND INTER-RELATIONSHIP OF SOME MORPHO-PHYSIOLOGICAL TRAITS IN DURUM WHEAT (*TRITICUM DURUM* (L.) DESF.)

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Abstract

In this study which was performed with 20 durum wheat genotypes at three locations during two crop seasons. The relative large variations were observed for the characters except test weight and days to 50% flowering. The highest heritability and expected genetic advance values were estimated in plant height (92.8%-9.84) and 1000 grain weight (90.2%-5.96). The lowest value of heritability and expected genetic advance were obtained for grain yield (51.4%-0.94) and test weight (63.8%-2.41).

Grain yield was positive and significantly correlated with grain weight/spike, test weight, plant height, grains/spike, spikelets/spike, 1000 grain weight and spike length whereas it showed negative and important correlation coefficient with days to 50% flowering. The highest direct positive effect (0.3857) on yield was computed for grain weight/spike. On the other hand, days to 50% flowering and spike length had negative direct effect on yield.

Although grain weight/spike should be emphasised as reliable selection criteria, grains/spike, 1000 grain weight, plant height and earliness might be considered as indirect selection criterion for improvement in durum wheat yield potential.

Introduction

The genetic variance, genetic gain and heritability estimations are of great importance in plant breeding programmes. Plant breeders estimate genetic variances in their populations so that they can predict the response to selection, determine the best selection and breeding procedure for the populations. The magnitude of heritable variability and more particularly its genetic components is clearly the most important aspects of the genetic constitution of the breeding material, which has a close bearing on its response to selection (Falconer & MacKay, 1996). It is necessary to separate the total variation into heritable and non-heritable components with the help of genetic parameters i.e. genotypic and phenotypic coefficient of variation, heritability and genetic advance (Paul *et al.*, 2006), and the knowledge of the genetic association between grain yield and its components can help the breeders to improve the success and efficiency of the selection. Thus, it is important to study the relationships among the traits and to find their direct and/or indirect effects on grain yield.

The simplest way for the prediction of the variance components is the experimentation of a large number of genotypes for two or more years and at two or more locations (Mayo, 1980). The knowledge of genetic variability, the nature and the extent of association of various component characters with the yield are, therefore, important for genetic improvement of yield and other characters. Considering these facts, the present study was undertaken to measure the genetic variability, heritability, genetic advance and the genotypic correlation for the traits. The path-coefficient analysis for grain yield was carried out to partition the genetic correlation coefficients into direct and indirect effects.

Materials and Methods

Plant materials: The genetic material of durum wheat (17 lines), which was taken from macro-selection trials (DWL-1, DWL-2, DWL-3, DWL-4, DWL-5, DWL-6, DWL-7, DWL-8, DWL-9, DWL-10 and DWL-11) and developed by mutation (DWM-16, DWM-23, DWM-31, DWM -34, DWM-43 and DWM-47) and 3 check varieties (Tunca-79, Kızıltan-91 and Epidur) were evaluated in the study.

Cite characteristics: The study were carried out at Edirne (26^{o}35' E, 41^{o}38' N and elev. 32 m), Tekirdağ (27^{o}34' E, 40^{o}59' N and elev. 10 m) and Lüleburgaz (27^{o}16' E, 41^{o}22' N and elev. 41 m) locations of the Thrace Region during two consecutive growing years (2001-2002 and 2002-2003).

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 513.4-422.3 mm, 486.2-450.7 mm, 380.4-486.2 mm in both experimental years (Anon., 2003).

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 data for plant height (PH), spike length (SL), spikelets /spike (S/S), grains/spike (G/S), grain weight /spike (GW/S), 1000 grain weight (TGW), test weight (TW), days to 50% flowering (DF) and grain yield (GY) were recorded for each experimental unit.

Randomly combined analysis of variance on characters data from trials in 3 locations during 2 years was worked out according to the method given by Comstock & Moll (1963). The variance components, phenotypic and genotypic coefficient of variation (PCV and GCV) were computed as suggested by Singh & Choudhury (1985). Heritability and genetic advance were calculated. Genotypic (GCV) and phenotypic (PCV) correlation coefficients were determined according to Kwon & Torrie (1964). Path analysis, which measures direct and indirect effects of each character, was performed as the method of Dewey & Lu (1959) suggested, as detailed below:

PCV = (Phenotypic variance / mean value of the trait) x 100
GCV = (Genotypic variance / mean value of the trait) x 100
h^2_{BS} = (Genotypic variance / phenotypic variance) x 100
GA = k x (Phenotypic variance)$^{0.5}$ x h^2_{BS}
Where 'k' is selection intensity at 5 % level (value = 2.06)

