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Selection for Test Weight and Kernel Weight in High Yielding Wheat Using a Safety-First Index

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Abstract: Five breeding lines and 4 cultivars were grown in replicated trials at 1 location in 1999-2000 and 2 locations in 2000-2001 cropping seasons in İzmir in order to determine the usefulness of a safety-first selection index in making selection among high yielding wheat genotypes for test weight and thousand-kernel weight. Genotype × environment interactions were significant for these 2 quality traits. The regression coefficient (b_i) of genotypes, variance (S_i^2) of a genotype across environments, and a safety-first index (I_i) were calculated to evaluate the stability of genotypes for test weight and thousand-kernel weights. Wheat genotypes with lower b_i values and small variance (S_i^2) across environments (the most stable ones) tended also to have lower means for these 2 traits. However, those genotypes with the largest value of index (I_i), which is considered desirable, were found to have the highest mean values for both test weight and thousand-kernel weight. The rank-correlation coefficient between (I_i) and ($\overline{Y}_i$) values was significant for thousand-kernel weight. The ranking from I_i was significantly correlated with the rankings from the stability parameters b_i and S_i^2 for test weight. The rank-correlation coefficients between b_i and S_i^2 for the 2 physical quality traits were highly significant and of similar magnitude (r = 0.983). It was concluded that a safety-first selection index can be useful in plant breeding for the improvement of wheat cultivars with enhanced stability and consistency of quality characteristics when genotype × environment interaction is present.

Key Words: Bread wheat, yield, safety-first index, physical quality traits, rank correlation

Önce Güven İndeksi Kullanarak Yüksek Verimli Buğdaylarda Hektolitre Ağırlığı ve Bin Tane Ağırlığı İçin Seleksiyon

Özet: Yüksek verimli bazı ekmeklik buğday genotipleri arasında hektolitre ağırlığı ve 1000-tane ağırlığı için yapılacak bir seleksiyonda bir önce güven seleksiyon indeksinin kullanılabilirliğini belirlemek amacıyla beş ıslah hattı ve dört çeşit, İzmir ilinde 1999-2000 ürün döneminde bir ve 2000-2001 yılında da iki lokasyonda yürütülen tekrarlamalı denemelerde yetiştirilmiştir. Tane verimi, hektolitre ağırlığı ve 1000-tane ağırlığı için üç çevre üzerinden yapılan birleştirilmiş varyans analizleri iki fiziksel kalite özelliği için genotip x çevre interaksiyonlarının önemli olduğunu göstermişlerdir. Her genotipe ilişkin 1000-tane ağırlığı ve hektolitre ağırlığı için stabilite istatistikleri olarak doğrusal regresyon katsayısı (b_i), çevreler üzerinden varyans (S_i^2) ve önce-güven seleksiyon indeksi değeri (I_i) hesaplanmıştır. Ekmeklik buğday genotiplerinde artan stabilitenin bir göstergesi olarak daha düşük b_i ve S_i^2 değerlerine sahip genotiplerin çoğunlukla 1000-tane ağırlığı ve hektolitre ağırlığı ortalamalarının da daha düşük olduğu belirlenmiştir. Buna karşın, daha büyük değerlerin arzu edildiği önce güven indeksi bakımından her iki kalite özelliğinde en yüksek değerin elde edildiği genotiplerin aynı zamanda yüksek ortalamalara sahip oldukları gözlenmiştir. Ekmeklik buğday hat ve çeşitlerinin 1000-tane ağırlığına ilişkin önce güven indeksi (I_i) değerleri ile ortalama değerleri ($\overline{Y}_i$) ve hektolitre ağırlığına ilişkin önce-güven indeksi (I_i) değerleriyle de stabilite parametreleri (b_i ve S_i^2) arasındaki rank korelasyonları önemli bulunmuştur. Her iki fiziksel kalite özelliği bakımından b_i ve S_i^2 istatistikleri arasındaki rank korelasyon değeri çok yüksek olup benzer büyüklüktedir (r = 0,983). Elde edilen bulgulara göre, ekmeklik buğdayda tutarlı bir kalite performansına sahip çeşitlerin geliştirilmesinde önce-güven seleksiyon indeksi kullanımının bitki ıslahçısı için yararlı olabileceği sonucuna varılmıştır.

