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YIELD STABILITY OF SOME TURKISH WINTER WHEAT (*Triticum aestivum* L.) GENOTYPES IN THE WESTERN TRANSITIONAL ZONE OF TURKEY

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ABSTRACT

The purpose of the study was to evaluate the yield performance and stabilities of certain winter bread wheat cultivars grown widely in the winter wheat regions of Anatolian peninsula. Eight varieties were grown at 10 locations between 2007 and 2011 cropping seasons, in a field trial arranged in Randomized Complete Block Design with 4 replications. The combined analysis of variance was performed for the data obtained. The significant genotype x environment interactions were further investigated by the regression and the ecovalance analyses. It was concluded that cultivars Kate A1 and Mufit bey were found to be the most stable genotypes for all the environments whereas cultivar Gerek-79 was found to be the best performer for under poor soil and weather conditions.

Key words: bread wheat, yield performance, genotype x environment interaction, stability.

INTRODUCTION

Wheat is an important crop for human nutrition in the world with growing areas of the 217.2 million hectares, among cereals (FAO Stat., 2010). According to FAO's (Food and Agriculture Organization of the United Nations) reports, the biggest wheat producing countries in the world are European Union, China, India, United States, and Russia. The FAO also forecasted that the world wheat production in 2012 will be the second highest such 690 million metric tons (FAO, 2012). Wheat consumption in the world has been changed between 645 and 679 million metric tons for the past five years (International Grain Council, 2012).

Wheat is also an important staple crop in Turkey in terms of economy, nutrition and employment. Wheat growing area is 8.5 million hectares and total production is 19-20 million metric tons.

Wheat is grown in the all regions of Turkey, mostly under the rain fed conditions. Therefore, annual production is affected to large extent by the annual and seasonal distribution of precipitation (Turkish State Meteorological Service, 2011). Spatial variations in soil properties and cultural practices also contribute to fluctuations in wheat production.

Success of a wheat breeding program depends on the regional adaptability of the cultivars improved and adaptability of such cultivars in the target environments determined by its tolerance to biotic and abiotic stresses. The most important abiotic stress factor is the shortage of rainfall in the region. There are 3 critical periods of rainfall: Fall rains during the early vigor and tillering, early spring rains during the tiller survival and stem elongation, and late spring rains during grain filling period.

Pfeiffer and Braun (1989) explained sources of yield instability as spatial, temporal, and system dependent variations in the environmental conditions. Almost all breeding programs in the world aim to improve varieties with stable yields. The yield stability is generally grouped as static or dynamic stability. The static stability is defined as the lack of response to environmental variations while the dynamic stability is defined as the average response. Therefore, the static stability is an absolute value independent of the performances of the other cultivars in the trials, while the dynamic stability of a cultivar depends on the mean response of all the cultivars (Tollenaar and Lee, 2002).

Several methods have been developed to analyze and interpret genotype x environment interaction (Lin et al., 1986; Piepho, 1998). These methods can be univariate (based on regression or variance analysis) or multivariate. The earliest approach was the linear regression analysis (Mooers, 1921; Yates and Cochran, 1938). The regression approach was popularized in the 1960s and 1970s (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966 and 1969; Tai, 1971). In this approach, regression graphs are used to predict adaptability of genotypes. Some other univariate stability parameters (based on variance analysis) are the environmental variance (Lin et al., 1986), the Shukla stability variance (Shukla, 1972), Wricke's ecovalence (Wricke, 1962) and the coefficient of variability (Francis and Kanenberg, 1978). As multivariate, the additive main effects and multiplicative interaction (AMMI) model have been extensively applied in the statistical analysis of multi environment cultivar trials (Kempton, 1984; Gauch, 1988; Crossa et al., 1990; Gauch and Zobel, 1997; Akcura et al., 2009; Ilker et al., 2011). In Tai's stability analysis (Tai, 1971), the interaction term is partitioned into two components: the linear response to environmental effects, which is measured by a statistic , and the deviation from the linear response, which is measured by another statistic . A perfectly stable variety has (α , λ) = (-1, 1) and a variety with average stability is expected to have (α , λ) = (0,1).

Gerek 79, released by the Eskişehir Agricultural Research Institute in 1979, has been used as standart variety in the region. Bezostaja 1 is a Russian variety was introduced to the region in 1970, has been also grown for several years. Some newly bred wheat varieties also have been grown in the region.

The main objective of this study was to assess the yield and yield stabilities of some newly developed varieties and compare them with the varieties such as Gerek 79 and Bezostaja 1 widely grown in the western transitional zone of Turkey.