$r_g = Cov_{ij}.Var_{gi}.Var_{gj}$.
Where, r_g = Genotypic correlation coefficient
Cov_{ij} = Genotypic covariance of i^{th} ad j^{th} trait
Var_{gi} = Genotype variance of i^{th}trait
Var_{gj} = Genotype variance of j^{th} trait

Results and Discussion

The variance of the genotypes, genotype x environment interaction and error and the variations displayed by the characters in this study were put forward in Table 1. The genotypic and genotype x environment interaction variances were significant for all characters measured. In general, genotypic variances were higher than G x E variances. The relative large variations were observed for the characters except test weight and days to 50% flowering (Table 1). The variation was large enough to imply that populations could produce suitable genotypes to be utilized in intensive breeding programs. The highest coefficient of variation (CV) was shown by grain weight/spike, followed by grains/spike, grain yield and spike length. Dotlacil *et al.,* (2000) considered a minimum 10% CV a sign of wide diversity in wheat. Thus, The genetic material used are amendable to visual selection for improving grain yield for relative large variations in which grain weight/spike, grains/spike, grain yield and spike length, spikelets/spike, 1000 grain weight, and plant height (Table 1).

The most important variance components for defining adaptation strategy and yield stability targets are those relating to genotypic and genotype-environment effects (Annicchiarico, 2002). The highest genotypic and genotype x environment interaction variances were predicted in plant height, days to 50% flowering, grains/spike and 1000 grain weight. The high genotypic variance indicates that selection can be successfully applied in this population (Allard, 1960) in terms of these characters. However, the existence of the quite high genotype x environment interaction variances point out that selection should be carried out in more environments and it is inevitable to improve different cultivars for every environment (Falconer, 1985).

Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), estimates of the components of variance, broad-sense heritability and genetic advance are shown in Table 2. The PCV was generally higher than the GCV for all traits. But, the differences between PCV and GCV were high for grains/spike and grain yield. This denotes that environmental factors mainly influencing their expression. However, the narrow difference between PCV and GCV for the other characters implied that their relative resistance to annual and regional climatic alteration.

Table 1. Phenotypic variation and mean squares in 9 characters of the durum wheats.

	Range	Mean	S.E. (±)	CV %	MS G	MS GxE	MS Error
Plant height	67.0-110.0	84.4	0.4058	9.127	480.892**	64.785**	1.901
Spike length	4.7-10.4	7.41	0.0552	14.150	6.540**	1.049**	0.055
Spikelets/spike	13.0-25.0	19.8	0.1039	9.986	26.564**	5.707**	0.349
Grains/spike	14.0-66.0	38.2	0.3756	18.645	246.817**	88.881**	3.931
Grain weight/spike	0.82-3.75	1.90	0.0193	19.282	1.244**	0.194**	0.046
1000 grain weight	34.2-62.0	46.1	0.2275	9.367	166.008**	18.746**	0.488
Test weight	71.14-84.87	79.3	0.1242	2.972	44.688**	9.510**	0.172
Days to 50% flowering	163.0-198.0	178.7	0.3641	3.866	394.709**	14.426**	0.515
Grain yield	1.50-8.45	5.47	0.0435	15.114	1.272**	0.707**	0.263

Table 2. Phenotypic (PCV) and genetic coefficient of variation (GCV), components of variance, broad-sense heritability (h^2_{BS}) and genetic advance (GA) for the characters of 20 durum wheat genotypes.

	Estimates of components of variance*			PCV (%)	GCV (%)	h^2_{BS} (%)	GA
	σ^2_{ph}	σ^2_{g}	σ^2_{e} /r				
Plant height	26.5382	24.6167	0.6338	31.4	29.2	92.8	9.84
Spike length	0.4008	0.3438	0.0183	5.4	4.6	85.8	1.12
Spikelets/spike	1.1298	0.8762	0.1162	5.7	4.4	77.6	1.70
Grains/spike	37.6535	24.3566	1.3104	98.6	63.8	64.7	8.18
Grain weight/spike	0.1034	0.0716	0.0152	5.4	3.8	69.3	0.46
1000 grain weight	10.2859	9.2723	0.1626	22.3	20.1	90.2	5.96
Test weight	3.3625	2.1438	0.0573	4.2	2.7	63.8	2.41
Days to 50% flowering	9.6997	6.5704	0.1717	5.4	3.7	67.7	4.35
Grain yield	0.7887	0.4050	0.0877	14.4	7.4	51.4	0.94

* σ^2_{ph}, σ^2_{g} and σ^2_{e} /r: phenotypic, genetic and error variance of genotype means, respectively.

