GENOTYPES ENVIRONMENT INTERACTION AND GENETIC DIVERSITY ASSESSMENT OF BREAD WHEAT (*Triticum aestivum* L.) GENOTYPES

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Abstract

The significant genotype (G) and environment (E) interaction and genetic diversity in breeding program are an essential issue for breeder to develop new cultivars. An experiment was conducted to assess genetic diversity by cluster and biplot analysis for yield, agro-morphological and quality characters. In this study a total of 25 bread wheat genotypes were tested during 2011-2012 seasons at 4 environments condition. The experiment was conducted in randomized completely blocks design with four replications. Grain yield, days of heading, plant height, lodging resistant, 1000-kernel weight, test weight, protein ratio, gluten value, gluten index, hardness and sedimentation were investigated. Mean grain yield for four locations ranges from 5626 kg ha^{-1} to the 7356 kg ha^{-1}. The highest grain yield performed by cultivar Bereket and Tekirdağ was the highest yielding location. Environmental variations are important in determining performance of wheat genotypes. Graphical result from PCI showed that the first principal component PC1, explained 40.3% of interaction some of square while the second principal component, PC2 explained 26.8% of some of square interaction. The result of PCA revealed that the 2 principal components (PC1, PC2) contributed 67.2% of the total variability. GGE biplot analysis permitted estimation of interaction effect of a genotype in each environment and it helped to identify genotypes best suited for specific environments. According to biplot, Gelibolu, G9 and G11 are both high yielding and stable. Pehlivan, G7 were the best genotypes as it is more stable than the other genotypes based on TW, TKW, protein ratio and gluten value. We can see that Pehlivan and G7 are also very stable for these parameters and so could be used in a breeding program. The cluster analysis revealed that there is considerable variation among genotypes that could be implicated in selection of bread wheat for the development or improvement of cultivars.

Key words: *Bread wheat, genotypes, genetic divergence, GE Interaction, GGE Biplot*

1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the most important and widely producing cereal crop throughout the Thrace region of Turkey. Although the amount of the rainfall (589.1 mm) during growing season is enough for wheat production, the distribution of this rainfall is not regular. This fluctuation of rainfall causes reducing grain yield and quality (Öztürk and Korkut, 2017; Öztürk and Korkut, 2018a). Because of the various environment conditions yield and quality in wheat varies and GGE biplot analysis provides an easy and comprehensive solution to genotype by environment data analysis and it not only allows effective evaluation of the genotypes but also allows a comprehensive understanding of the target environment and the test environments. Drought is mainly abiotic stress factor and low moisture during grain filling period affect bread wheat yield and quality (Öztürk and Korkut 2018b). Evaluation of genotypes across diverse environments and over several years is needed in order to identify spatially and temporally stable genotypes that could be recommended for release as new cultivars and/or for use in the breeding programs (Sharma et al., 2010). Superior genotypes must be evaluated on the basis of multi-environment trials (MET) and multiple traits to ensure that the selected genotypes have acceptable performance in variable environments within the target region. For this reason, MET are conducted throughout the world for major crops every year in which multiple traits and characteristics are usually recorded (Yan and Rajcan, 2002). The success of crop improvement activities largely genotype evaluation by eliminating unnecessary testing depends on the identification of superior genotypes for sites (Letta, 2009). G × E interactions are of major importance, because they provide information about the effect of different environments on cultivar performance and have a key role for assessment of performance stability of the breeding materials (Moldovan et al., 2000). G x E interaction may offer opportunity for selection and adaptation of that should positive interaction with specific location which helps in effective utilization of specifically adapted genotypes (Ceccarelli and Grando, 2007). To develop varieties for different environments, very essential for breeders to evaluate their genotypes based on many years and several locations. Environmental variations are important in determining performance of elite materials. Genotype ranks consistently across different tested location has less response for highly unstable environment (Solomon et. al., 2018). The different response of genotypes across the testing environment is considered as hindrance in selecting and recommending of crops and cause yield fluctuation (Kang, 1998). Stable yield performance of genotypes under both favorable and drought stress conditions is vital for plant breeders to identify drought tolerant genotypes (Pirayvatlou, 2001). Most breeding programs face complex mega-environments with unpredictable GEI and genotype evaluation based on mean performance and stability has been a perennial problem and challenge (Yan and Kang, 2003). GGE biplot analysis results can discriminate between expected and realized responses of genotypes and has been widely used in recent years to determine the stability of disease resistance through multi-environment trials. GGE biplot is an effective method to fully examine the data. The biplot method originated with Gabriel (1971). Performance trials have to be conducted in multiple environments because of the presence of GE. Variety trials provide essential information for selecting and recommending crop cultivars. However, variety trial data are rarely utilized to their full capacity. Although data may be collected for many traits, analysis may be limited to a single trait (usually yield) and information on other traits is often left unexplored. Furthermore, analysis of genotype by environment data is often limited to genotype evaluation based on genotype main effect (G) while genotype-by-environment interactions (GE) are treated or a confounding factor (Yan and Tinker, 2006). 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 (Pfeiffer and Braun, 1989). Therefore, the objective of this study was to evaluate the performance of the advance genotypes and to investigate their yield stability and genotype-by-environment interactions across various environment conditions.