MATERIALS AND METHODS

The genetic materials used in the study are given in Table 1.

Table 1. The genotypes tested and their origins in the study

Variety	Origin	Date of release	Place of release
Bezostaja 1	Russia (USSR)	1970	Eskişehir - Turkey
Gerek 79	Turkey	1979	Eskişehir - Turkey
Kate A1	Bulgaria	1988	Edirne - Turkey
Harmankaya 99	Turkey	1999	Eskişehir - Turkey
Altay 2000	Turkey	2000	Eskişehir - Turkey
Izgi 01	Turkey	2001	Eskişehir - Turkey
Sonmez 01	Turkey	2001	Eskişehir - Turkey
Mufitbey	Turkey	2006	Eskişehir - Turkey

Eight bread wheat varieties were tested in the field trials. Experiments were carried out in a total of 27 environments at 9 different locations from 2007 to 2011. The name of the locations and the number of the experiments conducted at each location were given in Table 2. Among these experiments, 25 trials were conducted under the rainfed conditions, while supplemental irrigation was applied to the other 2 experiments. Since locations vary among the years, each individual year x location combination was considered as a separate environment in the statistical analysis.

Sowings were performed by using a plot drill. Planting dates varied between September 20th and October 30th throughout the trials. Seeding rate was kept uniform such as 500 seeds m^{-2} in all experiments. Experimental layout was, the Randomized Complete Block Design with 4 replications in all trials. Plot sizes were 7 x 6 x 0.2 = 8.4 m^2 at planting and 5 x 6 x 0.2 = 6 m^2 at harvest. 60 kg P2O5 ha^{-1} and 30 kg N ha^{-1} were applied at planting, and additional 50 kg N ha-1 N was given in the early spring. Weeds were chemically controlled in the spring. Supplemental irrigation in two trials was applied; At Cumra the supplemental irrigation was given in the spring, while at Eskisehir the supplemental irrigation was given (60 mm water) at planting to secure emergence.

Statistical Analyses

Each individual trial was subjected to ANOVA. Since the genotype x environment interaction was expected, a combined ANOVA was performed to estimate this interaction. The Duncan's Multiple Range test was used to compare variety means (Steel et al., 1997).

Finlay and Wilkinson's joint regression model (1963) and Eberhart and Russel's method (1966) were applied and the regression coefficients (b), determination coefficients of the regression equations (R^2), and residual MS values (s_d^2) were calculated. To estimate the statistical parameters of regression for stability the proc reg in SAS 9.0 Software were used just by adding a statement to test hypothesis of b=1. Wricke's (1962) ecovalence values were also calculated.

Statistical analyses of the data were performed by using the SAS software (SAS, 2002) and applying General Linear Model procedure.

RESULTS AND DISCUSSION

The average grain yields for the environments are given in Table 2.

Table 2. Average grain yields of 8 winter wheat cultivars grown at 9 locations for five years in the Western Transitional Zone of Turkey

Location	**Grain yield (ton ha^{-1})**				
	2007	2008	2009	2010	2011
Afyon	—**	1.64	—	—	—
Altıntaş-Kütahya	3.13	2.88	3.69	1.67	6.06
Çumra-Konya (Sup. irr.)*	—	—	5.38	—	—
Emirdağ-Afyon	2.77	—	4.47	2.96	3.98
Eskişehir (Sup. irr.)*	—	—	—	—	3.93
Eskisehir	3.28	2.96	4.84	__	3.25
Hamidiye- Eskisehir	1.47	—	—	—	4.75
Konya	1.89	5.15	4.43	3.85	3.92
Uşak	1.67	2.86	3.05	—	6.02
Average	2.37	3.11	4.31	2.84	4.54

*: Supplementary irrigation. __**: No trial was conducted

Table 2 shows, the highest mean yield obtained at Altıntaş- Kütahya location in 2011, with 6.06 tons ha^{-1}; while the lowest mean yield was recorded at Hamidiye-Eskişehir location in 2007, with 1.47 tons ha^{-1}.

The combined ANOVA indicated that the genotype x environment interaction was statistically significant. Therefore, the stability analysis could be performed to estimate the overall performance and adaptation of the genotypes (Table 3).

There was significant genotypic variation for grain yield among the 8 standard cultivars used in the stability analysis. Sonmez 01 had the highest mean yield with 3.80 tons ha^{-1}, while the lowest mean yield was obtained from Bezostaja 1, with 3.23 tons ha^{-1} (Table 4 and Figure 1).

