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EVALUATION OF YIELD PERFORMANCE AND QUALITY PARAMETERS OF BREAD WHEAT CULTIVARS CULTIVATED IN RAINFED CENTRAL ANATOLIA

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ABSTRACT

There are limited number of wheat cultivars recommended for successful cultivation under the rainfed conditions of the Central Anatolia. This research was conducted for determining grain yield potential and some quality traits of five commonly cultivated bread wheat cultivars (Bezostaja 1, Gerek 79, Bayraktar 2000, Tosunbey, and Sonmez 2001) cultivated over large areas in the Central Anatolia. The experiments were conducted using randomized complete block design with four replications during 2007-2015. The cultivars were evaluated in terms of mean grain yield, regression coefficient (b_i), regression constant (a), coefficient of determination (R^2) and coefficient of variation (CV) for their stability in 38 environments. In addition, stability of the cultivars was assessed on the graphs generated with the use of GGE (Genotype + genotype by environment interaction) biplot analysis. Genotype × environment interaction (GEI) was found significant (p<0.01). In the GGE-biplot analysis of the grain yields, 72.84% of the total variation was explained by PC1 and PC2. Mean grain yields of the genotypes varied between 4018.4-4826.4 kg ha^{-1}, thousand-kernel weights varied between 30.0-35.6 g, test weights between 76.5-79.1 kg, protein contents between 13.4-15.3% and Zeleny sedimentation values between 34.2-46.7 ml. These detailed stability level of the studied cultivars will be helpful for their utilization in future breeding programs. Bayraktar 2000 and Sonmez 2001 had the highest grain yields, the b_i values of greater than 1. Negative values indicated that these genotypes have potential to improve grain yields under appropriate environmental conditions. Bezostaja 1 was identified as the most prominent genotype for quality traits. The results of this study emphasize importance of selecting genetically stable wheat genotypes in breeding programs.

Keywords: *Triticum aestivum* L., cultivar development, grain yield and quality, stability, GGE-biplot, rainfed agriculture

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INTRODUCTION

Wheat and barley are the primary agricultural products of the Central Anatolia. The region is dominantly composed of arid, semi-arid and irrigated lands. It is connected to other regions through east-west and north-south transitional regions. Yield and quality in wheat cultivation fluctuate with the climatic conditions of the region and year. Annual total precipitation of the region is around 300-350 mm (TSMS, 2018) and monthly distribution of precipitation play a great role in cultural practices. Photosynthesis of wheat is affected by low and high temperatures throughout critical growth stages of the plants, and could result in significant variations in yield levels of the cultivars. Lodging of cultivars developed for arid conditions in wet years is another problem influencing yield and quality of wheat. Bread wheat is generally bred for high yield and inducing resistance against biotic and abiotic stresses like yellow rust resistance, cold and drought tolerance in the Central Anatolia Region (Yazar *et al*., 2013). Majority of these bread wheat cultivars are tested and registered for sowing under irrigated conditions. The cultivars brought from abroad, especially European countries are generally tested before registration for regions with high annual total precipitations or irrigated conditions and rarely dry conditions.

Ozturk and Korkut (2018) investigated the effects of droughts in different growth stages of bread wheat on yield and yield components and displayed the significance of genotype for high yield levels. Sometimes extreme deviations are encountered in climatic data that affect and may alleviate yellow rust disease especially under cool and humid conditions. Yield and quality traits are significantly influenced in seasons with intensive pandemic of the disease and serious economic losses are encountered in long run (Akan, 2019). Breeding of wheat genotypes overcoming the effects of frequent droughts, variations in annual precipitations, seasonal distribution of these precipitations, harsh winter conditions, pests, and diseases especially yellow rust pandemic are the primary issues are desired (Author's pers. obs.).

According to seed certification data of the year 2016, 17.8 thousand tons certified seeds were produced in Bezostaja 1, 12.9 thousand tons in Sonmez 2001, 9.3 thousand tons in Tosunbey and 7.9 thousand tons in Bayraktar 2000 (VRSCC, 2016). Because of sensitivity of Gerek 79 to yellow rust (Yazar *et al*., 2013), the cultivar Es 26, a backcross of Gerek 79, was registered in 2010 (VRSCC, 2020). Thereafter, significant decrease was observed in production of Gerek 79 with a large area of cultivation in the region. Low number of wheat genotypes are available for successful cultivation in the arid and semi-arid conditions of the Central Anatolia Region. However, these cultivars may show different response in irrigated areas. The performances of five genotypes in multi-environments and nine growing seasons were determined in rain-based agricultural lands in this study by evaluating them in 38 trials. The study tended to provide enormous and useful information to breeders in developing new varieties under the arid conditions of the Central Anatolia.

Therefore, the aim of the study was to measure some stability parameters together with GGE-biplot analysis allowing graphical assessment of Genotype (G) and Genotype × Environment (GE) interactions.

MATERIALS AND METHODS

This study was conducted during 2007-2015 at Ankara (Haymana, Yenikent, Polatli), Eskisehir, Konya (Center and Gozlu), Kirsehir (Malya) and Aksaray (Kocas) locations in randomized complete block design with four replications under rainfall conditions of Central Anatolia. The locations of experiment have different ecological characteristics from each other and are shown on the map of Turkey (Fig. 1). Plot area varied in sizes between 6.0-9.6 m^2 based on rainfed and irrigated trials. Sowing dates were between the second and the last week of October depending on the locations and years. Each plot was supplied with 23 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} at sowing and 40 kg N ha^{-1} at tillering period. The harvests were performed between the second and last week of July each year with a “plot combine harvester”.