2. MATERIAL AND METHODS

The experiments were conducted during 2011-2012 growing years at four locations of Trakya Region, Turkey. Twenty five bread wheat genotypes were studied in a randomized complete block design (RCBD) with four replications. Each plot was 6 meter long and had 6 rows, spaced 0.17 meters apart. A seed rate of 500 seeds m^2 was used. Grain yield, days of heading, plant height, lodging resistant was taken from plot in each replication. In the study, 1000-kernel weights and test weight (Blakeney et al., 2009), protein ratio, grain hardness, gluten value, gluten index, and sedimentation (Köksel et al., 2000; Perten H. 1990; Anonymous, 2002; Anonymous, 1990) were determined. The quality analysis of Zeleny sedimentation test and wet gluten content were determined according to ICC standard methods No. 116/1 and 106/2, respectively (Anonymous, 1972; Anonymous, 1984). For stability of the genotypes the mean yield (x), determinations coefficient (R^2), deviation from regression (S^2d), intercept value (a), regression coefficient (b) were calculated (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Tai, 1971; Teich 1983).

In order to visually display relations of observed traits and genotypes multivariate biplot analysis (genotype by trait biplot), described by Yan and Rajcan, (2002), Yan and Tinker (2006) and Yan and Kang (2003) was used. A positive correlation between two traits is represented by an acute angle between them, while obtuse angle represents a negative correlation. The cluster analysis (CA) was used to see whether the cultivars fell into groups or clusters. The CA's were performed that adopts squared Euclidian distance as a measure of dissimilarity and the Ward's method as the clustering algorithm (Ward, 1963). Correlations between all characteristics were calculated. Data were analysed statistically for analysis of variance the method described by Gomez and Gomez (1984). The significance of differences among means was compared by using Least Significant Difference (L.S.D. at a %5) test (Kalaycı, 2005).

3. RESULTS AND DISCUSSION

A genotype having stabile grain yield across the environment condition is very important in wheat. Trakya region has various environment condition so G x E interaction is a mainly issue for plant breeders in improving high yield across variable environments. Twenty five advanced genotypes were tested at four locations to investigate yield and quality components based on Principal Component Analysis (PCA), stability and cluster. The analysis variance for yield and quality components was performed and given in Table 1, and 2. The results of variance analyses showed that there were significant differences (P<0.01) among genotypes based on locations.

Table 1. Combined analysis of variance for wheat genotypes across four environments

Source of variation	DF	MS	F value
Environment	3	5.87	11.535**
Replication	12	5089701.0	
Genotypes	24	822780.0	5.783**
G x E Interaction	72	368952.0	2.593**
Error	12	5089701.0	
Total	399	324501738.0	

Note: *, ** Significance at respectively 5% and 1% level probability

Mean grain yield across four locations ranged from the highest 7356 kg ha^{-1} to the smallest 5626 kg ha^{-1}. The mean grain yield was 6806 kg ha^{-1}. The highest grain yield performed by cultivar Bereket and followed by Gelibolu. Because of the favorable environment condition Tekirdağ was the highest yielding location. The mean grain yield for tested genotypes was lower relative in Lüleburgaz location than other location.

Wheat (*Triticum aestivum* L.) is economically one of the most important cereal crops in the world. Genetic improvement in wheat yields in dry areas has not been as easy as in more favorable environments or where water is not a limiting factor (Richards et al., 2001). Apparently, morpho-physiological traits for growth and development have the greatest impact on the adaptation of plants to the target environments with the aim of achieving a maximum productivity. Selection criteria based on morphological, physiological and biochemical traits have been suggested for screening drought tolerance in wheat (Araus et al., 2002).

Based on Genotypes (G) environment (E) interaction there was significant difference among locations and genotypes. Cultivar Bereket had higher grain yield in Edirne and Kırklareli locations. Genotypes G13 and G2 had higher grain yield in Lüleburgaz and, TE6025-21 had higher grain yield in Tekirdağ location. Mean grain yield of the genotypes varied between 5904-7957 kg ha^{-1} in Edirne location, 5141-6794 kg ha^{-1} in Kırklareli, 4294-6760 kg ha^{-1} in Lüleburgaz, and 7168-9632 kg ha^{-1}grain yield in Tekirdağ location (Table 2).

Table 2. Mean yield of genotypes across four different environments in 2011-2012 cycle

Entry	Genotype	Locations				Mean Yield (kg da^{-1})
		Edirne	Kırklareli	Lüleburgaz	Tekirdağ	
1	Aldane	590.4 j	514.0 ı	429.4 f	716.8 m	562.6 h
2	TCI981318-2 (G2)	697.2 e-h	615.8 a-f	672.0 a	831.6 g-k	704.2 abc
3	TE5843-3 (G3)	742.5 a-f	539.2 ghı	611.8 a-d	828.6 h-k	680.5 b-f
4	TE5857-4 (G4)	748.5 a-e	586.0 c-ı	597.0 a-e	820.1 h-l	687.9 bcd
5	Selimiye	714.3 c-h	651.0 a-d	598.6 a-e	797.6 jkl	690.4 bcd
6	TE5427-6 (G6)	684.5 e-h	648.5 a-d	543.3 a-f	870.9 d-h	686.8 bcd
7	TCI01-7 (G7)	614.7 ıj	558.7 f-ı	575.6 a-e	856.0 e-ı	651.3 d-g
8	OCW00M-8 (G8)	681.0 fgh	623.1 a-f	525.7 b-f	728.1 m	639.5 fg
9	TE5857-9 (G9)	745.0 a-f	617.9 a-f	602.2 a-d	795.3 kl	690.1 bcd
10	Bereket	795.7 a	679.4 a	545.7 a-f	921.7 a-d	735.6 a
11	TE5857-11 (G11)	724.3 c-g	670.2 ab	644.1 ab	821.8 h-l	715.1 ab
12	TE5402-12 (G12)	729.9 b-g	608.8 a-g	521.1 b-f	816.8 h-l	669.1 c-f
13	TCI98-IC-13 (G13)	653.3 hıj	639.8 a-e	676.0 a	870.3 d-h	709.8 abc
14	TE5793-14 (G14)	779.7 abc	617.6 a-f	526.5 b-f	948.9 ab	718.2 ab
15	Pehlivan	705.6 d-h	582.2 d-ı	497.8 c-f	819.7 h-l	651.3 d-g
16	TE5793-16 (G16)	749.8 a-e	642.1 a-e	571.0 a-e	898.4 b-f	715.3 ab
17	TCI2133-17 (17)	696.3 e-h	599.3 b-h	650.2 ab	793.8 kl	684.9 b-e
18	TE5402-18 (G18)	686.5 e-h	656.7 abc	521.7 b-f	801.0 ı-l	666.4 c-f
19	TCI01-573-19 (G19)	695.2 e-h	574.0 e-ı	488.9 def	911.6 a-e	667.4 c-f
20	Gelibolu	768.5 a-d	601.5 b-g	625.1 abc	885.8 c-g	720.2 ab
21	TE6025-21 (G21)	675.3 ghı	589.8 c-h	591.6 a-e	963.2 a	705.0 abc
22	TE6025-22 (G22)	741.1 a-f	583.8 c-ı	550.1 a-f	929.9 abc	701.2 abc
23	TE6038-23 (G23)	685.6 e-h	526.0 hı	502.0 c-f	851.9 f-j	641.4 efg
24	TE5734-24 (G24)	728.7 b-g	561.3f-ı	433.8 f	765.3 lm	622.3 g
25	TE5793-25 (G25)	790.3 ab	643.3 a-e	464.7 ef	902.3 b-f	700.1 abc
Mean		712.9	605.2	558.6	845.9	680.6
L.S.D. (0.05)		65.6**	73.8**	135.8*	56.6**	43.7**
C.V (%)		6.5	8.6	17.2	4.7	9.2

