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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Genotype and Environment Effect on Yield and Quality Parameters and Stability in Bread Wheat (*Triticum aestivum* L.) Cultivars under Rainfed Conditions

Ekmeklik Buğday (*Triticum aestivum* L.) Çeşitlerinde Yağışlı Koşullarda Verim ve Kalite Parametrelerine Genotip Çevre Etkisi ve Stabilite

İrfan ÖZTÜRK[1]

Abstract

The significant genotype by environment interaction is a major matter for wheat breeding research. The study was carried out for seven growing season (between 2010-2011 and 2016-2017) in the Edirne location in the Trakya region, Türkiye. Each year was considered as a single environment. In the study, a regional yield trial of 25 genotypes, 5 of which were standard cultivars were evaluated across seven environments. The experiments were arranged in a randomized complete block design (RCBD) with four replications. The characters such as yield, days to heading, plant height, thousand kernel weight, hectoliter weight, protein ratio, wet gluten content, gluten index, grain hardness and sedimentation value were investigated in the study. The result of the variance analysis (ANOVA) demonstrated considerable differences (p<0.01 and p<0.05) among environments for the characters and among genotypes except for test weight and grain hardness. The highest grain yielding cultivar was Gelibolu with 7234 kg ha^{-1}. According to the results, the yield was affected by the environment by 70.90%, genotypes by 3.46% and their interaction by 11.35%. Environmental impact was responsible for much of the change. Mean grain yield over seven environments varied with the lowest being 4454 kg ha^{-1} in E6 and the highest being 8158 kg ha^{-1} in environment E4. The fact that there was an 83.2% yield difference between the environments in the study showed the importance of the environmental impact. The highest grain hardness, sedimentation value, gluten content and protein ratio were determined in E1. The biplot analysis results explained that Selimiye is an ideal cultivar and E1 is an ideal environment. In the study, E7 and E2 were the most discriminative environments, while E4 was the least discriminating. Among the varieties, Aldane had high values in terms of sedimentation, protein ratio and gluten value, while Pehlivan variety had high values in terms of test weight, 1000 grain weight and grain hardness. As a result of the research, the importance of genotype and environmental effects on yield and quality was also seen in this research.

Keywords: Bread wheat, Cultivar, Environment, Yield, Quality, GGE biplot

[1]***Sorumlu Yazar/Corresponding Author:** İrfan Öztürk, Trakya Agriculture Research Institute, Edirne, Türkiye. E-mail: ozturkirfan62@yahoo.com OrcID: 0000-0002-1858-0790
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Öz

Genotip çevre etkileşimi buğday ıslahı araştırmaları için önemli bir husustur. Araştırma, Trakya Bölgesi (Türkiye) Edirne lokasyonunda 2010-2011 ve 2016-2017 üretim yıllarında yürütülmüştür. Araştırmada her yıl tek bir ortam olarak kabul edilmiştir. Araştırma 25 genotipten oluşan bölge verim denemesindeki beş ekmeklik buğday çeşidi yedi farklı çevrede test edilmiştir. Deneme tesadüf blokları deneme desenine göre (RCBD) dört tekerrürlü olarak yürütülmüştür. Tane verimi, başaklanma gün sayısı, bitki boyu, 1000 tane ağırlığı, hektolitre ağırlığı, protein oranı, yaş glüten oranı, glüten indeksi, tane sertliği ve sedimantasyon değerleri incelenmiştir. Birleşik varyans analizi (ANOVA), tüm özellikler için çevreler arasında önemli farklılık, çeşitler arasında ise hektolitre ağırlığı ve tane sertliği dışında diğer parametrelerde önemli farklılıklar ($P<0.01$ ve $P<0.05$) olduğunu ortaya çıkarmıştır. En yüksek tane verimi 7234 kg ha^{-1} ile Gelibolu çeşidinde belirlenmiştir. Açıklanan faktörler, tane veriminin %70.90 çevre, %3.46 genotip ve %11.35'i ise genotip çevre etkileşimimden olduğunu göstermiştir. Varyasyonun büyük bir kısmının çevresel etkiden kaynaklandığı görülmüştür. Yedi farklı çevre koşullarına göre ortalama tane verimi, en yüksek 8158 kg ha^{-1}' ile E4'te, en düşük 4454 kg ha^{-1} ile E6'da belirlenmiştir. Çalışmada yüksek ve düşük çevreler arasında %83.20 verim farkı olması, çevresel etkinin önemini göstermiştir. En yüksek protein oranı, yaş gluten içeriği, tane sertliği ve sedimantasyon E1'de belirlenmiştir. Biplot analizi sonuçları, Selimiye'nin daha ideal bir çeşit olduğunu ve E1'in daha ideal bir ortama sahip olduğunu göstermiştir. Orijinden en uzun vektörler ile E7 ve E2 ortamları en fazla ayırt edici çevre olurken, E4 en az ayırt edici çevre olmuştur. Aldane çeşidi, sedimantasyon değeri, protein oranı ve yaş gluten içeriği ile öne çıkarken, Pehlivan çeşidi, hektolitre ağırlığı, 1000 tane ağırlığı ve tane sertliği bakımından yüksek değerlere sahip olmuştur. Araştırma sonucu, çevrenin incelenen parametrelere etkisinin çok önemli olduğu, bu nedenle ıslah çalışmalarının farklı çevre koşullarında yürütülmesinin etkili bir seleksiyon için çok önemli olduğunu göstermiştir.