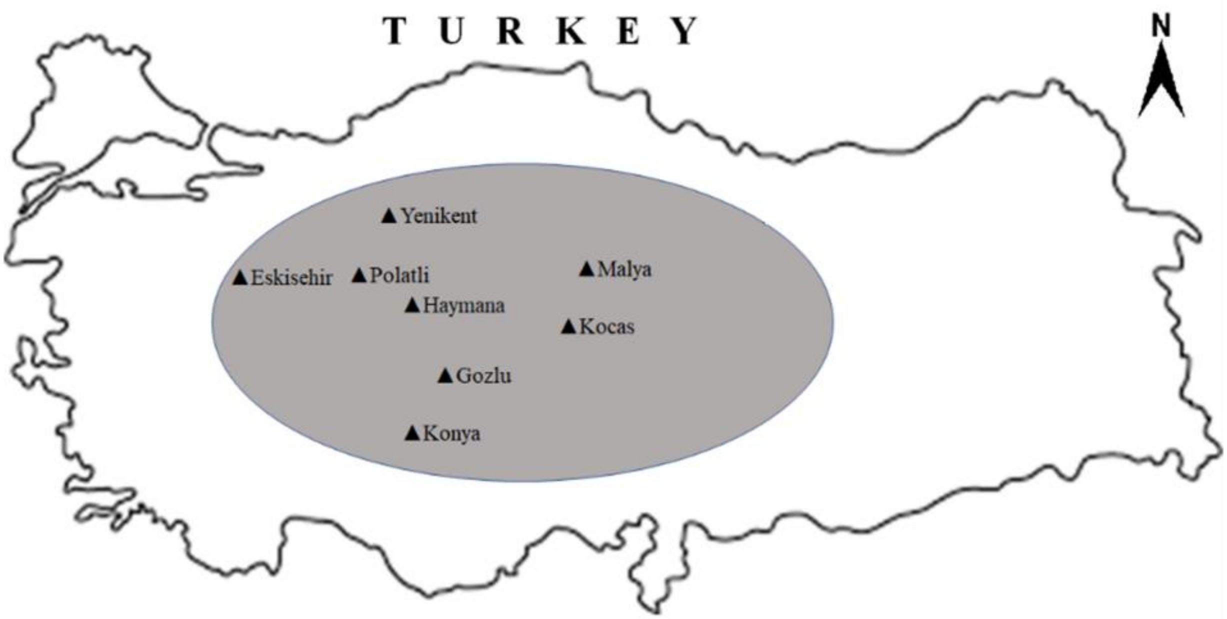

Fig. 1. Map of Turkey showing the locations of the experiments.

Five genotypes were used as the plant material in this study. The Bezostaja 1 is a Russian cultivar registered by Sakarya Maize Research Institute in 1968. The Gerek 79 and the Sonmez 2001 are local cultivars and were registered by Eskisehir Transitional Zone Agricultural Research Institute in 1979 and 2001 in the same order. Whereas, the Bayraktar 2000 and Tosunbey are also local cultivars but were registered by the Ankara Central Field Crops Research Institute in 2000 and 2004, respectively (VRSCC, 2020). The experimental years and locations described in this study are provided in Table 1. The trials were established on fallow lands. Soil texture class was clay and clay-loam, organic matter content was generally low with the soil pH ranges between 7.5-8.2.

Central Anatolia is a large region and exhibits large differences in climate data. Sometimes regional precipitations are replaced with local precipitations. Quantity and seasonal distribution of precipitations are the most effective factors on yield and quality traits in Central Anatolia region. While annual precipitations were lower than the long-term averages in 2007, 2008 and 2013, they were higher compared to long-term averages in the other years (Fig. 2) (TSMS, 2018).

The trials were conducted for bread wheat cultivars under arid conditions to evaluate yield and some quality traits of five cultivars in this study. Thousand-kernel weight, test weight, protein content and Zeleny sedimentation were used as the quality traits. Protein content was determined in accordance with ICC 105/2 method and the results were expressed in dry matter (ICC, 2002a). Zeleny sedimentation analysis was conducted in accordance with the principles specified in ICC 116-1 method (ICC, 2002b).

Statistical analyses were conducted in accordance with randomized complete block design with the use of SAS (SAS Institute, 1999) statistical analysis software. Genotype × environment interaction was found significant and stability analysis was conducted assuming a regression coefficient of 1 (Finlay and Wilkinson, 1963; Eberhart and Russel, 1966). Cultivars were assessed over mean grain yield, regression coefficient (b_i), regression constant (a), coefficient of determination (R^2) and coefficient of variation (CV). A stability graph was generated with the use of mean grain yield and b_i values and the graph was then divided into nine sections with the addition of confidence intervals. Regression graph or expected yield graph was drawn with the use of regression coefficient (b_i) and regression constant (a). GGE-Biplot analysis method was used to assess Genotypes and Genotypes × Environments interactions using GenStat analysis software (GenStat, 2009). Since the locations were not distributed evenly in the experimental years; therefore, each location was considered as an environment and analyses were conducted accordingly.

Table 1. Experimental years and locations.

Experimental locations	Years								
	2007	2008	2009	2010	2011	2012	2013	2014	2015
Haymana-Ankara			+	+	+		+	+	
Yenikent-Ankara		+	+	+	+	+	+		
Polatli-Ankara		+			+		+		+
Eskisehir	+	+	+			+	+		
Konya	+	+	+		+	+			+
Gozlu-Konya			+					+	+
Malya-Kırsehir	+		+	+	+			+	+
Kocas-Aksaray		+	+		+				

+ indicates the locations from which the results are obtained.