Finlay and Wilkinson's joint regression model (1963), Eberhart and Russell's (1966) model, and Wricke's (1962) ecovalence (W_i) calculations were applied to the grain yield data obtained from the total 27 environments.

The stability parameters calculated through these different methods are given in Table 4.

Table 3. Combined analysis of variance for grain yield (ton ha^{-1}) of wheat genotypes tested at 9 locations for 5 years in the Western Transitional Region, Turkey.

Source of variation	**Degrees of freedom**	**F value**
Environments	26	152.12**
Reps (Environments)	81	2.76**
Genotypes	7	9.61**
Genotypes x environments	182	2.82**

CV%=16.4, R^2 =0.90** , ** significant at the 0.01 probability level

Table 4. The stability parameters estimated for 8 winter wheat genotypes.

Genotypes	a	b	Se	R^2	*P ≤	Wi	S_d^2	Mean $ton.h^{-1}$
Altay	-0.522	1.112	0.06	0.94	0.059	3443	0.13874	3.437
Bezostaja	0.030	0.899	0.06	0.89	0.119	3227	0.17011	3.231
Gerek	0.197	0.885	0.07	0.86	0.114	3337	0.21314	3.349
Harmankaya	-0.182	1.098	0.07	0.90	0.175	3727	0.21626	3.729
Izgi	0.222	0.913	0.07	0.88	0.193	3467	0.18543	3.472
KateA 1	0.011	1.057	0.08	0.87	0.488	3773	0.28059	3.773
Mufitbey	0.081	1.001	0.09	0.84	0.991	3647	0.32079	3.646
Sonmez	-0.109	1.098	0.06	0.93	0.099	3810	0.14273	3.801

*Probobilty of rejection the H_0 : b=1 hypothesis at the P ≤ 0 level. Any genotype with b values significantly different from 1 is accepted as nonstable LSD(0.05): 0.154 $ton.ha^{-1}$

Table 4 shows that the regression coefficients (b) were not significantly different from 1. The b values ranged between 0.885 (Gerek 79) and 1.112 (Altay 2000). Residual mean square (MS) values (s_d^2) which are indicative of deviations from the regression, were close to 0 (0.13874) for Altay 2000, while Mufitbey had the highest s_d^2 (0.32074). The other genotypes b and s_d^2 values between these values.

According to Finlay and Wilkinson model, b values show the slope of the regression lines indicating adaptability of given genotypes to the range of environments tested in the study. Although high b values are generally indicative of high yield potential (Lin *et al*., 1986), since those genotypes also generally had low intercept (a) values, they could be considered suitable for specific environments with a yield potential over a given level. Therefore, genotypes with b values close to 1 are preferred since it is indicative of wide adaptation (dynamic stability) provided their mean yield is over the general mean. Mufitbey was found to be the genotype with the b value close to 1 (1.001). Considering it also had a positive intercept value and a mean yield higher than the general mean, this genotype could be accepted to have a wide adaptation over the range of environments used in the study.

On the other hand, the Eberhart and Russell model compares the deviations of genotypic yields from their relative regression lines, indicated by s_d^2 values. This method is generally used to check the reliability of the Finlay and Wilkinson's regression line method. Therefore, these two methods were used together in this study. Since sd2values are desired to be as close as possible to 0, genotypes with the smallest s_d^2 values are considered to have reliable regression equations. However, it is known that s_d^2 values are not totally independent of level of yields, meaning that genotypes with higher yield levels generally tend to give higher s_d^2 values than the low yielding genotypes. Therefore, the genotypes in the study were compared by using the parameters of two methods together. The results indicated that genotypes Altay 2000 and Harmankaya 99 were more suitable to high yielding environments, since they had low intercept values (- 0.522 and – 0.182, respectively) and the highest b values (1.112 and 1.098, respectively). When the genotypes were compared for their wide adaptation (dynamic stability) parameters, the genotypes were Mufitbey and Kate A1 had b values equal to 1 (1.001 and 1.057, respectively). However, Sonmez had the highest mean yield and the lowest s_d^2, indicating its reliability, unless the environmental yield potential is too low since its intercept value was also low. There were also other genotypes with low s_d^2 values, with low yields. Sonmez with low s_d^2 despite its high yield was found to be the most reliable genotype based on the Eberhart and Russell analysis.

Wricke's ecovalence evaluation expressed very similar trend with Eberhart and Russell's s_d^2 values. Since this method indicates the contribution of individual genotypes to the overall genotype x environment interaction, it was expected to give similar results as Eberhart and Russell method. Consequently, it could be concluded that the Finlay and Wilkinson type analysis is a preferable method for assessment of specific or wide adaptation of genotypes, while the other 2 methods could be used to test the reliability of genotypes against yield fluctuations in the varying environments.