Anahtar Kelimeler: Ekmeklik buğday, Çeşit, Çevre, Verim, Kalite, GGE Biplot

1. Introduction

The widespread cultivation of the crop all along the globe is broadly due to the high versatility of evolution, which allows its adaptation to various agro-climatic conditions. The knowledge about the essence and content of genotype × environment relations can help plant breeders. Consistently good adaptation across various environments must be one of the essential criteria while assessing any wheat genotype (Kant et al., 2014). Bread wheat is the most widely produced crop due to the various environmental conditions yield and bread quality in various wheat genotypes. Biplot analysis is an important method used to evaluate genotypes according to target environments with the interaction of genotype and environment (Öztürk and Korkut, 2018; Öztürk, 2021). Drought stress is the primary abiotic stress factor and lower moisture during grain filling stages influenced the bread wheat yield and yield component (Öztürk and Korkut, 2017). Due to the presence of genotype by environment relations, multi-environmental trials are essential for effective breeding line selection and cultivar recommendation. AMMI and biplot analysis are two prevalent graphical analysis systems for multi-environmental trial data analysis (Yan, 2011). Genotype, Environment and its interaction biplot analysis consisting of two principal component analyses (PC1 and PC2), which considers the effects of genotype, environment and G×E interactions as important sources of variation, has been suggested during the genotype evaluation phase (Yan et al., 2000). Biplot analysis is used to specify stable cultivars with high yield potential. It can also be useful in determining which-won-where wins which of the genotypes represent (Yan, 2001). The polygonal sight of the GGE biplot shows the most suitable genotype or genotypes in individual conditions and environmental group. The polygon model is made by merging the genotype points distant from the biplot source so that all other genotypes are included in the polygon (Yan and Hunt, 2002). Genotype environment interactions can be determined in multi-year yield trials at the same location or in multi-year yield trials at different locations. Studies to determine the stability of genotypes should be long-term (Kang, 1993). Genetic improvement in wheat yields in arid regions has not been as significant as in more favourable environments or where irrigation is available. A possible explanation for this is that arid conditions are indicated by unreliable and highly irregular seasonal precipitation and, therefore, favourably varying yields. This results in slow genetic advances in breeding programs because the genetic divergence in yield is hidden by comprehensive genotype x year and genotype x location interactions (Reynolds et al., 2001).

In bread wheat, baking quality and yield are connected to genetic factors, environmental conditions and the interaction between genotype × environment (Yan and Holland, 2010; Coventry et al., 2011; Zhang et al., 2007). In the breeding experiment, genotype by environment interaction is the main issue in improving high-yielding and stable genotypes across variable environments. Quality parameters in wheat are significantly affected by changing environmental conditions. The existence of different interactions between cultivars and environments shows the importance of genotype-environment interaction in breeding studies. The environmental effect was significant in protein ratio, wet gluten content and sedimentation value (Öztürk and Kahraman, 2022). The protein ratio in wheat depends primarily on genotype, but it is also greatly influenced by the environment and the relations between environment and genotype (Zhu and Khan, 2001).

Bread wheat is the most important cereals with the production and consumption of many different bakery products. Due to the production of bread wheat in very large areas and various environmental conditions, it is exposed to environmental stresses with the effect of climate change. Yield in bread wheat is highly affected by climatic factors such as precipitation and temperature. Especially in the heading-flowering and grain-filling period, the high temperature reduces the yield and quality significantly. Quality in bread wheat is affected by genotype, nitrogen fertilization and environmental conditions such as precipitation and temperature. For these reasons, it is necessary to conduct multi-location studies to develop genotypes that are stable in yield and quality and adapt to changing environmental conditions in bread wheat. This study was performed to examine the environmental effects on the yield and quality parameters of the wheat varieties.

