*Pak. J. Bot.*, 41(2): 753-759, 2009.

# HERITABILITY, VARIANCE COMPONENTS AND CORRELATIONS OF YIELD AND QUALITY TRAITS IN DURUM WHEAT (*TRITICUM DURUM* DESF.)

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**Abstract**

This study was carried out during the years 2001 and 2004 to determine the inheritance of important agronomical and quality traits and also the correlations between these traits in durum wheat. The research, studies concluded that genotypical variance is important with regard to spike length, number of spikelet per spike and test weight and that the useful selections could be made with respect to these traits. Environmental variance was found important for seed number per spike, seed weight per spike and thousand kernel weight, while the variance component of genotype x environment was found important for seed yield, gluten content and protein content. Environmental and genotype x environment variances were determined to be important for SDS-sedimentation.

The estimated values of broad-sense heritability were found between 0.72% and 30.43%. Sedimentation had the lowest heritability value, whereas spike length had the highest. Heritability values determined were 6.35%, 9.38%, 6.13%, 5.26%,9.45% and 3.12% for plant height, number of spikelet per spike, seed number per spike, seed weight per spike, thousand kernel weight and seed yield, respectively. The test weight had the highest heritability value (17.69%) among the quality traits, followed by gluten content and protein content with 10.12% and 5.38%, respectively.

Significant positive correlation was determined between the seed yield, plant height and spike length. The negative and significant correlations determined between gluten content and seed number per spike, seed weight per spike and plant density, as well as between the sedimentation and number of spikelet per spike and seed number per spike and between protein content and seed number per spike indicated that generally the important agronomical characteristics were inversely correlated with the quality traits.

## Introduction

Durum wheats carry a great importance as the raw material of numerous foods such as macarony and semolina in the allimentation of world population. Turkey and Middle East countries in which durum wheats have been grown for a long time are known as the conventional growers of these products. However, durum wheat cultivation areas have gradually decreased in these countries due to the wrong price policies as well as the fact that high yield durum wheat cultivars which can compete with bread wheats (*T.aestivum* L.) have not been developed. Therefore, plant breeders should increase their efforts directed towards developing new cultivars. It is of great importance for the wheat breeders to know the heritabilities of agronomical and quality characteristics to improve the yield and quality effectively (Baker *et al*., 1971). However, these traits is influenced by the genotype and environment and because of the polygenic nature of the characteristics involved (Gaines *et al*., 1996, Novoselovic *et al*., 2004). Furthermore, correlations and genotype x environment interactions that exist among characteristics, makes progress using conventional breeding procedures even more diffucult (Barnard *et al*., 2002).

Broad-sense heritability is defined as the ratio of genotypical variance to the phenotypical one. In such a type of heritability, it is accepted that genotype and environmental effects will form the phenotype together. Therefore, heritability is the combined result of population and environmental conditions, rather than a character dependent trait. In general, heritability is low for the characteristics with agronomical importance since these characteristics are influenced by a large number of genes. Heritability is a parameter which is widely used in the establishment of breeding programs and formation of selection indexes (Falconer, 1985). Knowing the correlations between the traits is of great importance for success in selections to be conducted in breeding programs. The analysis of correlation coefficient is the most widely used one among numerous methods that can be used for this purpose.

The aim of this study was to determine the heritabilities of agronomical and quality traits and relationship among these in durum wheat.

## Material and Methods

This study was carried out in the Research and Application Center of Faculty of Agriculture, Uludağ University (Bursa / Turkey) between the years of 2001 and 2004. Eleven different durum wheat genotypes were used as plant material. Ten advenced lines (> $F_{11}$) which were obtained through the hybridisation of 3 land races collected from different regions of Turkey and 1 cultivar of CIMMIYT origin (Buck-Balcarce/ Barrigon-Yaqui-nano*2/Tehucan-60) and Gediz cv. (Ld-357-E/2*Tehucan-60//(Sıb)Jorı) in these genotypes. The values of cumulative precipitation recorded along the plant growth period (November-July) were 535.6 mm, 461.5 mm and 555.7 mm, respectively, for 2001/2002, 2002/2003 and 2003/2004 in Bursa (Anon., 2004). The soils of the center were mostly heavy textured, in alkaline pH and in low salt concentration. Contents of organic matter, nitrogen, phosphorus, potassium, calcium, magnessium, iron, copper and manganese were quite higher than the required level (Ozguven & Katkat, 1997).