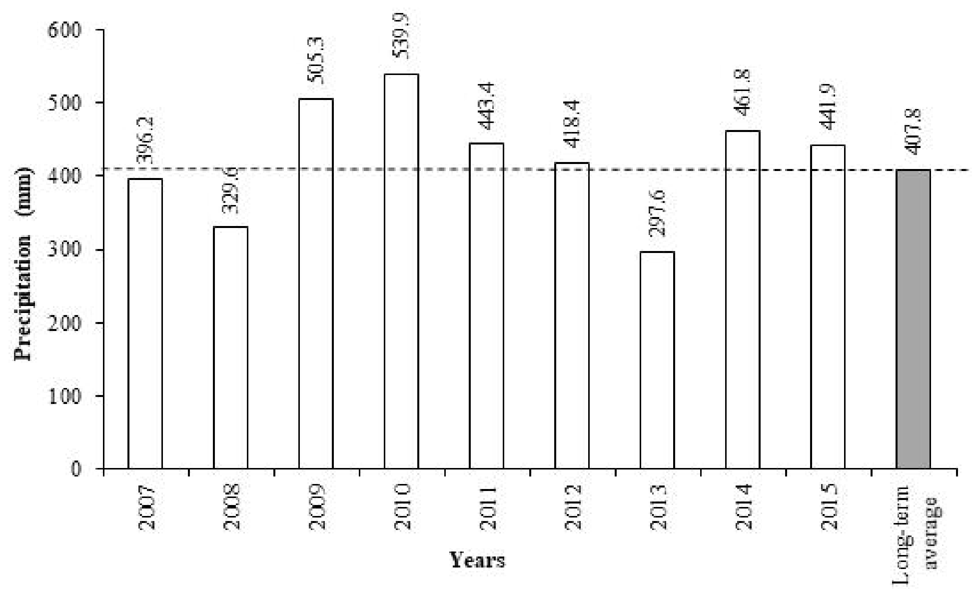

Fig. 2. Annual precipitations of the experimental years for the Central Anatolia region.

RESULTS AND DISCUSSION

The data obtained from 38 environments and five bread wheat cultivars were subjected to analysis of variance. The results showed significant (p<0.01) differences among genotypes and significant genotype × environment interactions. Among the experimental environments, the maximum mean grain yield (7996.9 kg ha^{-1}) was obtained from Konya-2015 and the lowest mean grain yield (1941.2 kg ha^{-1}) was obtained from Malya-2010 (Table 2). Large differences in grain yields of the years within the same location indicated significance of quantity and distribution of precipitations throughout the growing season. Large differences between grain yields of trial environments were due to genotypic response to low and high environmental indices. Khan *et al.* (2020) and Bishwas *et al.* (2021) have emphasized that genotype, environment, and their interaction have a significant effect on grain yield.

Mean grain yields of the cultivars are provided in Table 3 and the stability parameters for grain yield are provided in Table 4. Grain yields of the cultivars varied between 4018.4-4826.4 kg ha^{-1} with the highest value from cvs. Bayraktar 2000 and Sonmez 2001 and the lowest value from cv. Gerek 79.

Among the investigated cultivars, cv. Gerek 79 with a mean grain yield of lower than general mean, low b_i value, positive *a* value, high coefficient of variation *(CV)* and low determination of coefficient (R^2) was identified as the least stable genotypes. In the stability graph generated based on mean yield and regression coefficients, cv. Gerek 79 was placed into moderate adaptation region to low yield environmental conditions (Fig. 3). Gerek 79 had greater expected yield potential in low environmental indices compared to Tosunbey (Fig. 4). It did not exhibit equivalent performance to other cultivars that were moved to high yield environments and thus was left behind all genotypes.

Table 2. Mean bread wheat grain yields in the experimented environments.

	Environments (Location-year)	**Grain yield*** (kg ha^{-1})		**Environments** (Location-year)	**Grain yield*** (kg ha^{-1})
1	Konya-2015	7996.9 a	20	Eskisehir-2012	4371.9 jk
2	Kocas-2008	7485.5 b	21	Yenikent-2009	4358.3 jkl
3	Kocas-2011	7085.7 c	22	Gozlu-2009	4214.6 klm
4	Gozlu-2015	6826.2 c	23	Konya-2009	4047.3 lm
5	Yenikent-2011	6390.1 d	24	Konya-2011	3950.5 m
6	Kocas-2009	6079.9 de	25	Eskisehir-2013	3940.4 m
7	Malya-2014	5759.8 ef	26	Malya-2007	3579.2 n
8	Malya-2011	5754.3 f	27	Malya-2015	3572.4 n
9	Polatli-2011	5392.2 g	28	Eskisehir-2009	3506.2 n
10	Yenikent-2013	5374.8 g	29	Haymana-2014	3483.9 n
11	Haymana-2011	5317.3 g	30	Konya-2012	3024.6 o
12	Malya-2009	5267.4 g	31	Gozlu-2014	3018.0 o
13	Polatli-2015	4831.7 h	32	Haymana-2010	2909.7 op
14	Polatli-2013	4754.2 hi	33	Eskisehir-2008	2859.8 op
15	Haymana-2013	4600.4 hij	34	Polatli-2008	2811.6 op
16	Konya-2008	4568.1 hij	35	Eskisehir-2007	2800.9 op
17	Yenikent-2008	4561.0 hij	36	Haymana-2009	2691.3 p
18	Yenikent-2010	4438.8 ijk	37	Konya-2007	2671.8 p
19	Yenikent-2012	4426.4 jk	38	Malya-2010	1941.2 q

*The means indicated with the same letters are not significantly different (p<0.05).