2. Materials and Methods

The study was carried out during 7 consecutive growing seasons (between the 2010-2011 and 2016-2017) in the Edirne location (41º 38´ 59´´ N) in the Trakya region, Turkey. Each year was considered as a single environment. Year and climate differences were evaluated as different environments. A total of 5 bread wheat cultivars were tested across seven environments. The experiments were performed with four replications in a randomized complete block design (RCBD). In the study, each plot was 6 meters long and had 6 rows, spaced 0.17

meters apart. A plot drill performed sowing and 500 seeds per square meter were used. Sowings were performed using a plot drill in October and 170 kg ha^{-1} N was applied three times (at planting, tillering and shooting stages). For weed control, a chemical was used. Data on yield (GY), plant height (PH), days to heading (DH) were collected. Yield was determined from plots of 6 m^2.

Days to 50% heading**:** The number of days from the date of 1 October up to the date when the tips of the spike first emerged from the main shoots on 50% of the plants in a plot (Zadoks 55) (Zadoks et al., 1974).

Plant height (cm): The height of ten randomly taken plants was measured at harvest maturity from the ground level to the tip of the tallest spike in centimetres and averaged.

2.1. Wheat quality analyses

Data on 1000-kernel weight (TKW), test weight (TW), protein ratio (PRT), wet gluten value (GLT), gluten index value (IND) and sedimentation value (SED) were collected. In the study, in order to determine the 1000-kernel weight an electronic seed counter was used. The test weight of the cultivars was determined by Anonymous, (1992) (AACC Method no: 55-10). The protein ratio in genotypes was established using the Kjeldahl method (Perten, 1990; Anonymous, 2002). Wet gluten content and gluten index, and were described by the Perten (1990) and McDonald (1994). Sedimentation test was also performed on the varieties (Anonymous, 1999).

2.2 Meteorological Conditions

Total rainfall and mean temperature in the experimental area from the 2010-2011 to 2016-2017 crop cycles were given in *Table 1* and *2*. Total precipitation has varied over the years, with the highest being in 2012-2013 and the lowest being in 2010-2011. There were also changes in total precipitation according to months. Precipitation and temperature during the heading and grain filling periods are more important for yield and quality than other months. The highest rainfall was 679.9 mm, while the lowest rainfall was 331.0 mm (*Table 1*).

The average temperature varied from 9.0 ºC in 2016-2017 to 13.2 ºC in the 2012-2013 growing seasons. There was a significant difference in average temperatures between months and years during the heading and grain filling periods. Especially temperature during the grain filling period affects yield and quality parameters (*Table 2*).

Table 1. Monthly total precipitation for the growing seasons from 2010-2011 to 2016-2017 cycles

Months	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
October	68.5	95.0	169.9	30.7	121.8	52.6	44.4
November	39.7	1.4	24.8	73.9	43.2	26.2	3.2
December	34.4	71.4	184.6	2.3	111.3	0.3	3.2
January	34.4	108.8	100.0	74.9	42.2	114.8	67.8
February	45.8	43.4	88.8	3.8	68.6	91.4	43.4
Marc	16.0	4.6	52.8	124.5	67.8	54.8	51.0
April	47.4	55.7	16.0	36.8	44.4	116.1	65.6
May	12.4	104.6	8.0	61.7	45.2	81.4	85.0
June	32.4	0.4	35.0	68.8	31.0	10.2	44.4
Total	331.0	485.3	679.9	477.4	575.5	547.8	408.0

Table 2. Monthly mean temperature for the growing seasons from 2010-2011 to 2016-2017 cycles

Months	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
October	13.0	12.3	19.2	12.8	15.4	15.6	14.3
November	13.5	6.1	13.7	11.0	9.3	13.5	0.7
December	5.7	7.8	6.4	2.7	6.6	5.5	0.7
January	5.7	2.0	6.5	5.5	3.8	2.8	-1.9
February	2.5	1.5	7.8	7.6	6.4	9.2	5.3
Marc	7.4	8.9	9.6	10.1	9.0	10.2	10.2
April	10.5	15.5	13.5	13.6	13.1	15.5	12.5
May	17.4	19.1	19.5	18.6	20.4	17.4	17.9
June	21.9	25.3	22.4	22.9	22.5	23.9	21.2
Mean	10.8	10.9	13.2	11.6	11.8	12.6	9.0

Seven different environments where the research was conducted were defined according to rainfall amount and temperature. E1 was the period with the least rainfall during growing period the heading stages. In E2, the grain filling period was high drought and temperature. In E3, there was low rainfall and drought during the heading stage. E4 and E5 are the periods in which there is no drought or heat stress during plant development. E6 is the period in which there is drought stress during grain grain-filling stage. E7 is the period in which there is drought stress during plant emergence and tillering stage.

2.3. Statistical analyses

The analysis of variance (ANOVA) for the characters were performed in methods suggest by Gomez and Gomez (1984). The significance of differences among means of genotypes and environments for the traits was tested by the Least Significant Difference (LSD at a %5 level) test. To obtain relations of investigated parameters and wheat cultivars multivariate biplot analysis was used (Yan and Kang, 2002; Yan and Rajcan, 2002; Yan and Tinker, 2006). The GGE biplot methodology was used to graphically analyse the GE interaction data (Yan et al., 2000).