The variation exhibited by the 20 durum wheat genotypes in grain yield and its components except test weight, days to 50% flowering indicates that selection for these traits might be effective. Selection efficiency, however, is related to magnitude of heritability and genetic advance (Johnson *et al.*, 1955). In this study, low to high estimates of heritability were observed for the characters. Among estimates of heritability and genetic advance (Table 2), grain weight/spike and test weight exhibited moderate broad sense heritability with low genetic advance (69.3-0.46 and 63.8-2.41, respectively). Moderate heritability estimates suggested that selection should be delayed to more advance generations for these characters. Low genetic advance indicates slight changes of improvement of these traits in subsequent generations as discussed by Teich (1984), and Chaturvedi & Gupta (1995). The highest heritability values (92.8% and 90.2%) coupled with high genetic advance (9.84 and 5.96) were observed for plant height and 1000 grain weight similar with the findings of Khan & Bajwa (1993), and Ajmal et al. (2009). Besides, days to 50% flowering showed moderate heritability (67.7%) and relatively high genetic advance (4.35). These estimates reflect the possibility of effective selection for this trait. Spike length and spikelets/spike displayed high heritability values (85.8% and 77.6%) with low genetic advance (1.12 and 1.70) in conformity with the findings of Ul-Haq *et al*., (2008). In addition to this, grains/spike exhibited moderate heritability (64.7%) with high expected genetic advance (8.18). This present result is in accordance with the earlier findings of Ahmed *et al*., (2007). As in many other crops, the low heritability estimate (51.4%) with low genetic advance (0.94) was observed for grain yield (Table 2) indicating low transfer of this in the subsequent generations similar in agreement with the findings of Pathak & Nema (1985), Belay *et al.,* (1993), Budak (2000), Kashif & Khaliq (2004). The fact that these low heritability estimates are usually lower than other traits in wheat suggests that environmental effects constitute a major portion of the total phenotypic variation for these traits. Therefore, selection of superior genotypes on the basis of these characters would not be as effective as selection for plant height, 1000 grain weight and grains/spike. The results are supported by the findings of Paul *et al.,* (2006) (Table 2)

Genotypic correlations for all possible combinations for characters under study were calculated and presented in Table 3. A review of Table 3 denoted that plant height showed positive and significant correlation with 1000 grain weight, test weight and grain yield. It was supported by findings of Kole (2006). Plant height correlated negative and significant with days to 50% flowering and spike length. Hence, the lesser plant height is to be more spike length and lower grain filling period in durum wheat. Similar results were found by Akram *et al*., (2008) and Gashaw *et al*., (2007).

The genotypic correlations among the spike characteristics, namely spike length, spikelets/spike, grains/spike and grain weight/spike, and with grain yield were positive and significant implying that one or more of the spike characteristics could result in high grain yield. These findings are supported by the findings of Zecevic *et al*., (2004) and Tazeen *et al.,* (2009).

The characters related to grain largeness and influencing semolina production (Novaro *et al*., 2001), which are 1000 grain weight and test weight, were positively correlated and with plant height and grain yield similar with the finding of Budak (2000) and Yağdı & Sözen (2009). In addition to this, two characters showed negative correlation with days to 50 flowering. Based on these results, it is recommended that 1000 grain and test weight should be taken into consideration by the durum wheat breeders for high yield and semolina production.

The correlation coefficients of grain yield hectare with nearly all characters studied except days to 50 flowering were positive and important, implying that improving one or more of the characters could result in high grain yield for durum wheat. These results are substantiated with those of Bilgin *et al*., (2008), and Yağdı & Sözen (2009). On the contrary, grain yield had strong negative correlation with days to 50 flowering, suggesting that selection early heading genotypes with long grain filling period would give high yield under semi-arid conditions in conformity with the observations of Paul *et al*., (2006), (Table 3).

Correlation estimates are helpful in determining the components of a complex trait, such as grain yield, being the complex outcome of different characters, they do not provide an exact picture of the relative importance of direct and indirect influences of each of the components characters towards this trait (Bhatt, 1973). Path analysis is to be a useful tool for understanding grain yield formation and provides valuable additional information for improving grain yield via selection for its components (Garcia del Moral *et al*., 2003).

Table 3. Genotypic correlation coefficients among the characters of 20 durum wheat genotypes.