Anahtar Sözcükler: Ekmeklik buğday, verim, önce güven indeksi, fiziksel kalite özellikleri, rank korelasyonu

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Introduction

Generally wheat is ground at the first stage into flour and semolina and later several food products are made with them. Therefore, the concept of quality varies in between milling industries - the ones producing semi-processed goods such as flour and semolina and the others manufacturing products for end-users such as cake, biscuit, and macaroni (Atlı, 1999). Test weight and thousand-kernel weight characteristics, which can be used to predict potential flour yield in wheat grain, are recognized as principal quality parameters by milling industry (Uluöz, 1965; Ünver and Kınacı, 1980; Schuler et al., 1995; Toklu et al., 1999; Ünal, 1999; Karababa et al., 1999). Importance of test weight for growers was reported by Schuler et al. (1995) because of its influence on market grade. Atlı (1987, 1999) revealed that traits that can be quality parameters for bread wheat are to display the genetic potential; and, thousand-kernel weight can be used confidently for the purpose of quality predictions at the early generations of breeding programs. Significant environmental effects and genotype × environment interactions on some quality parameters were estimated in previous studies involving diverse wheat crops grown under different ecological conditions (Ghaderi and Everson, 1971; Bhatt and Derera, 1975; Basset et al., 1989; Peterson et al., 1992; Kanbertay, 1994; Schuler et al., 1995; Çağlayan and Elgün, 1999; Kılıç et al., 2003; Altınbaş et al., 2004).

Considering the consistency response of quality parameters to different environments, i.e. optimal stability concept of a genotype, it is clear that there is a difference from the conventionally used definition of yield stability. Peterson et al. (1992) emphasized that a genotype should have small deviations from mean performance across environments with a low regression coefficient (b_i). In this definition, the mentioned b_i value estimated from regression analysis, which is a statistical parameter used to measure the yield stability of genotypes (Finlay and Wilkinson, 1963; Eberhart and Russel, 1966), has been adopted to evaluate the stability performance of some physical and technological quality parameters in wheat in previous studies (Busch et al., 1969; Ghaderi and Gverson, 1971; Atlı, 1987; Basset et al., 1989; Peterson et al., 1992; Kılıç et al., 2003).

It was not clearly shown in any stability method how an index can be developed based on both average performance and stability. In this case, Eskridge (1990) pointed out that decision to weigh the importance of stability relative to yield performance during the final selection phase remained to the plant breeder. He suggested the use of some statistical models, known as "selection indices for stability based on the assumption of safety-first behavior under risk," which would be very useful for breeders to select superior genotypes when genotype × environment interaction was relatively large. In these indices, the integration of stability performance with the mean value of a genotype across environments into a single criterion was achieved by using the genotypic variance (S_i^2) (Lin et al., 1986), regression coefficient (b_i) (Finlay and Wilkinson, 1963), stability variance (σ_i^2) (Shukla, 1972) and the deviation of regression (S_{di}^2) (Eberhart and Russel, 1966) as stability measures. Index values that can be calculated for each stability parameter represent the lowest performance limit or level that is expected in a probability (α) of having a lower performance specified in diverse environments. Probability of lower performance, which has to be determined by plant breeder before selection, may vary between 0.30 and 0.05 depending on that the growing conditions are favorable for high performance or unfavorable (Eskridge, 1990; Annicchiarico, 2002). Considering, for instance, a farmer who desires to grow varieties showing better performance ever in the most unfavorable environments, plant breeder should specify a low probability (α). With lower ratios, differences among genotypes further increase because more importance is given to stability relative to the performance level in safety first indices (Eskridge, 1990).