3. Results and Discussion

Results of the AMMI analysis for grain yield of bread wheat cultivars tested across seven environments are summarised in *Table 3*. The AMMI analysis results explained variation among genotype, environment, and their interaction at $p< 0.01$ level revealed significant differences.

Results of the analysis of variance for the quality parameters of mean square and F ratio were given in *Table 4*. The combined ANOVA showed significant differences ($p<0.01$ and $p<0.05$) among environments for parameters (*Table 4*). A significant difference was also determined among cultivars except for test weight (TW), and hardness (HARD). The partitioning of SST revealed that the interaction of the environment effect was a predominant source of variation followed by the G×E interaction effect. The analysis of variance in grain yield indicated that environment effects accounted for 70.90%, genotype 3.46%, and GE interaction effects accounted for 11.35% of the total sum of squares (*Table 3*).

Table 3. The analysis of variance of AMMI on grain yield of bread wheat cultivars

Source of variation	DF	SS	MS	F ratio	SST%
Treatments	34	2046915	60203**	20.20	
Genotypes (G)	4	82751	20688**	6.94	3.46
Environments (E)	6	1693040	282173**	65.43	70.90
Block	21	90564	4313	1.45	
Interactions (G×E)	24	271125	11297**	3.79	11.35
IPCA	9	147456	16384**	5.50	6.17
IPCA	7	85155	12165	4.08	3.56
Residuals	8	38514	4814	1.62	
Error	84	250395	2981		
Total	139	2387874	17179		

**: Significant at the 1% level of probability, DF: Degree of freedom, SS: Sum of square, MS: Mean of square, SST%: Percentage relative to the sum of squares total

Table 4. Mean square of genotype, environment and its interaction for quality traits in seven environments

Quality characters	Genotypes (G)		Environment (E)	
	MS	F Ratio	MS	F Ratio
1000-kernel weight (TKW)	45.694**	5.073	127.220**	14.123
Test weight (TW)	2.488	2.104	17.889**	15.126
Protein ratio (PRT)	4.087**	6.785	12.927**	21.461
Wet gluten value (GLT)	110.717**	11.698	174.113**	18.396
Gluten index (IND)	1398.534**	15.840	279.055*	3.161
Hardness (HARD)	17.029	1.633	45.048**	4.320
Sedimentation (SED)	408.314**	18.876	490.714**	22.686

The results of the analysis of variance explained that there were significant differences ($p<0.01$) among cultivars for grain yield. The mean grain yield across seven environments varied from the smallest 4454 kg ha^{-1} in

E6 to the highest 8158 kg ha^{-1} in environment E4. The fact that there was an 83.2% yield difference between the environments in the study showed the importance of the environmental impact. Significant differences were found between cultivars due to environmental effects. The highest grain yield was performed by cultivar Selimiye (6957 kg ha^{-1}) and followed by Bereket and Pehlivan (*Table 5*).

Table 5. The average grain yield of the cultivars over seven environments

No	Cultivars	E1	E2	E3	E4	E5	E6	E7	Mean
1	Aldane	6323^{a}	5904^{d}	7030^{a}	7601^{b}	6583^{b}	4922^{a}	7033^{b}	6485^{c}
2	Selimiye	6970^{a}	7143^{bc}	7555^{a}	8560^{a}	6625^{b}	3947^{b}	7895^{a}	6957^{ab}
3	Bereket	6121^{a}	7957^{a}	7570^{a}	7816^{ab}	6289^{b}	4254^{b}	7662^{a}	6810^{b}
4	Pehlivan	7133^{a}	7056^{c}	7439^{a}	8045^{ab}	6399^{b}	3821^{b}	7748^{a}	6806^{b}
5	Gelibolu	6212^{a}	7685^{ab}	6767^{a}	8768^{a}	7934^{a}	5327^{a}	7948^{a}	7234^{a}
Mean		6552	7149	7272	8158	6766	4454	7657	6858
C.V (%)		10.90	4.95	8.88	7.62	9.25	9.39	3.57	7.96
L.S.D (0.05)		110.06	54.38	99.14	95.41	96.04	64.18	42.03	28.88

* and ** indicate that significant at p<0.05 and p<0.01, ns: not significant

According to the investigated parameters, there was a significant difference between cultivars as a result of environmental effects. A significant difference was found among the mean of cultivars for thousand kernel weight. Cultivar Pehlivan had a higher 1000-kernel weight (45.8 g) and followed by Aldane. Generally, the effects in drought-sensitive cultivars are more than in resistance cultivars. It is necessary to use large seeds, which are obtained from grown plants in areas without drought stress, to reach a high grain yield in bread wheat (Balkan, 2019). In the study, higher grain weight was determined in Pehlivan, which is a large-grained variety. The lowest test weight was 81.5 kg (cv. Bereket) and the highest was in Selimiye (82.7 kg.) and Pehlivan (82.6 kg). The highest protein ratio (12.9%) and gluten value (37.0%) were determined for cultivar Aldane. In the study, except Pehlivan all cultivars had a higher gluten index. Sedimentation values in genotypes varied from a minimum of 41.7 ml in Pehlivan to 60.9 ml in Aldane (*Table 6*).