Agronomical traits such as plant height, spike length, number of spikelet per spike, number of seeds per spike, seed weight per spike, thousand kernel weight, plant density and seed yield were examined, as well as the quality traits such as test weight (hectolitre mass), gluten content, protein content and SDS-sedimentation . The experiment was arranged in a randomized complete block design with three replications. Eight rows of five meter length and 15 cm apart were grown for each genotype in each replication. Analysis of variance and its components were realized according to Comstock & Moll (1963) and Fehr (1987) and analysis of phenotypical correlation coefficient according to Steel & Torrie (1980).

## Results

The results of variance components determined from the means of three years are given in Table 1, the minimum, maximum and average values of these traits are given in Table 2. The traits with which the genotypical variance was found significant were mainly spike length, number of spikelet per spike and test weight. The environmental (the year) variance was found significant in seed number per spike, seed weight per spike and thousand kernel weight. The traits with which genotype x environment interaction was found significant were seed yield, gluten content and protein content. For SDS-sedimentation was found significant in both environment and genotype x environment variance component (Table 1).

**Table 1. Analysis of variance of traits in durum wheat (Mean Squares).**

| Source | DF | PH | SL | STNPS | SNPS | SWPS | TKW |
|---|---|---|---|---|---|---|---|
| Year | 2 | 178.97 | 0.32 | 38.43 | 881.01** | 3.11* | 88.42* |
| Replication | 6 | 43.18 | 0.64 | 0.67 | 56.78 | 0.13 | 13.60 |
| Genotype | 10 | 60.21 | 2.15** | 5.76* | 59.41 | 0.16 | 16.78 |
| Genotype x year | 20 | 36.61 | 0.26 | 2.31 | 25.94 | 0.08 | 7.60 |
| Error | 60 | 32.18 | 0.45 | 2.52 | 29.37 | 0.09 | 6.54 |
| **Source** | **DF** | **PD** | **SY** | **GC** | **SED** | **PRO** | **TW** |
| Year | 2 | 27851 | 21751 | 156.58 | 202.18* | 6.44 | 1.50 |
| Replication | 6 | 10499* | 9426 | 2.10 | 1.97 | 0.13 | 0.63 |
| Genotype | 10 | 1576 | 17518 | 78.13 | 55.12 | 2.34 | 3.97* |
| Genotype x year | 20 | 3592 | 14905** | 55.33** | 53.62** | 1.93** | 1.67 |
| Error | 60 | 4212 | 5366 | 1.38 | 1.81 | 0.15 | 0.95 |

*, ** =Significant at 0.05 and 0.01 level, respectively.

| | | | | | |
|---|---|---|---|---|---|
| PH | : | Plant height | PD | : | Plant density |
| SL | : | Spike length | SY | : | Seed yield |
| SPNPS | : | Spikelet number per spike | GC | : | Gluten content |
| SNPS | : | Seed number per spike | SED | : | Sedimentation |
| SWPS | : | Seed weight per spike | PRO | : | Protein content |
| TKW | : | Thousand kernel weight | TW | : | Test weight |

**Table 2 .Average, minumum and maximum values for durum wheat genotypes. (average of three years)**

| Traits | Average | Minumum | Maximum |
|---|---|---|---|
| Plant height | 85.43 | 80.79 | 89.59 |
| Spike length | 7.07 | 6.30 | 7.71 |
| Spikelet number per spike | 19.86 | 18.20 | 20.72 |
| Seed number per spike | 39.80 | 36.38 | 45.63 |
| Seed weight per spike | 1.92 | 1.76 | 2.21 |
| Thousand kernel weight | 45.55 | 43.40 | 47.66 |
| Plant density | 420.03 | 397.59 | 444.24 |
| Seed yield | 4608.60 | 3882.30 | 5178.10 |
| Gluten content | 20.08 | 17.29 | 25.87 |
| Sedimentation | 22.88 | 20.00 | 27.22 |
| Protein | 11.23 | 10.65 | 12.28 |
| Test weight | 81.26 | 80.32 | 82.58 |