Cv. Bezostaja 1 had a mean grain yield of lower than general mean, b_i value of lower than 1 and negative but not too small *a* value. While it was behind all cultivars in low environmental index, yield level passed over Gerek 79 as the environmental conditions improved (high environmental index) (Fig. 4). The lowest *CV* and the greatest R^2 value indicated that cv. Bezostaja 1 was a stable genotype and had a high capability of reflecting environmental variations on yield. However, lower mean yields compared to the general mean indicated that genetic yield potential of Bezostaja 1 was lower compared to cultivars Bayraktar 2000, Sonmez 2001 and Tosunbey. The studies are supported by the observations of Popovic *et al.* (2020) and Eltaher *et al.* (2021). The authors have suggested importance of G × E interaction. They concluded that selection of the maximum yielding varieties could be utilized for improved grain yield subjected to several environments.

Cultivars Bayraktar 2000, Sonmez 2001 and Tosunbey had grain yields greater than general mean. These three cultivars had similar stability parameters. The b_i>1 and negative values indicated that they might improve yield levels under good environmental conditions. In stability graph, they were placed into moderate adaptation region to moderate environmental conditions (Fig. 3). As presented in Fig. 4, cultivars Bayraktar 2000 and Sonmez 2001 had the greatest expected yield in low environmental index and exhibited the greatest expected yield values compared to the other genotypes as they moved from low to high environmental conditions. These cultivars were followed by Tosunbey.

Table 3. Means for grain yield and quality traits.

Cultivars	Grain yield (kg ha^{-1})	Thousand-kernel weight (g)	Test weight (kg)	Protein content (%)	Zeleny sedimentation (ml)
1-Bezostaja 1	4161.7 c	35.63 a	79.02 a	15.31 a	46.68 a
2-Gerek 79	4018.4 d	30.01 d	76.48 c	14.28 c	34.45 cd
3-Bayraktar 2000	4826.4 a	33.69 b	78.38 b	13.38 d	34.21 d
4-Sonmez 2001	4823.4 a	34.38 b	79.12 a	14.31 c	36.92 c
5-Tosunbey	4625.9 b	31.68 c	78.45 b	14.68 b	43.95 b
F	80.20**	54.47**	34.36**	31.78**	39.89**
CV (%)	11.60	5.64	1.43	5.33	14.25

** significant at p<0.01. The means indicated with the same letters are not significantly different.

Table 4. Some stability parameters for grain yield.

Cultivars	*Mean*	b_i	*A*	*CV*	R^2
1-Bezostaja 1	4161.7	0.94	-57.71	12.68	0.87
2-Gerek 79	4018.4	0.77	581.97	17.84	0.71
3-Bayraktar 2000	4826.4	1.10	-115.35	13.97	0.85
4-Sonmez 2001	4823.4	1.11	-169.75	14.50	0.84
5-Tosunbey	4625.9	1.08	-239.85	15.16	0.83

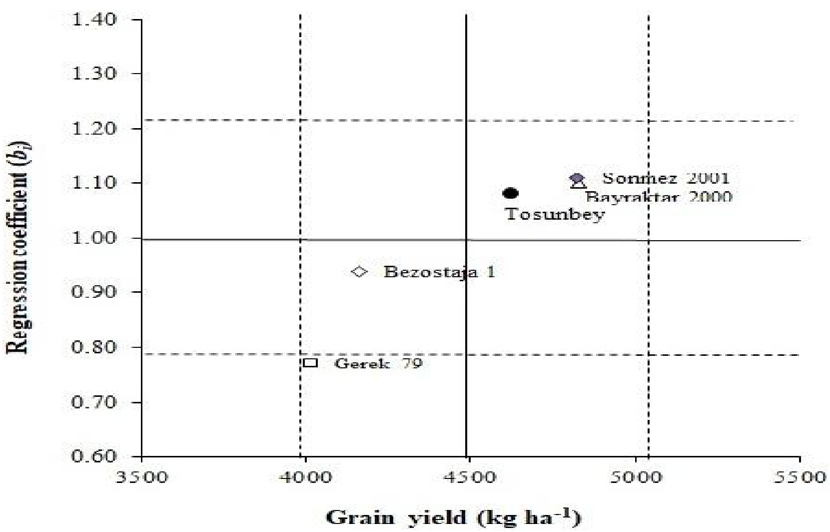

Fig. 3. Distribution of cultivars based on mean grain yield and regression coefficients.

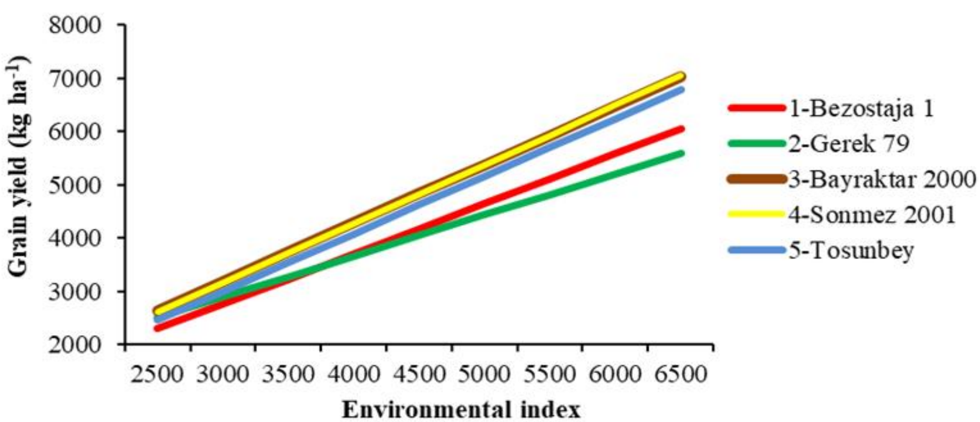

Fig. 4. Regression graph for grain yield of the cultivars (expected grain yield graph).