Table 6. The mean quality characters of the wheat cultivars tested across seven environments

Cultivar	TKW	TW	PRT	GLT	IND	HARD	SED
Aldane	43.6 ab	81.6 ab	12.9a	37.0 a	90.8 a	47.0 b	60.9 a
Selimiye	42.1 bc	82.7 a	12.0b	37.0 a	82.8 a	50.7 a	50.7 b
Bereket	39.7 c	81.5 b	11.3bc	31.9 b	87.1 a	48.4 ab	45.4 c
Pehlivan	45.8 a	82.6 ab	11.4bc	36.3 a	57.7 b	50.6 a	41.7 c
Gelibolu	40.0 c	81.7 ab	11.0c	28.0 c	92.2 a	49.6 ab	44.0 c
Mean	42.2	82.0	11.7	34.0	82.1	49.3	48.5
CV (%)	7.1	1.32	5.9	8.8	11.4	6.53	9.5
LSD $_{(0.05)}$	3.29	1.19	0.84	3.37	10.34	3.54	5.1

Significance at **: p<0.01; *: p<0.05; TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Wet gluten content (%), IND: Gluten index (%), HARD: Grain hardness (PSI), SED: Sedimentation value (ml)

Thousand-grain weights being a very important yield component are considered an essential quality parameter and a component used in the calculation of the number of seed to be sown in the unit area (Balkan et al., 2019). Precipitation and temperature have a significant impact on the TKW during the grain-filling period. High temperatures and low precipitation reduce the TKW by shortening the grain-filling period. For 1000-kernel weight, a significant difference was found among environments. Concerning environmental effects, the highest TKW was in environment E4 (47.2 g) and the lowest in E1 (34.3 g). Environmental factors also affect the weight of test weight which is much related to the genotypic trait. The highest test weight was measured in environment E2 (*Table 7*).

Table 7. The mean quality parameters of wheat cultivars tested across seven environments

Environment	TKW	TW	PRT	GLT	IND	HARD	SED
E1	34.3 c	82.5 bc	14.6 a	43.4 a	86.7 ab	54.6 a	64.8 a
E2	46.4 a	85.2 a	12.2 b	37.2 b	79.5 bc	51.6 ab	43.4 bc
E3	44.2 ab	80.1 d	10.5 de	29.3 de	80.8 bc	47.0 c	42.6 bc
E4	47.2 a	80.4 d	9.6 e	25.4 e	93.3 a	45.8 c	40.0 c
E5	41.6 b	81.3 cd	12.3 b	34.7 bc	87.2 ab	49.4 bc	59.8 a
E6	36.5 c	83.7 b	11.0 cd	31.5 cd	71.3 c	47.6 bc	40.6 c
E7	45.4 ab	80.9 d	11.7 bc	36.7 b	75.9 bc	48.8 bc	48.6 b
Mean	42.2	82.0	11.7	34.0	82.1	49.3	48.5
LSD (0.05)	3.89	1.40	1.01	3.99	12.24	4.20	6.05

Significance at **: $p<0.01$; *: $p<0.05$; TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Wet gluten content (%), IND: Gluten index (%), HARD: Grain hardness (PSI), SED: Sedimentation value (ml)

The protein ratio in grain, which can change with the effect of genotype, environmental factors such as highest and lowest temperature during the grain filling stages and cultural practices such as fertilizer amount and time, is an important quality parameter. To determine how the environment affects protein ratio was evaluated over seven environments. In the experiment, the lowest protein ratio was 9.6% in environment E4 and the highest protein ratio was 14.6% in environment E1 (*Table 7*).

The lowest wet gluten content was 25.4% in environment E4 and the highest wet gluten content (43.4%) was measured in environment E1. Sedimentation value also significantly varied over environments and ranged from the lowest 40.0 ml in E4 to the highest 54.6 ml in environment E1. The sedimentation value was low in environmental conditions where low protein and gluten content was obtained. Grain hardness is another quality parameter affected by genotype, environment and agronomic practices. Therefore, significant variation was found among environments for grain hardness the minimum was 45.8 in E4, and the maximum was 54.6 in environment E1. Similar results were obtained for grain hardness, which is highly correlated with the sedimentation value.