On account of plant breeding and variety recommendation, Annicchiarico (2002) reported that it is of special interest in yield reliability assessments to incorporate parameter of variance (S_i^2) defined as required stability criterion for the indices by Eskridge (1990), across environments with mean value. Annicchiarico (2002) also noted that the calculation of Kataoka index value is easier than other stability measures (regression coefficient and stability variance). Varieties having high average values as well as showing low standard deviations (S_i) across environments can be selected when this index is used (Eskridge, 1990). It is possible to say that the mentioned suggestion coincides with consideration of Peterson et al. (1992) in relation to the wheat variety with optimal stability, which is desired by end users such as millers and bakers because of quality properties. According to the definitions of stability, if b_i value is equal to zero, Type 1 stability is implied (Lin et al., 1986; Annicchiarico, 2002). In safety-first model suggested by Eskridge (1990) where the regression coefficient was used to evaluate stability by how far its b_i value deviates from the unity coefficient 1.0 represents Type 2 stability (Annicchiarico, 2002). In this fashion, because of the previously stated reasons, to rank a set of wheat genotypes according to a safety first selection index, which involves variance of a genotype across environments as a measure of stability, could be more useful than the regression coefficient (Type 1 stability) used by Peterson et al. (1992) and in some other studies for quality parameters of wheat (Busch et al., 1969; Ghaderi and Gverson, 1971).

It has been previously reported that comparisons were based on the trait mean values for some physical and technological quality characteristics including test weight and thousand-kernel weight among genotypes in the Aegean region (Kanbertay, 1994; Demir et al., 1999; Altınbaş et al., 2000; Yüce et al., 2001; Altınbaş et al., 2004; Tosun et al., 2006). However, selection for stability has not been made in the presence of genotype × environment interactions in spring bread wheat trials conducted at different locations. All these investigations used bread wheat lines developed for high grain yield at the preliminary stages of selection, where only the genotype × environment interaction for thousand-kernel weight was found to be significant (Yüce et al., 2001; Altınbaş et al., 2004). Demir et al. (1999) who studied 1000-kernel weight as an indicator for large seed size desired by millers reported a deficiency on seed size in some bread wheat genotypes. Similarly, Altınbaş (2000) emphasized that selection with respect to large-seeds has an unfavorable effect to the yield potential due to negative association between yield and large seed size.

In the present work, selected lines for high yield from an international performance nursery and 4 locally adapted varieties were used to evaluate their stability for test weight and 1000-kernel weight across different locations and growing seasons by using a safety-first index.

Materials and Methods

Five high-yielding advanced bread wheat lines selected from the International Spring Wheat Yield Trials (ISWYN-96) distributed by the International Maize and Wheat Improvement Center (CIMMYT) and 4 registered bread wheat varieties for Aegean region (Table 1) were evaluated

Table 1. Name and pedigree information of the bread wheat genotypes evaluated in the present study

Line/Variety	Pedigree/Source
ISWYN-96/47	SERI M82CM 33027-15M-500Y
ISWYN-96/60	PICUS/CRG.70-7Y-5B-0Y
ISWYN-96/67	KAUZ^{+2}/OPATA/KAUZ/CRG 737
ISWYN-96/69	KAUZ^{+2}/BOW/KAUZ/CRG 900-3Y
ISWYN-96/72	KAUZ^{+2}/MNY/KAUZ/CRG 958
Menemen-88	Ege Üniversitesi Ziraat Fakültesi-İzmir
Kaşifbey	Ege Tarımsal Araştırma Enstitüsü-İzmir
Basribey	Ege Tarımsal Araştırma Enstitüsü-İzmir
Cumhuriyet-75	Ege Tarımsal Araştırma Enstitüsü-İzmir

in 3 trials conducted in 1999-2000 and 2000-2001 growing seasons in Bornova, İzmir and in 2000-2001 growing season in Menemen, İzmir. Menemen (33,545 ha), a part of large Gediz delta plain, has a well drained and sandy-loamy structure of alluvial soil (İlker, 2000), whereas Bornova has a heavy soil structure with clay-silt soil at 0-20 cm depth and clay-loamy structure at 20-40 cm depth (Kovancı, 1990). Average long term annual precipitation and temperatures measured at Menemen and Bornova locations are 585 mm, 16.9 °C (Acar et al., 2007) and 689 mm, 17.7 °C (Records of İzmir Meteorology Station, 2007), respectively.