Note: **: P<0.01, *: P<0.05

The adaptation strategies of the plants to drought stress include drought escape, drought avoidance and drought tolerance. Among these strategies, escaping drought involves the completion of the life cycle before the onset of the drought period. Therefore, early maturity has been known as a major drought escaping mechanism, particularly in terminal drought stresses (Levitt, 1980; Chaves et al., 2002). Due to fluctuation of rainfall mid-early genotypes generally are favorable in bread wheat in the region. Days of heading ranged from 123.5 to 129.0 among genotypes and mean value were 126.3 days (Table 3).

With regard to genotypic effects, although the G6 genotype exhibited the highest plant height of 102.5 cm under rainfed condition, it was significantly difference from mean plant height. On the other hand, genotype G11, which was showed the lowest plant height of 78.8 cm, and followed by G24 with plant height of 79.3 cm. Plant breeders have tried to select and release intermediate varieties (Richards et al., 2001; Calderini et al., 1999).

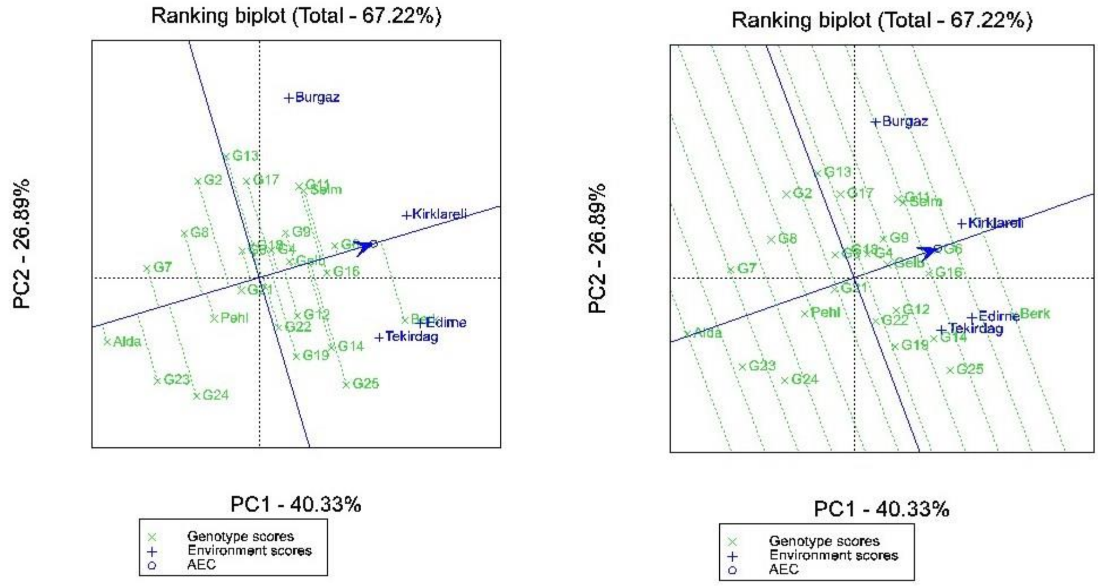
Table 3. Mean performance of physiological and quality parameters based on four various environments conditions