In GGE-biplot analysis on grain yield data of five bread wheat cultivars in 38 environments, 72.84% of the total variation was explained by PC1 and PC2 (Fig. 5a). Environment-focused model, PC1 (Principal component 1) explained 46.82% and PC2 explained 26.02% of total variation. All environments, except for Malya-2010 and Haymana-2010, had positive PC1 value (Fig. 5a). This indicated the existence of crossover GEI (Yan and Kang, 2003). Present environments had either positive or negative PC2 values indicating existence of crossover GEI also in terms of PC2. Environments connected to biplot origin through the vectors with different angles and lengths. Lower vector angles indicate similarities and similar responds of genotypes in respective environments (Yan, 2001). The results of this study showed that environmental variance was significantly larger compared to the Genotypic variance. Similar and like patterns are reported by other researchers in durum and bread wheat by Rozeboom *et al*. (2008) and Mohammadi (2016, 2019). This can be conceived that the environment is the main source of variation in yield of various types of wheat. A significant G×E interaction reflects low performance of genotypes in variable environments (Kendal and Sener, 2015; Mohammadi *et al.*, 2015). The results of this study are also in agreement with Mohammadi *et al*. (2020). The researchers emphasized that the identification of factors responsible genotype × environment (GE) interaction in under rainfed and drought prone areas could help allow breeders to increase and improve wheat yield. The identified similar genotypic and climatic variables responsible for GE interaction to improve grain yield. These results emphasize the role of temperature, (average, minimum and maximum), precipitation, relative humidity.

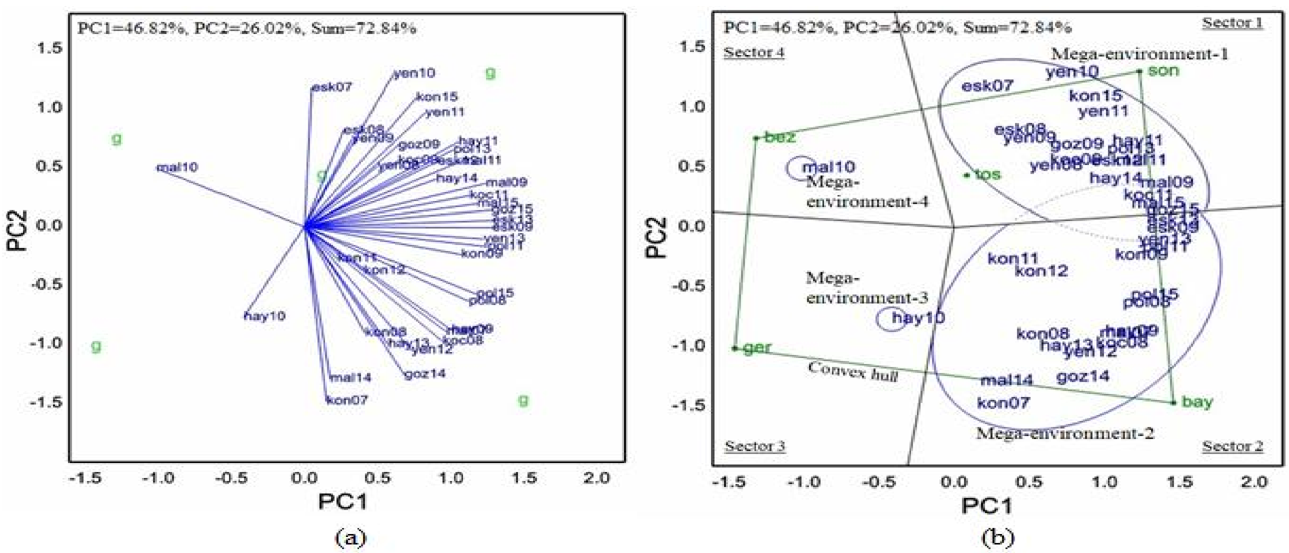

Fig. 5. (a) Position of environments in GGE-biplot graph and vector views (b) Polygon generated in genotype and environment-focused GGE-biplot graph.

A polygon view was generated through connecting the markers of genotypes positioned the furthest from the biplot origin and so called as vertex (Fig. 5b). A tetragon was obtained with cultivars Bezostaja 1, Gerek 79, Bayraktar 2000 and Sonmez 2001 as vertex cultivars and Tosunbey was placed inside the tetragon. Resultant biplot graph was divided into 4 sectors. Environments generated 4 mega-environments, a single environment (Malya-2010 and Haymana-2010) was placed in 2 mega-environments, 36 environments were gathered in 2 mega-environments and some of them were placed into intersection set (Fig. 5b).

Position of the genotypes in reference to average environment coordinate (AEC) generated through a line passing from mean average point and biplot origin reveals information about the stability of the genotypes (Yan, 2001; Yan, 2002). Gerek 79 and Bezostaja 1 were positioned behind the AEC ordinate (Fig. 6). Although, Tosunbey was positioned closest to AEC apsis, PC1 score was lower compared to Bayraktar 2000 and Sonmez 2001. Bayraktar 2000 and Sonmez 2001 connected to AEC apsis with similar vector lengths. Although increasing vector lengths to AEC apsis indicate decreasing stability, these two cultivars were positioned ahead of average environment point. The genotypes with low response to environmental changes are positioned closest to biplot origin (Yan and Kang, 2003). Tosunbey was positioned closest to biplot origin in present study.