Regression coefficients (b) given in Table 4 indicated that, Mufitbey had the b value (1.01) close to 1 followed by Kate A1 (1.057), Izgi 01 (0.913), Harmankaya 99 (1.098) and Sonmez 01 (1.098). The other genotypes, giving the small b values also close to 1, were Bezostaja 1 (0.899), Altay 2000 (1.112) and Gerek 79, previously the most stable cultivar in rain fed conditions, with the lowest b value (0.885). The highest b value of Altay 2000 indicated same possible failure in low yielding environments, while low b values of Bezostaja 1 and Gerek 79 implied their relatively lower ability to respond to improved environmental conditions. The average yields and the b values of the genotypes are shown graphically in Figure 1.

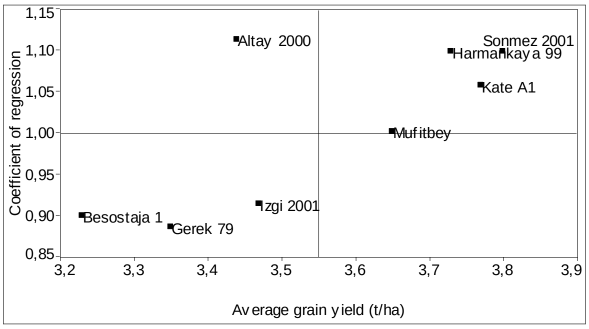

Figure 1. Grain yields and the regression coefficients of the genotypes.

The static stability defined in theory is not valid in practice. Since even in the lowest yielding environments, there would be a certain level of variation in the environmental index and a desirable genotype should be able to respond to the improved conditions to reach to the acceptable yield levels.

Figure 1 shows the genotypes with b values higher than 1 also had higher yields than the average grain yields, with the exception of Altay 2000. Another parameter used in the stability evaluations is the residual mean square (s_d^2) which is a measure of average deviations from the regression line. As suggested by Eberhart and Russell (1966), smaller values of s_d^2 indicates high level of stability. This approach has also been used by Francis and Kannenberg (1978), Motametdi (2011), and Baker (1969). However, this method has been criticized by some researchers (Pfeiffer and Braun, 1989) since the sd2 values are highly yield dependent and this may result in higher s_d^2 values for higher yield levels. Therefore, it has been suggested that the s_d^2 values should be used together with Finlay and Wilkinson's b values to test the reliability of regression equations, rather than using them alone as stability parameters (Linn et al., 1986). The s_d^2 values of the 8 genotypes tested are given in Table 4. Altay 2000 had the lowest and Mufitbey had the highest s_d^2 values, as 0.13874 and 0.32079, respectively. Average yields and sd2 values of the genotypes are shown in Figure 2.

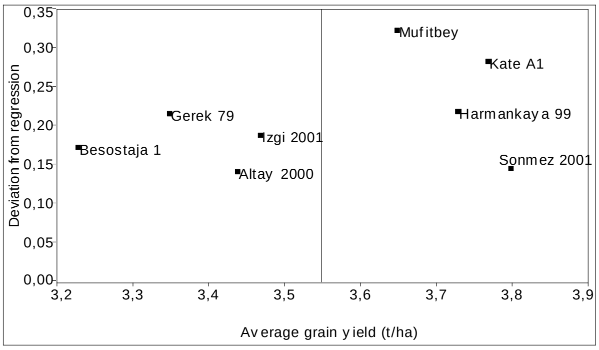

Figure 2. Grain yields and deviations from the regression of 8 wheat genotypes averaged over 27 environments.

After the comparison of the 8 genotypes by using the stability parameters estimated, Kate A1 and Mufitbey appear to be the most stable genotypes, followed by Sonmez 01 and Izgi 01. Since, Izgi 01 with low grain yield was replaced by Harmankaya 99 in the high yielding environments. Gerek 79, Bezostaja 1 and Altay 2000 were found to be the least stable genotypes at the locations tested.

Figure 3 shows the grouping of genotypes according to Finlay and Wilkinson (1963) method. It could be seen in figure 3, Sonmez 01, Harmankaya 99, Kate A1 and Mufitbey were in the same stability group, showing good adaptation to all the environments tested in the study. Izgi 01 was moderate, Altay 2000 could have specific adaptation to the high yielding environments, Gerek 79 had specific adaptation to the low yielding environments, and Bezostaja 1 showed poor adaptation to all the environments tested.