No	Genotype	DH	PH	LOD	TKW	TW	PRT	GLT	IND	HARD	SED
1	Aldane	124.3^{ijk}	94.5^{bc}	4.5^{bc}	46.5^{abc}	82.5^{hi}	13.4^{ab}	39.7^{a-d}	83.1^{a-d}	51.3^{gh}	54.8^{a}
2	G2	124.8^{g-k}	87.8^{c-h}	3.0^{f}	38.3^{hi}	82.4^{i}	12.1^{c-g}	37.0^{d-g}	49.8^{j}	54.3^{b-f}	37.8^{ghi}
3	G3	127.3^{cde}	91.3^{c-f}	3.5^{def}	44.3^{c-f}	83.3^{e-i}	11.9^{c-g}	36.0^{efg}	76.2^{b-f}	53.8^{c-g}	44.0^{b-e}
4	G4	123.5^{k}	84.3^{f-i}	3.0^{f}	43.0^{d-g}	83.2^{e-i}	11.8^{c-g}	34.0^{gh}	85.1^{abc}	54.0^{b-g}	44.3^{bcd}
5	Selimiye	125.8^{fgh}	93.0^{bcd}	4.5^{bc}	46.9^{abc}	84.7^{abc}	12.4^{cd}	39.4^{b-e}	73.7^{c-g}	54.0^{b-g}	44.5^{bcd}
6	G6	124.0^{jk}	102.5^{a}	6.0^{a}	42.7^{efg}	85.1^{a}	12.5^{c}	39.1^{b-e}	77.3^{b-f}	54.8^{b-f}	48.0^{b}
7	G7	124.5^{h-k}	92.0^{b-f}	4.0^{cde}	41.1^{fgh}	84.1^{b-e}	12.6^{abc}	36.8^{d-g}	66.9^{e-i}	56.0^{a-d}	38.3^{f-i}
8	G8	125.5^{f-i}	92.3^{b-e}	4.0^{cde}	41.1^{fgh}	82.9^{ghi}	11.4^{efg}	38.2^{cde}	71.3^{d-h}	54.8^{b-f}	37.8^{ghi}
9	G9	126.0^{efg}	81.8^{hi}	3.0^{f}	41.0^{gh}	82.7^{hi}	11.4^{fg}	32.0^{h}	88.5^{ab}	53.0^{e-h}	45.0^{bcd}
10	Bereket	126.0^{efg}	99.8^{ab}	5.3^{ab}	45.3^{b-e}	83.1^{f-i}	11.3^{g}	33.7^{gh}	67.6^{e-i}	54.3^{b-f}	36.3^{hij}
11	G11	124.5^{h-k}	78.8^{i}	2.8^{f}	40.2^{gh}	82.8^{ghi}	11.4^{fg}	31.8^{h}	83.9^{abc}	53.3^{d-h}	42.8^{c-f}
12	G12	127.3^{cde}	93.5^{bc}	4.3^{cd}	48.4^{ab}	84.9^{ab}	12.2^{c-f}	40.1^{a-d}	65.6^{f-i}	56.3^{abc}	45.3^{bcd}
13	G13	124.5^{h-g}	91.0^{c-g}	3.3^{ef}	35.4^{i}	81.4^{jk}	12.4^{cd}	39.6^{bcd}	59.3^{hij}	55.3^{a-e}	36.5^{hi}
14	G14	128.3^{abc}	90.5^{c-g}	2.8^{f}	46.6^{abc}	80.7^{jkl}	12.5^{bc}	37.8^{c-f}	55.6^{uj}	55.5^{a-e}	39.0^{f-i}
15	Pehlivan	128.3^{abc}	94.5^{bc}	4.0^{cde}	49.6^{a}	83.9^{c-f}	12.3^{cd}	42.4^{ab}	55.5^{ij}	53.0^{e-h}	38.5^{f-i}
16	G16	128.8^{ab}	85.3^{d-i}	2.8^{f}	46.3^{bc}	80.7^{jkl}	12.7^{abc}	40.2^{a-d}	66.1^{e-i}	55.3^{a-e}	39.5^{e-h}
17	G17	125.0^{g-j}	94.8^{abc}	3.5^{def}	41.8^{fg}	83.4^{d-i}	12.6^{abc}	39.2^{b-e}	69.1^{e-h}	56.0^{a-d}	44.5^{bcd}
18	G18	126.8^{def}	90.5^{c-g}	3.0^{f}	47.8^{ab}	84.9^{ab}	12.4^{c}	40.6^{abc}	59.1^{hij}	56.8^{ab}	41.3^{d-g}
19	G19	129.0^{a}	87.5^{c-h}	3.5^{def}	40.8^{gh}	84.3^{a-d}	12.5^{bc}	34.3^{fgh}	90.8^{a}	57.8^{a}	47.0^{bc}
20	Gelibolu	126.5^{def}	82.5^{hi}	2.8^{f}	45.5^{b-e}	83.4^{d-h}	11.5^{d-g}	31.5^{h}	78.5^{a-e}	47.5^{i}	36.5^{hi}
21	G21	126.8^{def}	89.0^{c-h}	3.3^{ef}	46.2^{bcd}	80.4^{kl}	11.9^{c-g}	37.9^{cde}	68.3^{e-h}	50.8^{h}	29.8^{k}
22	G22	126.5^{def}	84.8^{e-i}	3.3^{ef}	48.0^{ab}	81.4^{j}	12.3^{cde}	38.0^{cde}	73.1^{c-g}	52.3^{fgh}	31.8^{jk}
23	G23	128.3^{abc}	82.5^{hi}	2.8^{f}	42.4^{efg}	81.2^{jkl}	13.4^{a}	43.2^{a}	62.7^{ghi}	53.0^{e-h}	34.5^{ij}
24	G24	127.5^{bcd}	79.3_{i}	2.8^{f}	42.5^{efg}	83.7^{d-g}	12.4^{c}	38.2^{cde}	75.1^{c-g}	56.0^{a-d}	39.0^{f-i}
25	G25	128.8^{ab}	83.3^{ghi}	2.8^{f}	46.8^{abc}	80.4^{l}	12.7^{abc}	40.7^{abc}	66.3^{e-i}	54.8^{b-f}	39.0^{f-i}
Mean		126.3	89.1	3.52	43.9	82.8	12.2	37.6	70.2	54.13	40.6
LSD (0.05)		1.43**	7.8**	0.74**	3.16**	0.95**	0.87**	3.54**	12.49**	2.74**	4.49**