According to the means of three years, spike length was determined between 6.30 and 7.71 cm (average 7.07 cm ) and number of spikelet per spike between 18.20 and 20.72 (average 19.86), and test weight between 80.32 and 82.58 kg100lt$^{-1}$ (average 81.26 kg100lt$^{-1}$). Seed yield was determined between 3882.30 and 5178.10 kgha$^{-1}$, being 4608.60 kgha$^{-1}$ in average. Gluten content was found between 17.29 and 25.87% (average 20.08% and protein content was determined as 12.28% in average (Table 2).

Values of environmental variance, genotypical variance, G x E variance, phenotypical variance and broad sense heritability are given in Table 3. Moreover, relative ratios (%) of these variance components in phenotypical variance are given Table 4. Negative values were not taken into consideration in calculating the heritability and the ratios of other variance components in phenotypical variance (Allard 1960). All variance components were determined to be insignificant with respect to plant height. The greatest part for this trait in the phenotypical variance belonged to the environmental variance (9.65 %). The effect of genotypical variance for spike length is significant ($p<0.01$) and its ratio in phenotypical variance was determined as 30.43%. Genotypical variance was also found significant (0.38; $p<0.05$) for number of spikelet per spike and test weight (0.26; $p<0.05$). The greatest part in phenotypical variance with respect to number of spikelet per spike belonged to the environmental variance with 28.40%, though this was not significant (p<0.05). Environmental variance was found significant with the values of 25.08 (p<0.01), 0.09 (p< 0.01) and 2.24 (p<0.05) for seed number per spike, seed weight per spike and thousand kernel weight, respectively. The share of these variance components in phenotypical variance was determined as 41.35%, 47.37% and 20.76% for seed number per spike, seed weight per spike and thousand kernel weight, respectively. As to the seed yield, genotype x environment interaction variance was found significant (3179.64; p<0.01). The share of this variance component in phenotypical variance was calculated as 34.23%. The genotype x environment variance was determined to be significant with respect to gluten content, sedimentation and protein content which were evaluated as quality characteristics in the study (Table 3). In addition, environmental variance component was found significant (p<0.05) for sedimentation value. The ratio of genotype x environment variance in phenotypical variance was found as 71.89%, 72.69% and 63.44% for gluten content, sedimentation, and protein content, respectively. The ratio of environmental variance in phenotypical variance which was especially important for sedimentation was 18.94% and the ratio of genotypical variance in phenotypical variance for test weight was 17.81%.

Broad-sense heritability estimated on the basis of genotypical and phenotypical variances were found to be between 0.72% and 30.43% for all traits. Sedimentation had the lowest heritability value (0.72%), whereas spike length had the highest (30.43%). Broad-sense heritability values was determined as 6.35%, 9.38%, 6.13%, 5.26% and 9.45 % for plant height, spikelet number per spike, seed number per spike, seed weight per spike and thousand kernel weight, respectively. As to the seed yield, the second lowest heritability value (3.12%) was obtained in the study. Of the quality traits, test weight had the highest heritability value with 17.69% and this was followed by gluten content with 10.12% and protein content with 5.38%. No genetical calculations were made for plant density which is an agronomical trait considered in the determination of correlations between the traits in the study ( Table 3).