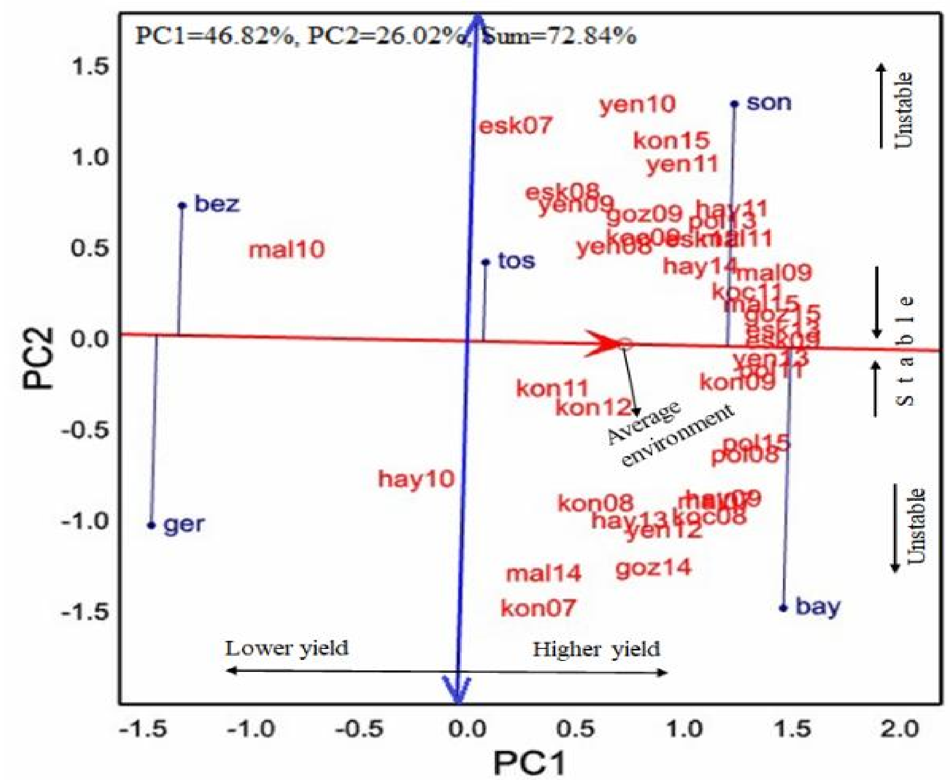

Fig. 6. Positions of the genotypes to AEC on GGE-biplot graph (for grain yield).

Comparison of cultivars Bayraktar 2000 and Sonmez 2001 with the greatest grain yields in GGE-biplot graph is presented in Fig. 7a. A straight line was drawn on the graph to connect two genotypes and an orthogonal axis passing through biplot origin was drawn to that line (Yan and Kang, 2003). In this way, environments in which genotypes exhibit better performance were separated. Cvs. Bayraktar 2000 and Sonmez 2001 shared trial environments fifty-fifty in terms of performance. Comparison of cultivars Gerek 79 and Bezostaja 1 is presented in Fig. 7b. The axis separated graph area into two halves, Bezostaja 1 showed improvement over Gerek 79 by showing its presence in 21 environments; whereas, Gerek 79 was represented in 17 environments only.

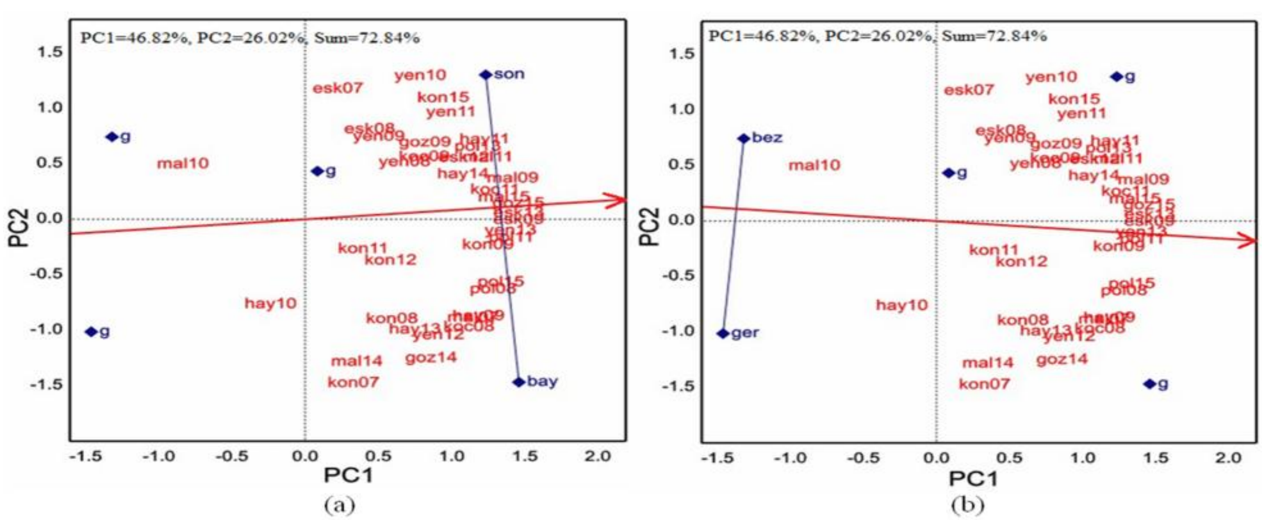

Fig. 7. Comparison of (a) Bayraktar 2000 and Sonmez 2001 (b) Bezostaja 1 and Gerek 79 on GGE-biplot graph (for grain yield).

Determination of genotype-environment interactions is one of the main goals of plant breeders in selecting superior genotypes (Abd Elhamid, 2020; Samyuktha *et al.,* 2020; Hashim *et al*., 2021). Compared to other studies, the five genotypes in this research were studied at the highest number (38) of locations. Ayranci (2020) approved the observations and has noted in a study under arid conditions of Kirsehir province and that grain yields of wheat genotypes ranged 2490-3620 kg ha^{-1}. They recommended cultivars Karahan 99, Nacibey, Bayraktar 2000, Izgi 2001 and Bagci 2002 for cultivation under arid conditions. Abbas and Topal (2016) conducted a study in 2014-2015 under arid conditions of Konya province and reported the greatest grain yields (8173 kg ha^{-1}) for Bayraktar 2000 and the lowest grain yield (5847 kg ha^{-1}) for Bezostaja 1. Results obtained from 38 environments revealed that three genotypes registered during 2000 and later (Bayraktar 2000, Sonmez 2001 and Tosunbey) had greater grain yields compared to the older cultivars.