Note: **: $P<0.01$, *: $P<0.05$, ns: not significant, DH: Days of heading, PH: Plant height (cm), LOD: Lodging (1-9), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Gluten value (%), IND: Gluten index, HARD: Hardness, SED: Sedimentation (ml)

Although the number of grain spike in wheat has a predominant importance over kernel weight with regard to grain yield, kernel weight is well documented to be a major yield component. There were significant differences among genotypes based on TKW and TW. 1000-kernel weight ranged from 35.4 g to 49.6 g among genotypes and mean was 43.9 g. Cultivar Pehlivan had the highest 1000-kernel weight and followed by G12 and G22 (Table 3). TW varied in genotypes from 80.4 kg to 85.1 kg and mean value of the test weight was 82.8 kg and G6 had the highest test weight (Table 3). Protein quality and quantity is the most important components of wheat grains governing end-use quality (Pena, 2008; Niu et al., 2010). In Trakya region environmental factors during the period of grain filling could be influence protein content. Table 3 shows mean and range of variations for protein ratio in all genotypes were evaluated and found protein ratio varied from 11.3% to 13.4% in the genotypes. The mean protein content was 12.2% and the highest protein ratio was determined in Aldane and G23 genotypes (Table 3). Gluten value of genotypes varied from 31.8% to 43.2%. The mean gluten value was 37.6% and the highest gluten value was determined in Pehlivan and G23 genotypes. Gluten index in genotypes varied based on genotypes and environment interaction. Mean gluten index was 70.2% and G19 had higher gluten index and followed by genotypes G9, G4, G11 and Aldane. The effect of different genotypes on the sedimentation showed that the highest and lowest was shown by the Aldane and G21 genotypes. In addition there was significant difference among genotypes.

One of the important aspects of plant breeding is evaluation of genotypes based on multiple traits. The technique of multivariate analysis genotype by trait (GT) biplot design, can be used for comparison of genotypes based on several traits, in order to isolate those particularly good with certain properties important for the breeding process (Yan and Rajcan, 2002). The studies of GEI have assumed great importance in breeding programs because the yield performance of a genotype is the result of interaction with the genotype and environment. Environmental factors such as precipitation, temperature and soil structure play an important role in genotype performance. Therefore, the release of a genotype with consistent performance over a wide range of environments should lead to stability in production (Akçura et al., 2009). To develop varieties for different environments, very essential for breeders to evaluate their genotypes based on many years and several locations. Environmental variations are important in determining performance of wheat genotypes. Based on grain yield graphical result from PCI showed that the first principal component PC1, explained 40.33% of interaction some of square while the second principal component, PC2 explained 26.89% of some of square interaction (Figure 1a). The result of PCA revealed that the 2 principal components (PC1, PC2) contributed 67.22% of the total variability.

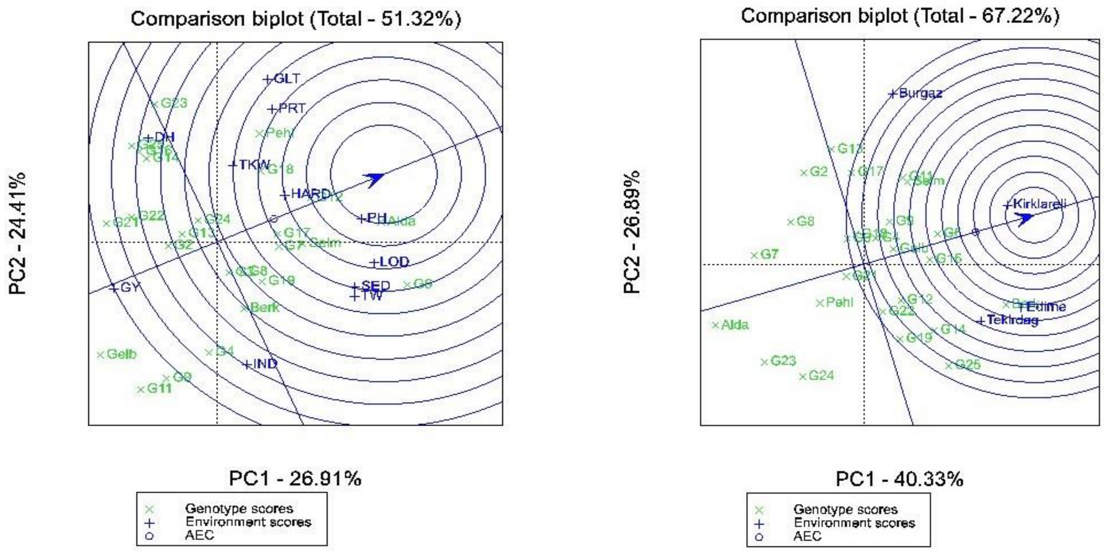


1a 1b

Figure 1. Ranking genotypes based on mean performance in four environments (1a) and GGE biplot with scaling focused on genotypes, for mean grain yield and stability of 25 bread wheat genotypes tested across four environments.

The highest yielder in Tekirdağ location was cultivar Bereket and the lowest yielder G12 line. To rank the genotypes based on their performance in an environment, a line is drawn that passes through the biplot origin and the environment. This line is called the axis for this environment, and along it is the ranking of the genotypes. A superior genotype should have both high mean performance and high stability across a mega-environment. Figure 1 ranks the genotypes based on performance in four environments. Cultivar Bereket, and G8, G14, G16, and G23 lines had higher than average yield, G3, G17, G6 and G4 had near average yield, and Aldane, G24, G23 and G7 had lower than average yields. Also, genotypes G25, G14, and Bereket had higher average yield in Edirne location, G21 and G22 AND Bereket had higher average yield in Tekirdağ location, and all others had lower than average yields (Figure 1a).