The correlation coeffficients calculated for determining the relations between the traits are given in Table 5. The correlation coefficient between the plant height and spike length which was 0.31 was found significant (p<0.05). Significant correlations (p<0.01) were determined between seed weight per spike and spikelet number per spike, as well as between seed weight per spike and seed number per spike with 0.35 and 0.74, respectively. Similarly, a significant correlation was determined between spikelet number per spike and seed number per spike with 0.36 (p<0.01). The correlations of seed number per spike and seed weight per spike with thousand kernel weight were found significant with the values of 0.20 (p<0.05) and 0.38 (p<0.01), respectively. The traits which were significantly correlated with seed yield in the study were determined to be plant height (0.40; p<0.01) and spike length (0.29; p<0.05). The trait gluten content was determined to be negatively correlated with seed number per spike (-0.26; p<0.01), seed weight per spike (-0.28 ; p<0.01) and plant density (-0.27; p<0.01), contrarily to the traits which were positively correlated. This trait was positively and significantly correlated only with protein content (0.23; p<0.05). Similarly, sedimentation value exhibited negative significant correlation with spikelet number per spike (-0.23;p<0.05) and seed number per spike (-0.28;p<0.01). As for the protein content, a significant negative correlation was determined with the trait seed number per spike (-0.26 ; p<0.01), and a positive one was noted with test weight (0.27,p<0.01) and gluten content.

**Table 3. Variance components and broad-sense heritability estimates for agronomic and quality traits in durum wheat.**

| Variance components traits | Environmental variance ($\sigma_e^2$) | Genotypic variance ($\sigma_g^2$) | Genotype x environment variance ($\sigma^2_{gxe}$) | Phenotypic variance ($\sigma_p^2$) | Broad sense heritability ($h^2$) % |
|---|---|---|---|---|---|
| Plant height | 3.98 ns | 2.62 ns | 1.48 ns | 41.26 | 6.35 |
| Spike length | -0.004 | 0.21 ** | -0.065 | 0.69 | 30.43 |
| Spikelet number per spike | 1.15 ns | 0.38 * | -0.070 | 4.05 | 9.38 |
| Seed number per spike | 25.08** | 3.72 ns | -1.143 | 60.65 | 6.13 |
| Seed weight per spike | 0.09** | 0.01 ns | -0.004 | 0.19 | 5.26 |
| Thousand kernel weight | 2.24* | 1.02 ns | 0.35 ns | 10.79 | 9.45 |
| Seed yield | 84.43 ns | 290.28 ns | 3179.64 ** | 9289.64 | 3.12 |
| Gluten content | 3.05 ns | 2.53 ns | 17.98 ** | 25.01 | 10.12 |
| Sedimentation | 4.50 * | 0.17 ns | 17.27 ** | 23.76 | 0.72 |
| Protein | 0.14 ns | 0.05 ns | 0.59 ** | 0.93 | 5.38 |
| Test weight | 0.01 ns | 0.26 * | 0.24 ns | 1.47 | 17.69 |

*, ** = Significant at 0.05 and 0.01 level, respectively.

**Table 4. Ratio of genotypic and genotypic x environmental variance components in phenotypic variance (%).**

| Var. Comp. | PH | SL | SPNPS | SNPS | SWPS | TKW | SY | GC | SED | PRO | TW |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\sigma_e^2$ | 9.65 | - | 28.40 | 41.35 | 47.37 | 20.76 | 0.91 | 12.20 | 18.94 | 15.05 | 0.68 |
| $\sigma_g^2$ | 6.35 | 30.43 | 0.94 | 6.13 | 5.26 | 9.45 | 3.12 | 10.12 | 0.72 | 5.38 | 17.81 |
| $\sigma^2_{gxe}$ | 3.59 | - | - | - | - | 3.24 | 34.23 | 71.89 | 72.69 | 63.44 | 16.33 |

**Table 5. Correlation coefficient of traits in durum wheat.**

| | PH | SL | STNPS | SNPS | SWPS | TKW | PD | SY | TW | GC | SED |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SL | 0.31* | | | | | | | | | | |
| STNPS | 0.23 | 0.22 | | | | | | | | | |
| SNPS | 0.10 | 0.16 | 0.36** | | | | | | | | |
| SWPS | 0.14 | 0.10 | 0.35** | 0.74** | | | | | | | |
| TKW | 0.03 | -0.13 | 0.04 | 0.20* | 0.38** | | | | | | |
| PD | -0.04 | -0.03 | 0.22* | 0.14 | 0.24* | 0.11 | | | | | |
| SY | 0.40** | 0.23* | 0.04 | 0.01 | -0.01 | 0.03 | -0.08 | | | | |
| TW | 0.09 | -0.11 | 0.00 | 0.12 | 0.16 | 0.11 | 0.01 | 0.19 | | | |
| GC | 0.09 | 0.13 | -0.12 | -0.26** | -0.28** | -0.19 | -0.27** | 0.16 | 0.11 | | |
| SED | 0.09 | -0.17 | -0.23* | -0.28** | -0.14 | 0.20 | -0.16 | -0.05 | 0.02 | -0.14 | |
| PRO | 0.11 | -0.01 | -0.09 | -0.26** | -0.12 | -0.03 | -0.13 | 0.25* | 0.27** | 0.23* | 0.03 |