The trials were laid out in a randomized complete block design with 3 replications. Plots consisted of 6 rows 5 m long spaced 20 cm apart where the seeds were drill-planted at 5 cm spacing within the row. At each trial, 120 kg N ha^{-1} and 60 kg P ha^{-1} fertilizer were applied equally at sowing time and during the stem elongation period. Grain harvest was performed in June for the both 2000 and 2001. Initially, grain yield was measured in grams per plot (from plots sized 4.0 × 0.8 m) and then converted to kilogram per hectare (kg ha^{-1}). Thousand kernel weight (in grams) was based on average weight of 4 random samples of 100 unbroken kernels from each plot. Test weight was determined in each plot, using standard methods (Uluöz, 1965), as the average weight of a measured 0.250 l volume of wheat grain then converted and expressed in kilograms per hectoliter.

A combined analysis of variance across all 3 environments was calculated for each trait considering each location-year combination as an independent environment after the error mean squares from individual environments were tested for homogeneity using Bartlett's test (Steel and Torrie, 1980) where genotypes and environments were treated as fixed effects. As a measure of Type 1 stability for each genotype, the regression coefficient (b_i) (Finlay and Wilkinson, 1963) of mean value of a genotype on the mean value of all genotypes in each environment (environmental index) and variance of a genotype across all environments (S_i^2) (Lin et al., 1986) were estimated. According to the definition of the mentioned stability, genotypes with the lowest b_i and S_i^2 have been accepted as the most stable ones (Lin et al., 1986; Peterson et al., 1992; Annicchiarico, 2002). Safety first selection index given below was computed (Eskridge, 1990; Annicchiarico, 2002) using the mean value of each genotype across environments and estimation for the relevant trait.

$$I_i = \overline{Y}_i - Z\,(1 - \alpha)\,S_i$$

where $\overline{Y}_i$ is the mean value of the *i*th genotype across environments, Z(I-α) is the percentage from the standard normal distribution at a value of $\alpha = 0.05$ and [Z(0.95) =1.645] (Steel and Torrie, 1980; Eskridge, 1990) and S_i is the square root of environmental variance (S_i^2) as a measure of stability. Genotypes having higher I_i values were considered for stability (Eskridge, 1990). On the basis of safety-first selection index (I_i) and b_i and S_i^2 parameters of Type 1 stability, the best 3 genotypes among bread wheat lines and cultivars were selected (33% selection intensity).

Relationships of mean values for test weight and 1000-kernel weight of bread wheat genotypes with Type 1 stability parameters (b_i and S_i^2) and safety-first selection index (I_i) were determined by computing rank correlation coefficients among them (Snedecor, 1956). Ranks were assigned for mean test weight and 1000-kernel weight with the genotype having the highest test weight and 1000-kernel weight being ranked no. 1. Conversely, ranks for Type 1 stability statistics (b_i and S_i^2) were determined in an ascending way, where the genotype with the lowest estimated value received the rank no. 1. In the case of safety first selection index (I_i), the genotype with the highest value was assigned the rank of no. 1.

Results

Results from the combined analysis of variance for all traits indicated that differences among mean values for both genotypes and environments were significant (Tables 2 and 3). Genotype × environment interactions for test weight and 1000-kernel weight were significant indicating that differences among mean values of genotypes varied with environments.

Mean grain yield values of the wheat genotypes varied between 4303.3 (Cumhuriyet-75) and 5508.3 (Basribey) kg ha^{-1} across environments (Table 4). It was found that there were no significant differences for yield between the variety Basribey (having the highest yield) and Lines 72 and 67. Except for Menemen-88, grain yields of all genotypes decreased in Bornova during 2000-2001 compared to the other 2 locations.

Mean values for 1000-kernel weight of lines and varieties ranged between 34.4 (Line 72) and 45.2 g (Cumhuriyet-75) (Table 5). While only 1 genotype (Line 47) out of 3 having the highest grain weight was determined to be stable according to Type 1 stability statistics. On grounds of the safety-first index (I_i), genotype Cumhuriyet-75, the one with the highest 1000-kernel weight among the genotypes, was identified as the most stable, followed by Line 47. In contrast, Line 69, the most

Table 2. Results of combined analyses of variance across all 3 environments for grain yield, test weight, and 1000-kernel weight.