The best genotype can be defined as the one with the highest yield and stability across environments. In the GGE biplot, genotypes with high PC1 scores have high mean yield, and those with low PC2 scores have stable yield across environments (Yan and Tinker, 2006). The average environment abscissa is represented in Figure 1b by a single head arrow pointing towards higher yield across environments (Yan and Hunt, 2001). Genotypes Aldane, G24 and G23 had mean grain yield lower than the grand mean. The genotype that yielded higher than the grand mean was Bereket (Figure 1b).



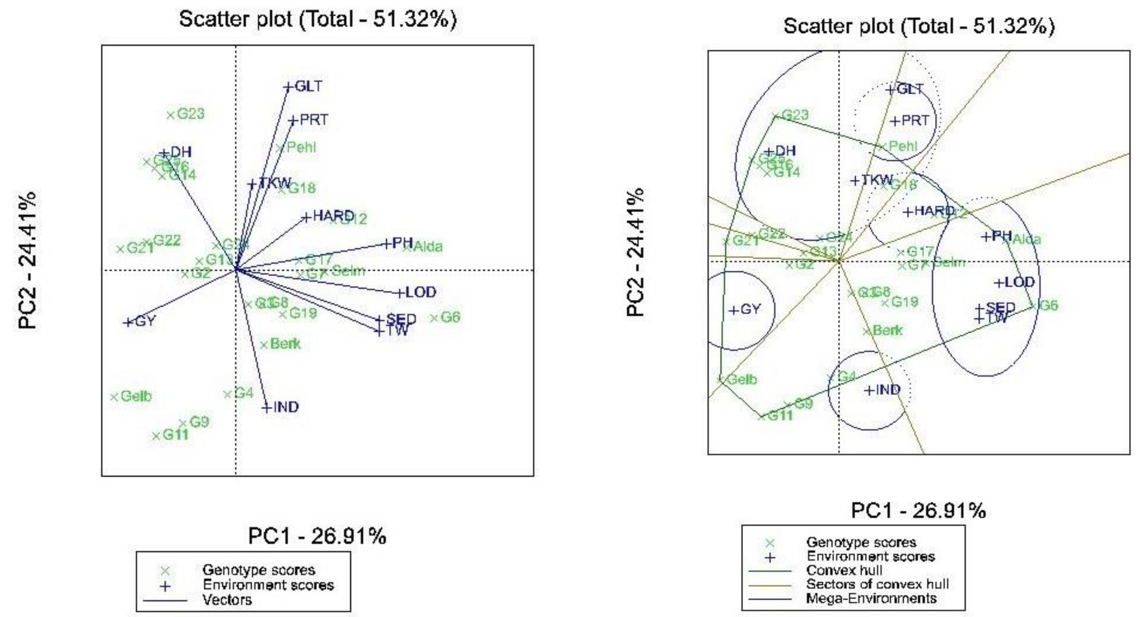
2a 2b

Figure 2. GGE biplot graph based on genotype-focused scaling for comparison of parameters with ideal genotype (2a). GGE biplot graph based on environment-focused scaling for comparison the environments with the ideal environment (Fig. 2b).

Also, it is obvious, according to this model and biplot, that Gelibolu, G9 and G11 is both high yielding and stable. Pehlivan, G7 were the best genotypes as it is more stable than the other genotypes based on TW, TKW, protein ratio and gluten value (Figure 2a). We can see that Pehlivan and G7 are also very stable for these parameters and so could be used in a breeding program.

An ideal genotype should have both high mean performance and high stability across environments. Therefore, genotypes located closer to the ideal genotype are more desirable than others. The ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important. Thus, variety Bereket and G6, which is close to the centre of concentric circles, was ideal genotypes in terms of yield capacity and stability compared with the other genotypes. Genotypes G16 located in the next concentric circle are also regarded as valuable genotypes in terms of yield capacity and stability (Figure 2b). Bereket, G14, and G25 genotypes were well performed in environment Edirne and Tekirdağ, while the Aldane and G7 showed the lowest performance.

The angle between two parameters indicates their similarity in response to the environments. An acute angle (test weight and sedimentation, protein and gluten) means that the two parameters responded similarly and that the difference between them was proportional in all environments. An obtuse angle (gluten and gluten index, grain yield and plant height) means that the two parameters responded inversely and wherever the first parameter performed well the other parameter performed poorly. A right angle indicates that the two parameters (Protein ratio and sedimentation) responded to the environments independently (3a).