Test environments that are both discriminating and representative are suitable to test environments for determining adapted genotypes. The representative and discrimination of the cultivars according to the parameters investigated showed in *Figure 1a*. A representative ideal environment or genotypes determine according to their nearness or distance to this centre. The optimal cultivars are located in the centre. If cultivars located below the vertical axis are unwanted. According to this, Selimiye is a more ideal cultivar due to it being closer to the ideal centre, while Gelibolu is located distant from the ideal centre so this is an unwanted variety based on the parameters investigated (*Figure 1a*). The discrimination and representation of the environment was given in *Figure 1b*. Based on the environment by genotype interaction, E1 is a more ideal environment because located in the first centre, followed by E3 because of the nearest to the ideal centre (*Figure 1b*). It has been determined that the Bereket variety is more productive than other varieties in drought stress conditions during the plant emergence, tillering stages and the grain filling period. It was determined that Bereket, Selimiye and Pehlivan varieties were more adapted to the drought stress conditions of the heading stages. Gallipoli has been found to be highly productive in good environments without drought stress. In addition, Gelibolu variety had high yield potential under drought stress during plant emergence, tillering and grain filling period (*Table 6*, *Figure 2a*). It has been determined that Selimiye and Pehlivan varieties are more adaptable to all environmental conditions (*Figure 1a*, *1b*).

A prolonged environmental vector showed a high ability to differentiate the cultivar. The angle between vectors of two environments, genotypes or parameters explains the correlation between them. *Figure 2a* showed that environments E7, E2 and E5 were the most discriminating with the most extended vectors from the centre. According to environments, E4 was the least discriminating with the short vectors. In the evaluation made according to the angle between the environmental vectors, E5 and E6 were highly significantly positively correlated. Because of the angle greater than 90 degrees' environment E2 and E1 were negatively correlated. Environment E6 and E3, and also E5 and E3 were significantly negatively correlated (*Figure 2a*).

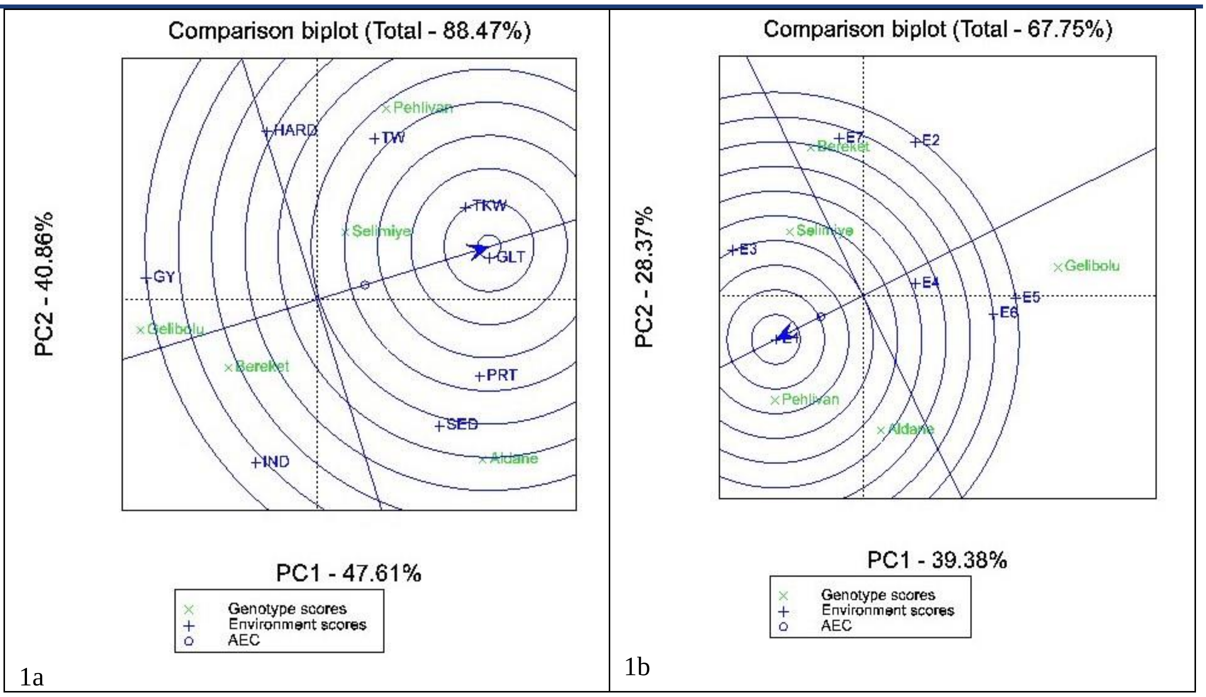

Figure 1. The GGE biplot graph shows the comparison of parameters with the ideal genotype (1a), and the GG biplot graph showed the stability of the genotypes with the ideal environment (1b).