Genotype means for quality criteria are provided in Table 3 and some stability parameters are provided in Table 5. In terms of thousand-kernel weight, cultivars were gathered in 4 different groups. The greatest thousand-kernel weight (35.63 g) was obtained from Bezostaja 1 and the lowest value (30.01 g) was obtained from Gerek 79. Cvs. Bayraktar 2000 and Sonmez 2001 were placed into the same statistical group. Cvs. Bezostaja 1, Sonmez 2001 and Bayraktar 2000 had higher thousand-kernel weights compared to the general mean. While cultivars Bayraktar 2000 and Sonmez 2001 had b_i >1 and negative *a* values, the others had b_i <1 and positive *a* values. In GGE-biplot analysis, 82.23% of total variation was explained (Fig. 8a). Cultivars Bezostaja 1, Sonmez 2001 and Bayraktar 2000 were placed above the AEC apsis and had positive PC1 scores. Of these genotypes, Sonmez 2001 had a short vector length to AEC apsis and Bayraktar 2000 had the longest vector length. Position of cv. Gerek 79 was almost on AEC apsis, but with the lowest PC1 score. This indicated that this genotype did not had potential to much increase in thousand-kernel weight under changing environmental conditions and genetic potential of the genotype stayed at a certain threshold. Ruzgas *et al*. (2017) indicated thousand-kernel weight as a yield component and reported positive correlations with yield. Zhang *et al*. (2013) indicated thousand-kernel weight as an important physical quality trait and pointed out that it was a gene-specific trait, largely influenced by environmental conditions.

Table 5. Some stability parameters for grain quality traits.

Cultivars	**Thousand-kernel weight**					**Test weight**				
	Mean	b_i	***a***	***CV***	R^2	***Mean***	b_i	***a***	***CV***	R^2
1-Bezostaja 1	35.63	0.96	3.80	4.39	0.87	79.02	0.79	16.34	0.99	0.82
2-Gerek 79	30.01	0.86	1.58	5.58	0.82	76.48	1.14	-12.39	1.51	0.81
3-Bayraktar 2000	33.69	1.25	-7.68	4.40	0.93	78.38	1.16	-12.50	1.39	0.83
4-Sonmez 2001	34.38	1.13	-2.99	5.11	0.88	79.12	0.84	13.42	1.32	0.74
5-Tosunbey	31.68	0.79	5.46	3.50	0.90	78.45	1.06	-4.85	0.88	0.91
Cultivars	Protein content					Zeleny sedimentation				
	Mean	b_i	*a*	*CV*	R^2	*Mean*	b_i	*a*	*CV*	R^2
1-Bezostaja 1	15.31	1.00	0.91	4.82	0.84	46.68	1.38	-7.46	10.70	0.88
2-Gerek 79	14.28	1.18	-2.63	4.41	0.91	34.45	0.88	-0.08	13.67	0.77
3-Bayraktar 2000	13.38	0.89	0.53	5.21	0.83	34.21	0.78	3.59	10.61	0.82
4-Sonmez 2001	14.31	0.97	0.34	4.94	0.85	36.92	0.84	3.90	11.89	0.78
5-Tosunbey	14.68	0.96	0.86	4.12	0.88	43.95	1.12	0.05	11.29	0.83

The cultivars were distributed in 3 statistical groups for test weights (Table 3). Gerek 79 was the only cultivar left below the general mean. Although Sonmez 2001 and Bezostaja 1 had b_i<1, they had the greatest *a* values. Tosunbey had the lowest *CV* and the greatest R^2 value. In GGE-biplot graph presented in Fig. 8b, PC1 explained 60.37% and PC2 explained 22.50% of total variation. Sonmez 2001 had the greatest PC1 value. Bezostaja 1 seemed a stable genotype with quite close position to AEC. Longer vector length of Bayraktar 2000 to AEC indicated that it exhibited high deviations with changes in environmental conditions and thus had low stability. Gerek 79 was positioned close to AEC apsis as mentioned for thousand-grain weight, but quite behind AEC ordinate. Bulut (2012) indicated test weight as an important parameter for the industry and reported positive correlations with flour yield and protein contents.

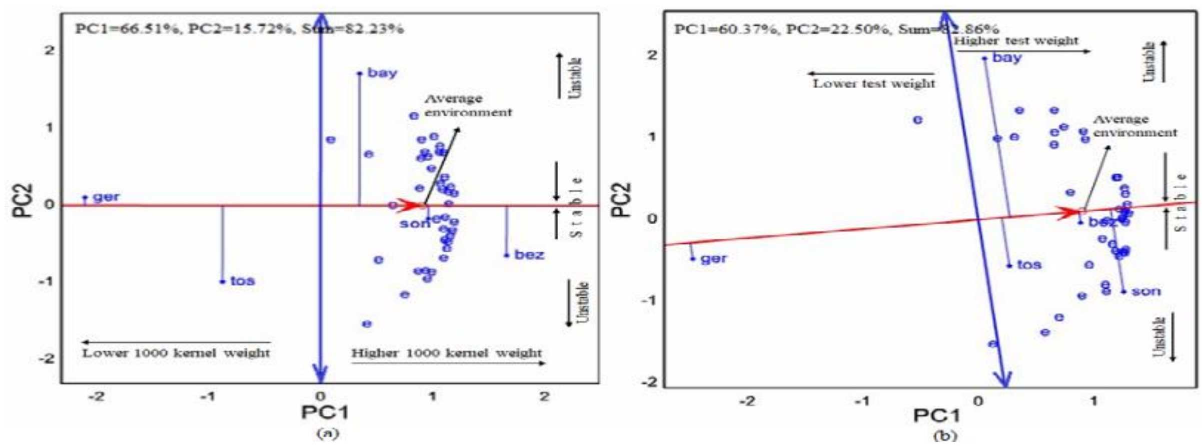

Fig. 8. (a) Thousand-kernel weight and (b) test weight performances of the cultivars, vectors to AEC on GGE-biplot graph.