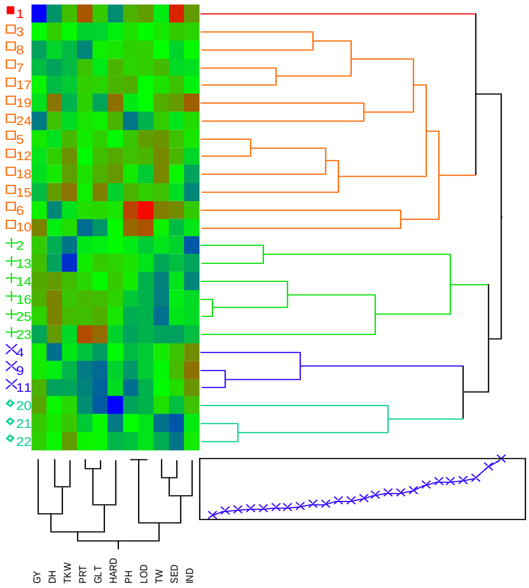


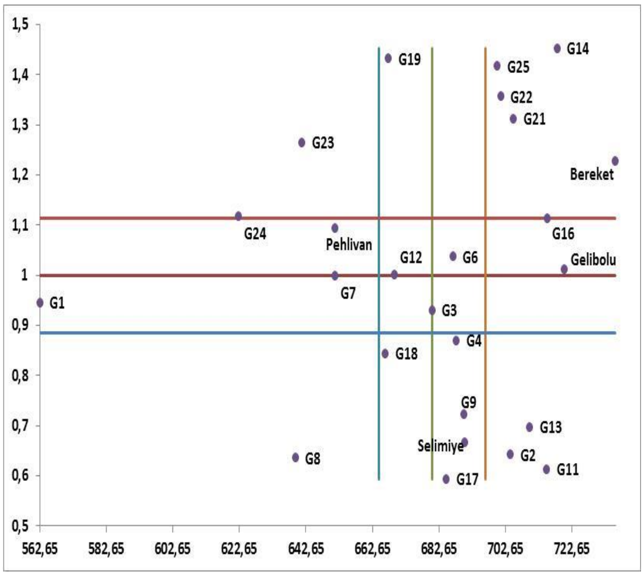
3a 3b

Figure 3. The GGE biplot to show which genotypes performed bets in which environments and a genotype by trait biplot representing 25 winter wheat genotypes measured for 11 parameters (3a). Polygon view of the GGE biplot based on environment and investigated parameters and genotypes (3b)

A genotype by trait biplot can help understand the relationships among traits and can help identify traits that are positively or negatively associated, traits that are redundantly measured, and traits that can be used in indirect selection for another trait. It also helps to visualize the trait profiles (strength and weakness) of genotypes, which is important for parent as well as variety selection (Yan and Tinker, 2006; Yan and Kang 2003). The biplot in Figure 3a presents data of 25 genotypes determined for eleven parameters. Across the 25 tested genotypes, sedimentation with test weight and protein ratio with gluten value was positively associated. Protein ratio with gluten value was negatively correlated with grain yield and gluten index. Also, sedimentation and test weight was negatively correlated with days of heading. These relationships suggest that it is possible to combine higher protein ratio with gluten value, and higher test weight and sedimentation in a single genotype (Figure 3a).

The vertices of the polygon were the genotype markers located farthest away from the biplot origin in various directions, such that all genotype markers were contained within the resulting polygon. Based on this, six genotypes identified as the markers farthest away from the biplot origin. The vertex genotype in each sector represented the highest yielding genotype in the environment that fell within that particular sector (Yan et al., 2000).The polygon view of the GGE-biplot analysis helps one detect cross-over and non-crossover genotype-by-environment interaction and possible mega environments in multi-location yield trials (Yan et al., 2007). Based on the GGE analysis the first two principal components explained about 51.32% of the total interaction variation. Aldane and G6 was the best genotype based on plant height, sedimentation value, test weight and lodging resistance. Pehlivan was the best cultivar for protein ratio and gluten value. According to Figure 3b, the vertex genotypes were G6, Aldane, Pehlivan, G23, G25, G21, Gelibolu, and G11. These genotypes were the best or the poorest genotypes based on parameters in some or all of the test environments since they had the longest distance from the origin of the biplot (Figure 3b).





4b Stability of the genotypes for grain yield

4a

Figure 4. Cluster diagram of 25 genotypes based on agro-morphological and disease traits (4a) and according to adaptability of varieties for the grain yield across four locations (4b)

The genotypes were evaluated over 11 parameters and showed wide variability for the components studied. The cluster analysis was done and 25 genotypes grouped into 5 clusters based on Ward's method. The cluster analysis revealed that there is considerable variation among genotypes that could be implicated in selection of bread wheat for the development or improvement of cultivars. In the first group of cluster 1 genotypes (Aldane) and in second group of cluster 12 genotypes, including cultivars Selimiye, Bereket and Pehlivan are located. In the third group of cluster 6 genotypes and in fourth group of cluster 3 genotypes and last group of cluster 3 genotypes are located one of them cultivar Gelibolu. First cluster with one cultivar (Aldane) had better quality as compared with other cluster. Fifth cluster with 3 genotypes had better yield potential and 1000-kernel weight as compared with other cluster. Three genotypes were grouped in fourth with higher gluten index and short plant height. The genotypes in cluster 3 may be used for improvement of gluten contents. The cluster and principal component analyses together with the agronomic and quality data of winter bread wheat revealed the existence of genetic variations within accessions, as well as differences between winter bread wheat genotypes (Figure 4a).

Correlation coefficients on the investigated parameters were determined by Pearson's correlation analysis (Table 4). It was found highly significant negative correlation between grain yield and protein content (r=-0.523**) and sedimentation (r=-0.435*). In the study, no correlation was found between grain yield and the days of heading, plant height, 1000-kernel weight and hardness. Grain protein content is among the key determinants affecting of both end use and market value in wheat (Pena, 2002; Pena, 2008). Protein ratio was highly significant positively correlated with gluten value (r=0.738**) and slightly correlated with hardness and sedimentation. The positive correlation between sedimentation with test weight (r=0.518**) and gluten index (r=0.509**) were medium. There was a negative significant relation with gluten value and gluten index (r=-0.605**). Test weight was slightly associated with gluten index and hardness.