	Spike length (cm)	Spikelets/spike (no)	Grains/spike (no)	Grain weight/spike (g)	1000 grain weight (g)	Test weight ($kg*hl^{-1}$)	Days to 50% flowering (days)	Grain yield ($t*ha^{-1}$)
Plant height	-0.177**	0.051	-0.072	-0.011	0.231**	0.191**	-0.276**	0.215**
Spike length		0.449**	0.649**	0.422**	-0.104	-0.064	0.326**	0.109*
Spikelets/spike			0.381**	0.307**	-0.005	0.032	0.095	0.199**
Grains/spike				0.658**	-0.103	-0.023	0.198**	0.209**
Grain weight /spike					0.103	0.102	0.198**	0.389**
1000 grain weight						0.273**	-0.054	0.127*
Test weight							-0.162**	0.239**
Days to 50% flowering								-0.268**

$r_{(P\leq0.05)}$ = 0. 0.106; $r_{(P\leq0.01)}$ = 0.138

Table 4. Direct (diagonal) and indirect effects matrix (dependent variable is grain yield) relating to plant height (PH), spike length (SL), spikelets/spike (S/S), grains/spike (G/S), grain weight /spike (GW/S), 1000 grain weight (TGW), test weight (TW) and days to 50% flowering (DF) .

Characters	PH	SL	S/S	G/S	GW/S	TGW	TW	DF
PH	**0.0818**	0.0068	0.0069	-0.0018	-0.0026	0.0059	0.0208	0.0949
SL	-0.0138	**-0.0403**	0.0398	0.0153	0.1460	-0.0027	-0.0061	-0.0861
S/S	0.0059	-0.0168	**0.0955**	0.0085	0.1088	0.0001	0.0018	-0.0121
G/S	-0.0064	-0.0273	0.0358	**0.0226**	0.2380	-0.0019	-0.0014	-0.0535
GW/S	-0.0006	-0.0153	0.0269	0.0140	**0.3857**	0.0025	0.0124	-0.0520
TGW	0.0171	0.0039	-0.0001	-0.0015	0.0337	**0.0281**	0.0364	0.0040
TW	0.0125	0.0018	0.0012	-0.0002	0.0350	0.0075	**0.1361**	0.0395
DF	-0.0275	-0.0123	0.0041	0.0043	0.0710	-0.0004	-0.0190	**-0.2822**

The direct and indirect effects of the eight grain yield-related characters are shown in Table 4. The investigated characters out of days to 50% flowering and spike length showed positive direct effects on grain yield. The highest direct effects of grain weight/spike and test weight were positive showing a computed path coefficient values of 0.3857 and 0.1361, respectively. The other high positive direct effects were obtained in spikelets/spike (0.0955) and plant height (0.0818). The genotypic correlations between grain yield and spikelets/spike, grains/spike, 1000 grain weight and test weight were moderate and positive (Table 3). The positive influences on grain yield were largely a reflection of positive indirect effects by those characters through grain weight/spike. The effect of days to 50% flowering on grain yield was highly negative. Whereas the correlation between spike length and grain yield was positive and important, direct effect of it on yield was negative as explained by Zecevic *et al*., (2004). This negative direct effect on yield was registered indirectly by spike length through days to 50% flowering.

Both, the genotypic correlation and path coefficient analyses carried out in our experiment suggested that grain weight/spike is important primary component of yield for durum wheat and main spike characteristics such as spikelets/spike, grains/spike and plant height, 1000 grain weight, test weight might and days to 50% flowering be considered as secondary components of yield. It would, thus appear that progress in yield improvement could accrue by selecting for mainly spike characters (Martincic *et al.,* 1996), rather than for yield per se alone, (Table 4).

Conclusion

In this study, highly significant genotypic differences were observed among the lines for various characters measured. The relative large variations were observed for the characters except test weight and days to 50% flowering.

The highest heritability values (92.8% and 90.2%) coupled with high genetic advance (9.84 and 5.96) were observed for plant height and 1000 grain weight. As in many other crops, the low heritability estimate (51.4%) with low genetic advance (0.94) was observed for grain yield.

The genetic correlation analysis indicated that positive and important relations were found between grain yield and grain weight/spike, test weight, plant weight, grains/spike, spikelets/spike, 1000 grain weight and spike length. Days to 50% flowering showed negative and important correlation coefficient with grain yield.

The path analysis gave a somewhat different picture from what the genotypic correlation analysis did. For instance, spike length showed positive and important genotypic correlation with grain yield, but path coefficient analysis suggested that spike length had direct negative effect on grain yield. On the contrary, path analysis verified some result of correlation analysis as in case of grain weight/spike. Grain weight/spike showing the highest genotypic correlation with grain yield was found as the most reliable yield component according to analysis of path coefficient.

The characters intercorrelated with grain yield like grains/spike, plant height and 1000 grain weight had comparatively high PCV, GCV, heritability and genetic advance, so more emphasis on these characters can be given during the selection process to increase yield.

Acknowledgment

We acknowledge financial support from Agriculture, Forestry and Food Technologies Research Grant Committee of The Scientific and Technical Research Council of Turkey. Thrace Agricultural Research Institute deserve gratitude for helping in the carrying the experiments.

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(Received for publication 6 September 2008)