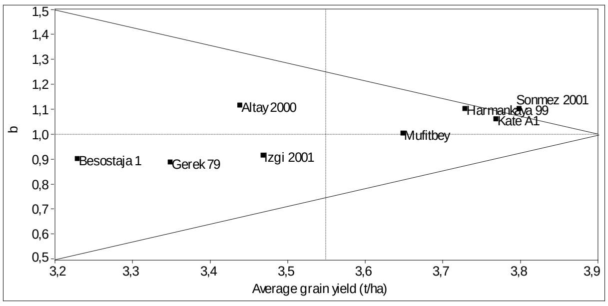

Figure 3. Regression coefficients of genotypes regressed over average grain yields.

Adaptation boundaries of the genotypes, based on expected yields for different environmental indices, calculated from regression equations are shown in Figure 4 indicated the boundaries of each genotype. Genotypes Kate A1 and Mufitbey were adaptable to all the environments used in the study. Kate A1, a cultivar introduced from Bulgaria, has been gaining acreage in the region. Mufitbey, a newly released genotype, was found to be suitable in the environments up to 5.432 tons ha^{-1} yield potential. Sonmez 01 was also found to be adaptable to environments with higher than 1.436 tons ha^{-1} index value, while Harmankaya was good in the environments with higher than 2.183 tons ha^{-1} environmental index value. On the other hand, Altay 2000 was found to have specific adaptation to high yielding environments (over 5.432 tons ha^{-1}). Izgi 01 and Gerek 79, on the contrary, were found to be suited to low yielding environments (lower than 2.183 and 1.436 tons ha^{-1} index values, respectively). Bezostaja1 did not show good adaptation to any environment in this specific set of experiments. Since it has high yield capacity and bread making quality, Bezostaja1 has been widely grown after 1970's. Later, Bezostaja1 could not compete with the new varieties especially in the high fertile transitional zone of Turkey. This study confirmed the calculated yield of Bezostaja1, by using a and b parameters for different environmental indexes, dropped back the yields of the newly developed varieties.

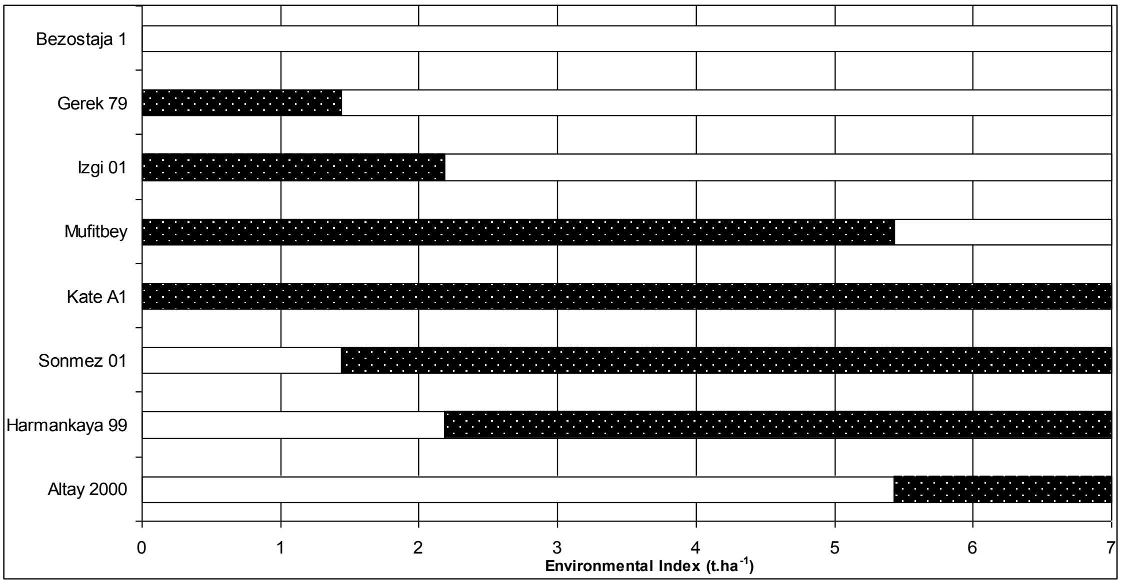

Figure 4. Adaptation boundaries of the genotypes (tons ha^{-1}).

It could be concluded that the stability parameters used were specific to the group of environments and genotypes used in this study. Therefore, their validity will be dependent on the suitability to the target region. Gerek 79 was found to be the most stable cultivar in several studies from 1980's to 1990's, when tested among a different group of genotypes. It was also concluded that newly developed cultivars appear to be superior to Gerek 79 not only in potential yield but also in yield stability.

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