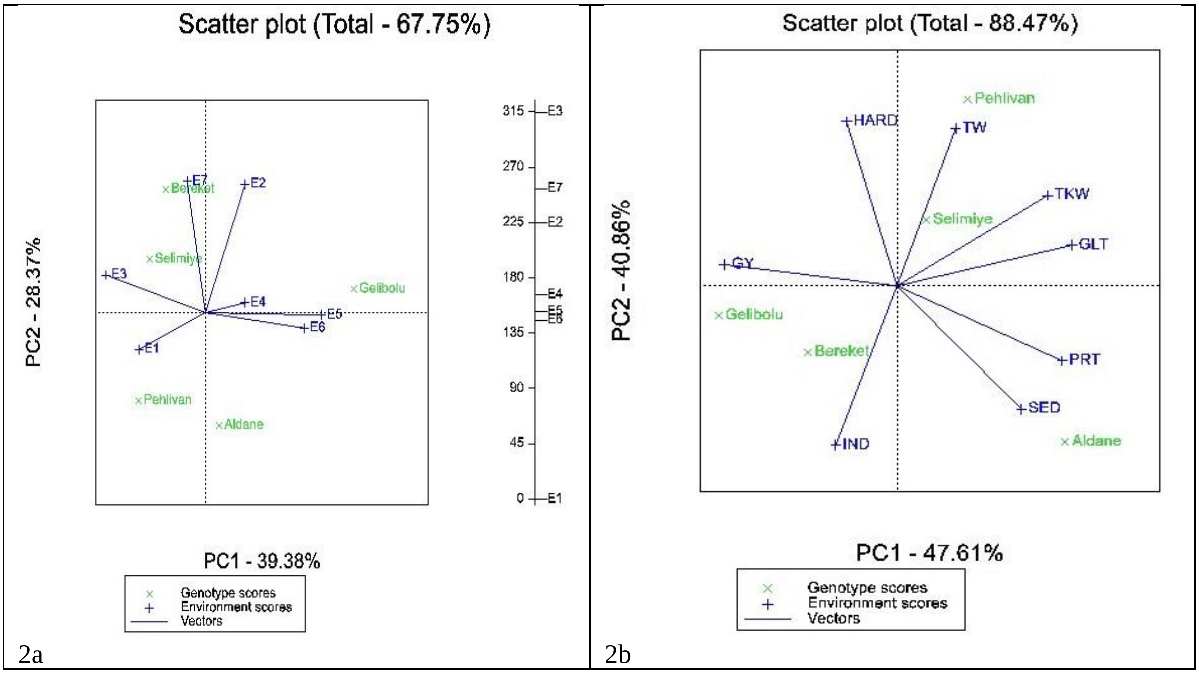

Figure 2. The GGE biplot graph explained the relation of environment vector view (2a), and association of parameters investigated and wheat cultivars with the vectors angle (2b).

Environment vector and parameter vector relations are given in *Figure 2*. The performance of a genotype in an environment is related to the angle between its vector and the environment vector. If the angle between the vectors is less than 90° it is better than the average, if it is wider it is worse than the average (Yan and Tinker 2006; Yan and Kang, 2003). The relationships among locations and parameters in *Figures 2a* and *2b* are visualized by genotype profiles. Cultivar Aldane was below average in all environments except for environments E1 and E6. Cultivar Gelibolu was above average in E4, E5, E6 and E2 (*Figure 2a*). According to the description, grain yield was negatively correlated with 1000-kernel weight, wet gluten content, protein ratio and sedimentation value.

Gluten index were also negatively correlated with test weight and hardness. Among other parameters, there was a positive high correlation between sedimentation with protein value, and 1000-kernel weight with hardness (*Figure 2b*).

The relation among genotypes and parameters by GGE Biplot analysis was given in *Figure 3a*. If the cultivars and parameters are located in the same sector when starting from the lower right part of the graph, they are closely related (Yan and Tinker, 2006). According to this description, cultivar Aldane was located in the same sector with sedimentation value, protein ratio and wet gluten content, so they are closely correlated with each other. With a similar description, the cultivar Pehlivan was closely correlated with test weight, 1000-kernel weight and grain hardness (*Figure 3a*).

Figure 3b shows the horizontal stability axis and a vertical mean axis of the cultivars based on parameters. If the cultivar is located below the vertical axis, they are undesirable cultivars. If the variety is located above the vertical axis, they are the desirable cultivar. Furthermore, cultivars located near or at the centre of the horizontal line are stable and if they move away from the horizontal line unstable. According to, cultivar Selimiye is stable because it is located close to the centre of the horizontal axis (*Figure 3b*).