Source	Df	Mean Square		
		Grain Yield ($\times 10^3$)	1000-kernel weight	Test weight
Environment (E)	2	9160.65**	777.69**	38.53**
Block	9	58.01	450.00	0.81
Genotype (G)	8	1232.66*	140.08**	6.17**
G × E	16	779.28	12.31*	1.63**
Combined Error	72	445.68	6.05	0.67
CV (%)		13.6	6.4	1.0

*, **: Significant at P = 0.05 and P = 0.01, respectively.

Table 3. Mean values for locations and growing years for grain yield, test weight, and 1000-kernel weight of wheat bread genotypes.

Location	Year	Grain Yield	1000-kernel weight	Test weight
		kg ha^{-1}	g	kg hL^{-1}
Bornova	1999-2000	5238	37.9	82.3
Bornova	2000-2001	4321	33.7	80.5
Menemen	2000-2001	5143	43.0	82.3
LSD (0.05)		314	1.2	0.4

Table 4. Mean grain yield values of bread wheat lines and varieties at individual location-year combination.

Line/Variety	1999-2000	2000-2001		Mean
	Bornova	Bornova	Menemen	
	kg ha^{-1}			
47	4673	4313	5633	4873.0
60	5103	3988	4800	4630.3
67	5540	4395	4998	4977.7
69	5740	4048	5065	4951.0
72	5373	4650	5000	5007.7
Menemen-88	4378	4913	5538	4943.0
Kaşifbey	5563	4063	5103	4909.7
Basribey	6130	4450	5945	5508.3
Cumhuriyet-75	4640	4065	4205	4303.3
Mean				4900.4
LSD (0.05)				544.0

Table 5. Type 1 stability parameters (b_i and S_i^2) and safety-first selection indices for 9 bread wheat genotypes grown in the 3 environments for 1000 kernel-weight.

Genotype	Mean	b_i	S_i^2	I_i
	g			
Cumhuriyet-75	45.2 (1)† (S)	1.34 (9)	41.23 (9)	34.6 (1) (S)
Menemen-88	40.6 (2) (S)	1.19 (7)	35.83 (8)	30.8 (4)
47	40.2 (3) (S)	0.74 (2) (S)	13.58 (2) (S)	34.1 (2) (S)
60	38.2 (4)	1.15 (6)	29.43 (6)	29.3 (7)
Basribey	37.9 (5)	0.79 (3) (S)	14.86 (3) (S)	31.6 (3) (S)
Kaşifbey	36.9 (6)	0.91 (4)	20.01 (4)	29.5 (6)
67	35.3 (7)	1.04 (5)	23.56 (5)	27.3 (8)
69	35.3 (8)	0.61 (1) (S)	8.53 (1) (S)	30.3 (5)
72	35.1 (9)	1.21 (8)	31.36 (7)	25.2 (9)
Mean	38.2			
LSD (0.05)	2.0			

†: Numbers in brackets are rank values of genotypes for each parameter
(S): Selected genotypes

Table 6. Mean test weight, Type 1 stability parameters (b_i and S_i^2), and safety-first selection index for 9 bread wheat genotypes growth in the 3 environments for test weight.

Genotype	Mean	b_i	S_i^2	I_i
	kg hL^{-1}			
72	82.7 (1)[†] (S)	0.98 (5)	1.33 (5)	80.8 (1) (S)
67	82.3 (2) (S)	1.53 (8)	2.58 (8)	79.6 (7)
69	82.2 (3) (S)	1.26 (6)	1.48 (6)	80.2 (4)
Basribey	81.9 (4)	1.54 (9)	2.86 (9)	79.1 (8)
Cumhuriyet-75	81.8 (5)	0.63 (2) (S)	0.46 (2) (S)	80.7 (2) (S)
Kaşifbey	81.6 (6)	0.69 (3) (S)	1.08 (4)	79.9 (5)
47	81.4 (7)	0.90 (4)	1.01 (3) (S)	79.7 (6)
Menemen-88	80.7 (8)	0.14 (1) (S)	0.08 (1) (S)	80.2 (3) (S)
60	80.6 (9)	1.33 (7)	1.93 (7)	78.3 (9)
Mean	81.7			
LSD (0.05)	0.7			