Table 4. Coefficients of correlation between grain yield and tested parameters

Traits	GY	DH	PH	LOD	TKW	TW	PRT	GLT	IND	HARD
DH	0.055									
PH	-0.087	-0.263								
LOD	-0.177	-0.361	0.864**							
TKW	-0.067	0.457*	0.170	0.134						
TW	-0.278	-0.266	0.386	0.524**	0.040					
PRT	-0.523**	0.245	0.093	-0.013	0.153	-0.132				
GLT	-0.394	0.300	0.297	0.113	0.321	-0.121	0.738**			
IND	-0.167	-0.211	-0.246	0.098	-0.127	0.254	-0.244	-0.605**		
HARD	-0.077	0.144	0.212	0.091	-0.219	0.278	0.246	0.271	-0.187	
SED	-0.435*	-0.269	0.270	0.374	-0.017	0.518**	0.207	-0.081	0.509**	0.237

Note: **: P<0.01, *: P<0.05, GY: Grain yield (kg da^{-1}), DH: Days of heading, PH: Plant height (cm), LOD: Lodging resistance, TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Gluten (%), IND: Gluten index (%), HARD: Hardness, SED: Sedimentation (ml)

Table 5. Mean yield and stability parameters of genotypes across four different environments

G. No	Genotype	X	R^2	b	S^2d	a
1	Aldane	562.65	0.98	0.95	35.28	-81.41
2	TCI981318-2 (G2)	704.15	0.80	0.64	206.20	267.00
3	TE5843-3 (G3)	680.53	0.84	0.93	338.19	47.30
4	TE5857-4 (G4)	687.90	0.93	0.87	114.04	95.53
5	Selimiye	690.38	0.99	0.67	10.10	236.04
6	TE5427-6 (G6)	686.80	0.94	1.04	138.64	-19.14
7	TCI01-7 (G7)	651.25	0.85	1.00	364.32	-28.54
8	OCW00M-8 (G8)	639.48	0.87	0.64	125.80	206.78
9	TE5857-9 (G9)	690.10	0.94	0.72	62.93	198.62
10	Bereket	735.63	0.95	1.23	151.43	-100.50
11	TE5857-11 (G11)	715.10	0.99	0.61	6.58	298.05
12	TE5402-12 (G12)	669.15	0.96	1.00	84.35	-12.20
13	TCI98-IC-13 (G13)	709.85	0.68	0.70	467.79	235.45
14	TE5793-14 (G14)	718.18	0.99	1.45	24.57	-270.76
15	Pehlivan	651.33	0.98	1.09	45.58	-93.26
16	TE5793-16 (G16)	715.33	1.00	1.11	7.96	-42.84
17	TCI2133-17 (17)	684.90	0.84	0.59	136.10	280.70
18	TE5402-18 (G18)	666.48	0.88	0.84	197.06	92.24
19	TCI01-573-19 (G19)	667.43	0.99	1.43	26.12	-307.43
20	Gelibolu	720.23	0.95	1.01	118.52	31.84

21	TE6025-21 (G21)	704.98	0.90	1.31	389.67	-188.61
22	TE6025-22 (G22)	701.23	0.99	1.36	19.60	-222.12
23	TE6038-23 (G23)	641.38	0.99	1.27	26.45	-220.11
24	TE5734-24 (G24)	622.28	0.86	1.12	414.20	-138.24
25	TE5793-25 (G25)	700.15	0.91	1.42	392.19	-264.37

Note: X: mean yield, R^2: determinations coefficient, S^2d: deviation from regression, a: intercept value, b: regression coefficient

A genotype having stabile grain quality across the environment condition is very important in wheat production. Genotype x Environment interaction is a mainly issue for plant breeders in improving high-quality, stable genotypes across variable environments. Determined stability parameters based on grain yield of the genotypes showed that all stability parameters were significantly different. For grain yield G16 was very stable with the optimum determinations coefficient (R^2). There was highly variation in regression coefficients (b) values and optimum b value was determined in genotypes G7 and G12. The highest intercept values (a) were determined in cultivars Selimiye and G2, G8, G9, G11, G13 and G17 lines. The highest intercept value indicated that these cultivars were higher grain yield both fertile and less fertile environment conditions. According to all stability parameters it could be seen that cultivar Gelibolu was very stable for the grain yield with higher coefficient of determinations (R^2), positive intercept value (a) and suitable regression coefficient (b) with close to 1.

4. CONCLUSIONS

Trakya region has various environment condition so genotype x environment interaction is a mainly issue in improving high yield across variable environments. A genotype having stabile grain yield across the environment condition is very important in wheat. According to result, it is concluded that multiple methods were employed and provided a good understanding of the adaptation level of wheat genotypes across a diverse range of environments. The results of analyses indicated that wheat grain yield and other parameters were highly affected by environmental effect followed by the magnitude of GEI. GGE biplot analysis permitted estimation of interaction effect of a genotype in each environment and it helped to identify genotypes best suited for specific environments. The polygon views of the GGE biplot pointed out that there are two possible mega environments. The highest grain yield performed by cultivar Bereket, and Tekirdağ was the highest yielding location. According to biplot, Gelibolu, G9 and G11 are both high yielding and stable. Pehlivan, G7 were the best genotypes as it is more stable than the other genotypes based on TW, TKW, protein ratio and gluten value. We can see that Pehlivan and G7 are also very stable for these parameters and so could be used in a breeding program. Bereket, G14, and G25 genotypes were well performed in environment Edirne and Tekirdağ, while the Aldane and G7 showed the lowest performance. A genotype by trait biplot can help understand the relationships among traits and can help identify traits that are positively or negatively associated. Sedimentation with test weight and protein ratio with gluten value was positively associated. Protein ratio with gluten value was negatively correlated with grain yield and gluten index. These relationships suggest that it is possible to combine higher protein ratio with gluten value, and higher test weight and sedimentation in a single genotype. Aldane and G6 was the best genotypes based on plant height, sedimentation, test weight and lodging resistance. According to all stability parameters it could be seen that cultivar Gelibolu was very stable for the grain yield with higher coefficient of determinations, positive intercept value and suitable regression coefficient. Also, cluster analysis revealed that there is considerable variation among genotypes that could be implicated in selection of bread wheat for the development or improvement of cultivars.

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