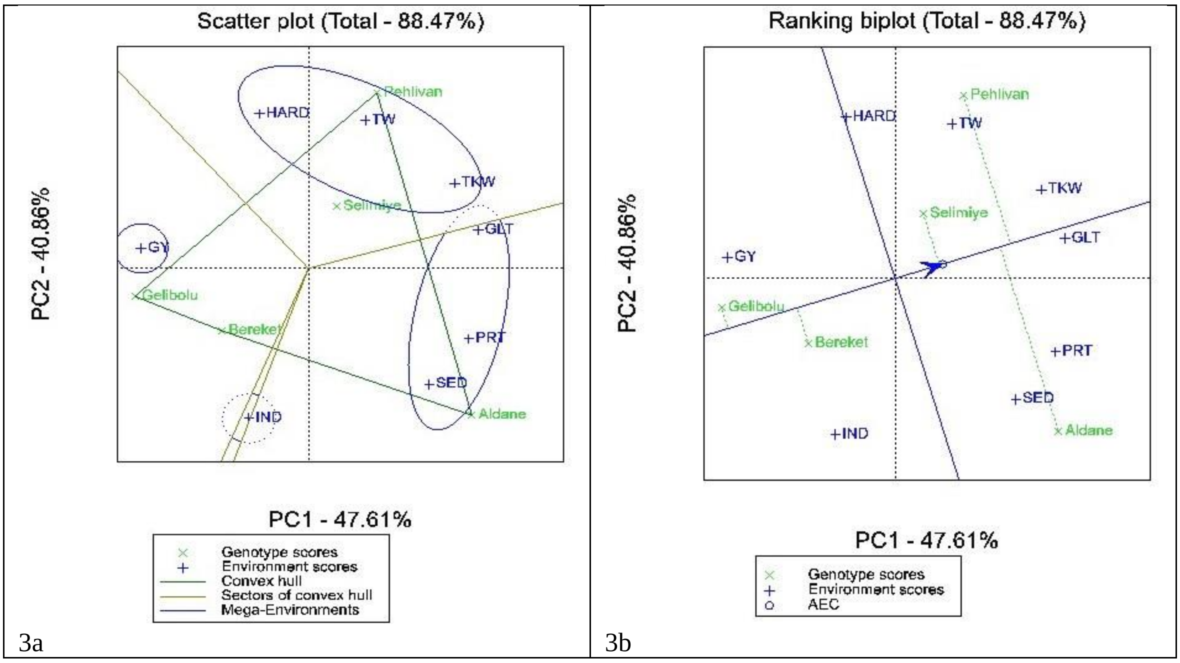

Figure 3. Grouping of the genotypes and traits by Biplot analysis based on parameters and relation of genotypes with parameters (3a), the GGE Biplot graph showed the mean performance by parameters and stability of cultivars (3b).

4. Conclusions

The environment has had a significant impact on yield and quality studied in the study. Therefore, there were significant differences in all quality parameters under different environmental conditions. Results of the AMMI analysis explained that grain yield was greatly impacted by environment and genotype effect. The environmental effect was the greatest main factor for variation than the genotype effect. There is a significant difference between the varieties and the cultivar Gelibolu was the highest yield potential. The average yield over seven environments differs from the highest in environment E4 (season without drought and heat stress) to the smallest in E6 (grain filling period is the season with drought). The fact that there was an 83.2% yield difference between the environments in the study showed the importance of the environmental impact. Due to the environmental effect the highest protein ratio, wet gluten content, grain hardness and sedimentation were established in environment E1, when there was less rainfall during the heading stage and during growing period. The study explained that Selimiye is a more ideal cultivar and E1 is a more ideal environment. For this reason, it can be explained that the Selimiye variety is more compatible with regions with low rainfall. According to the parameters investigated, environment E4 was the least while E7 (period of drought during plant emergence and tillering) and E2 (grain filling stage is the period of high drought) were the most discriminating. Cultivar Aldane had the sedimentation value, protein ratio and wet gluten content. Cultivar Pehlivan had the test weight, 1000-kernel weight and grain hardness. It has been determined that the environment has a significant effect on the change in the parameters examined in the research. According to the result of the research, to identify highly adaptable genotypes field studies should be performed over different rainfed environmental conditions. The results of the research showed that the environmental impact on the quality parameters was an essential factor. For this reason, breeders should carry out studies in different environmental conditions to select genotypes with good stability and high adaptability.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

The author declares that they have no conflict of interest.

Authorship Contribution Statement

Concept; Design; Data Collection or Processing; Statistical Analyses; Literature Search; Writing, Review and Editing: Öztürk, İ.

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