[†]: Numbers in brackets are rank values of genotypes for each parameter.
(S): Selected genotypes

stable genotype according to Type 1 stability with respect to b_i and S_i^2, was among the genotypes having the lowest 1000-kernel weight (Table 5).

Mean values for test weight across the genotypes varied between 80.6 (Line 60) and 82.7 (Line 72) kg hL^{-1} (Table 6). Although none of the 3 genotypes (Lines 72, 62, and 69) with the highest test weight was selected by Type 1 statistics, it was observed that Line 72 ranked in the same group with the other 2 genotypes with the highest index (I_i) value. In contrast, varieties Menemen-88 and Cumhuriyet-75 had significantly lower test weight than the mentioned breeding lines, but are the most stable genotypes based on Type 1 statistics.

There were positive rank correlations between safety-first index values (I_i) and mean values of all genotypes for 1000-kernel weight (Table 7). However, no significant rank correlation coefficient was found between the average test weight and Type 1 statistics (Table 8). Rank correlations among safety-first index values and Type 1 statistics (b_i and S_i^2) were very low for 1000-kernel weight (Table 7), but were positive and significant for the test weight (Table 8). Rank correlation coefficient between the 2 measures of Type 1 stability for 1000-kernel weight is similar in magnitude to that for the test weight and is highly significant ($r = 0.983^{**}$) (Tables 7 and 8).

Discussion

For the mean values in grain yield and the other 2 traits, significant reductions were observed at Bornova location in 2000-2001 growing season relative to 1999-2000 (Table 3). Winter wheat genotypes grown under

Table 7. Rank correlation coefficients among mean values, safety-first selection index, and Type 1 stability parameters (b_i and S_i^2) of 9 bread wheat lines and varieties for 1000-kernel weight.

	b_i	S_i^2	I_i
Mean	-0.300	-0.416	0.767^{*}
b_i	-	0.983^{**}	0.133
S_i^2		-	0.050

*, **: Significant at P = 0.05 and P = 0.01, respectively.

Table 8. Rank correlation coefficients among mean values, safety-first selection index, and Type 1 stability parameters (b_i and S_i^2) of 9 bread wheat lines and varieties for test weight.

	b_i	S_i^2	I_i
Mean	-0.383	-0.400	0.350
b_i	-	0.983^{**}	0.683^{*}
S_i^2		-	0.667^{*}

*, **: Significant at P = 0.05 and P = 0.01, respectively.

Mediterranean conditions may be subjected to late drought especially during the grain filling period (Calhoun et al., 1994). Water deficit during the grain setting period can cause grain yield decrease by reducing grain weight per spike and 1000-kernel weight (Genç et al., 1987; Korukçu and Arıcı, 1987; Koç et al., 1994). Total precipitation for March and April, an important time period for grain filling in wheat in the Mediterranean coastal zone, was 141.7 mm in 2000, and 84.7 mm in 2001 (Records of Bornova Meteorology Station, 2001). Genç et al. (1987) previously reported that there were significant differences between the years in terms of test weight in the bread wheat trials carried out in Çukurova, an agricultural coastal lowland under Mediterranean climate.

All of the 5 lines evaluated in this study were selected for high yield from the previous trials, including breeding lines (ISWYN 96), conducted in Bornova. Indeed, grain yields of all these genotypes for which there were no significant differences among mean yields across all environments decreased probably due to lower rainfall at the same location during plant growth in 2000-2001 growing season (Table 4). Basribey, Kaşifbey, and Cumhuriyet-75, 3 registered cultivars grown by local farmers in Aegean region, had a yield performance similar to previous reports (Aydemir et al., 2001). Responses like low soil moisture manifested as yield reduction in all the studied cultivars during the 2000-2001 growing season appeared to be the reason for the non-significant genotype × environment interaction for grain yield.