*, ** =Significant at 0.05 and 0.01 level, respectively.

## Discussion

Genotypical variance is a parameter which represents the magnitude of heritable effects and genetical variation. A high genotypical variance indicates that selection can be succesfully applied in this population (Allard, 1960). The availability of significant genetic variability regarding the spike length, spikelet number per spike and test weight in the population indicates that selection may be conducted with respect to these traits in the direction of increases or reductions.

Environmental variance was found significant for seed number per spike, seed weight per spike, thousand kernel weight and sedimentation. It may be understood that these traits were intensely affected by the environmental conditions varying on the basis of years. El-Shazy *et al*., (2000) reported that the year was an important factor for thousand kernel weight and seed number per spike in accordance with our study.

The genotype x environment variance component was determined to be significant for seed yield, gluten content, protein content and sedimentation. The existence of the genotype x environment interaction variance indicates that selection should be carried out in a range of environments and it is compulsary to breed different cultivars for every specific environment (Mayo, 1980, Falconer 1985). Considering these results obtained in the study, it is recommended to develop cultivars with different genotypes for different environments with respect to important quality traits and seed yield which is generally considered as major target in durum wheat breeding studies.

The heritability values was estimated at quite low levels (between 0.72% and 30.43%) for all the traits examined in the study. Especially the very little values determined in seed yield, seed weight per spike, gluten content, sedimentation and protein content can be explanned by the increased phenotytpical variance due to the effect of G x E interaction. Robinson (1963) recommends using family selection methods such as pedigree, sib tests and progeny tests for this type of traits. Barnard *et al*., (2002) determined broad-sense heritabilities of 57%, 12%, 67% and 88% for protein content, sedimentation, test weight and TKW, respectively and reported that a selection successful and rapid with respect to quality criteria may be in question only for the characters with high heritability. Zanetti *et al*., (2001) determined the heritability of 96% and 87% for protein and TKW,respectively. Budak *et al*., (2000), stated that broad-sense heritabilities of grain yield, protein content test weight were 67%, 64% and 29%, respectively. The same researchers suggested that the grain yield and protein content seem to be controlled by genotypes more than environment in comparison with test weight. Novoselovic *et al*., (2004) reported that they determined heritability of 21-78% and 54-81% for seed yield and plant height, respectively. The heritability estimated in our study were much lower than these ones exhibited differences from these results.

Positive significant correlations was determined seed yield between plant height and spike length in the study. Belay (1993), Pochaba & Wegrzyn (2001), Dokuyucu *et al*., (2002) and Kashif & Khaliq (2004) emphasied that plant height is one of the most important traits determining the yield. The correlation values in the study is in accordance with the results of these researches.

Negative significant correlations of seed number per spike, seed weight per spike and plant density was determined with gluten content, one of the quality components. Negative significant correlations of sedimentation was determined with number of spikelet per spike and seed number per spike; as well as between protein content and seed number per spike. This situation shows that important agronomical traits are generally inversely correlated with quality charactistics. A similar finding was also reported by Barnard *et al*., (2002). According to the researches, the negative correlations which often exist between quality and yield is a further constraint in breeding. Chung *et al*., (2003) found a negative correlation between protein content and yield contrarily to the positive correlation coefficient between these two traits in our research. Yağdı (2004) determined a positive correlation of gluten content with protein content, as well as with test weight and thousand kernel weight, and recommended that the resarcher take these components in to consideration. In this study, a positive and significant correlation was determined between only two of these traits i.e., gluten content and protein content.

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(Received for publication 25 July 2005)