For protein contents, genotypes formed 4 statistical groups and the greatest value (15.31%) was obtained from cv. Bezostaja 1 (Table 3). Bayraktar 2000 with the greatest value in grain yield left behind all genotypes in protein content. Gerek 79 had a b_i>1 and it was only genotype with a negative *a* value (Table 5). Bezostaja 1 and Tosunbey had higher protein contents compared to the general mean. In GGE-biplot analysis, 76.29% of total variation was explained (57.10% by PC1 and 19.20% by PC2) (Fig. 9a). Bezostaja 1 and Tosunbey were positioned far ahead of AEC ordinate and had positive PC1 scores. Although Bayraktar 2000 was positioned quite close to AEC apsis, it had the lowest PC2 value. Sonmez 2001 and Gerek 79 were positioned behind AEC ordinate and had higher vector lengths to AEC apsis. Protein content is the primary quality traits for wheat cultivars and is largely influenced by genotype and environments (Dogan and Kendal, 2013). Current study is supported by the studies of Karaman (2020). They have exhibited significantly negative correlation of grain yield and protein percentage in bread wheat.

For Zeleny sedimentation values of the genotypes, Bezostaja 1 (46.68 ml) and Tosunbey (43.95 ml) had values greater compared to the general mean and b_i >1, low *CV* and high R^2 values was prominent in several cultivars especially Bezostaja 1 with a high b_i (1.38) value (Table 5). In terms of distribution of Zeleny sedimentation data on GGE-biplot graph; Gerek 79, Bayraktar 2000 and Sonmez 2001 were positioned behind the AEC ordinate and connected to AEC apsis with similar vector lengths (Fig. 9b). Cvs. Bezostaja 1 and Tosunbey were positioned quite ahead of AEC apsis and had similar vector lengths. This indicated that they had a high genetic potential for Zeleny sedimentation, and was also influenced by environmental conditions. Atli (1999) and Erekul *et al*. (2012) indicated that besides genotype, Zeleny sedimentation is also influenced by climate and growing techniques. Aydogan and Soylu (2017) indicated that Zeleny sedimentation was accepted as an indicator of protein quality. It is commonly used by the industry and is reported the lowest using Zeleny sedimentation values for cultivars Bayraktar 2000 and Gerek 79.

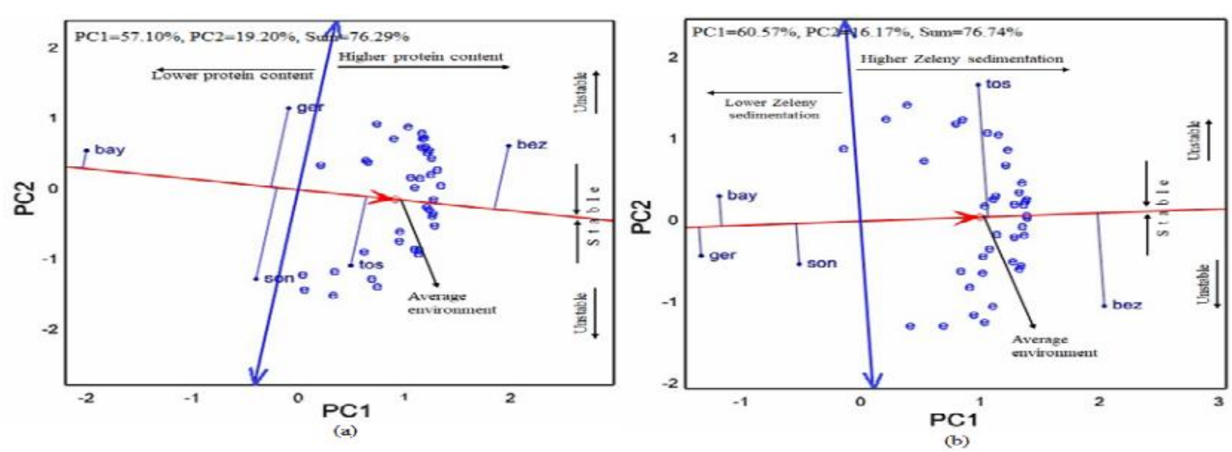

Fig. 9. (a) Protein content and (b) Zeleny sedimentation performances of the cultivars, vectors to AEC on GGE-biplot graph.

Conclusion: Rainfed wheat cultivation is practiced in majority of the Central Anatolia. Grain yield and some quality traits of five wheat cultivars grown in 38 environments were assessed in the present study. Cvs. Bayraktar 2000 and Sonmez 2001 were prominent for grain yield. Tosunbey had better performance for protein content and Zeleny sedimentation values. Bezostaja 1 was left behind the general mean in terms of grain yield but had high values in quality traits. Cv. Gerek 79 has the lowest grain yield and was also behind the other cultivars in the quality traits. No stability analysis studies have been found in these wheat cultivars by illustrating their yield and quality characteristics in 38 environments. The detailed stability analysis in this study would help future researchers for the probable utilization of these cultivars in future breeding programs. Therefore, it is of great importance to sort and identify stable varieties in future wheat breeding programs. The results obtained from this study have revealed the importance of selecting and cultivating of genetically stable wheat genotypes in the Central Anatolia.

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