Non-significant correlations between Type 1 stability statistics and mean values for 1000-kernel weight and test weight showed that there was no strong association among these 2 quality traits for both performance and stability. Pham and Kang (1988) suggested that for high performance and increasing genetic gains, selections should be made separately in the event when there are no strong and consistent correlations among mean performance and stability statistics. In terms of stability based on near zero regression coefficient (b_i) and low value of variance (S_i^2) across environments (Busch at al., 1969; Peterson et al., 1992), it was determined that all genotypes selected under these 2 stability criteria for both test weight (Cumhuriyet-75, Kaşifbey, Menemen-88 and line 47) and 1000-kernel weight (Basribey and line 69 -except for Line 47-) had a quality trait mean value lower than, or about equal to, overall mean (Tables 5 and 6). Also Peterson et al. (1992) pointed out that some winter wheat genotypes showed high stability (low (b_i) value) for some quality properties, which are not desired because of their low mean yield.

In this research, a safety-first model involving stability statistic S_i^2 (Eskridge, 1990) was used to select stable genotypes for both 1000-kernel and test weight. It gave different results to some extent when compared with selections based on the estimates of b_i and S_i^2 (Tables 5 and 6). According to this model, calculated index values express a lower confidence limit for the related trait of each genotype (Eskridge, 1990; Annicchiarico, 2002). In this way, considering higher index values, the genotypes that are expected to have more quality performance than others in the most adverse growing conditions will be selected. Consequently, instead of ranking the genotypes by their quality trait mean values across environments, it can be useful to rank them using a safety first index for cultivars because the consistency of performance is more important and desired by millers and bakers. Thus, genotypes Line 47 (for 1000-kernel weight) and Line 72 (for test weight) are the best 2 genotypes followed by Cumhuriyet-75 in terms of safety-first index values (I_i). Cumhuriyet-75 has been grown for a long time in Aegean region (Aydemir et al., 2001) and it is preferred by millers and bakers because of large seed size and grain color (Kanbertay, 1994; Demir et al., 1999). Grain yield of these 2 lines (Line 47 and Line 72) is significantly greater than Cumhuriyet-75. Likewise, Toklu et al. (1999) noticed that values of 1000-kernel weight and test weight of Balatilla, a registered cultivar developed by selection from another ISWYN nursery in a breeding program targeted to identify bread wheat genotypes adapted to Çukurova Coastal Zone, were higher than that of the other 2 check cultivars. It was also reported that 1000-kernel weight of this cultivar varied between 40 and 45 g and the mean test weight was 79.8 kg hL^{-1} for the years 1997 and 2000.

Rank correlations between index values and means of genotypes are significant and high for 1000-kernel weight but non-significant and low for test weight (Tables 7 and 8). Eskridge (1990), after determining a low correlation (r = 0.15) between mean yield and values of safety-first index based on the S_i^2 statistics, reported that the index is strongly affected by variance across environments in addition to the mean yield. Actually, index values for test weight were significantly rank correlated (r = 0.667) with S_i^2 in our research as well. This positive correlation indicates that those genotypes with large values of lower confidence limit have also an enhanced stability. According to Eskridge (1990), one of the advantages of safety-first index is that it clearly weighs the importance of stability in making selections. Also, Kang (1993) informed that giving more importance to stability in the selection process should be very beneficial to growers. Index values for 1000-kernel weight did not correlate significantly with S_i^2, but at least it is not subject to negative correlation (Table 7). In agreement with the results of some earlier studies (Becker et al., 1982; Pham and Kang, 1988), S_i^2 was highly rank correlated (r = 0.983) with b_i for both 1000-kernel weight and test weight; therefore, it appeared that both stability parameters rank the genotypes identically. Based on these results, it is concluded that, as an alternative method, safety-first selection index may be effective in selecting superior wheat genotypes especially for test weight, which is 1 of the 2 physical quality parameters important in determining flour yield in wheat.

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