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Research Article

Heat Stress Response of Bread Wheat Genotypes Under High and Low Rainfall Environments

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Abstract: The research was carried out to determine the yield, yield components, quality, and stability of the bread wheat *(Triticum aestivum* L.*)* genotypes in heat-stressed and water-limited environments for two years. ANOVA and GGE biplot analysis were applied to determine the differences and relationships of investigated traits belonging to 10 different wheat varieties. While grain yield (GY) is associated with thousand-grain weight (TGW) and test weight (TW); protein ratio (PR) was found to be positively correlated with heading time (HT) and the number of spikes per square meter (SN). Besides, spike weight (SW) was found to be negatively correlated with PR, HT, and (SN). The biplot graph showed that PC1 explained 83.67% of the variability and the proportion attributed to PC2 was 16.33%. The cultivar of Kate A-1 was the most stable genotype, according to the biplot graph and it could be visually determined from the biplot graph in PC1 and PC2 together to explain 100% of the variability. In terms of the quality characteristics examined, Tahirova 2000 passed other varieties. It was concluded that Kate A-1 and Anapo varieties can be used for grain yield-oriented breeding studies, while Tahirova 2000 and Karatopak varieties can be used as parents for quality purposes.

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1. Introduction

Since wheat is of great importance in human nutrition worldwide, one of the most important targets of wheat breeders is to increase the grain yield (GY) obtained per unit area (Aktas, 2016; Barutcular et al., 2017; Yildirim et al., 2018; Kizilgeci et al., 2019a). Optimizing agronomic applications and developing varieties with high yield capacity are two main factors in increasing GY (Aktas, 2016; Güngör and Dumlupınar, 2019; Yüce et al., 2022). Different statistical methods are used in the evaluation of genotypes according to the data obtained in breeding programs. The responses of genotypes to different environmental conditions may be different. The GGE (genotype, genotype x environment) biplot model used to determine the response of genotypes under different environmental conditions provides an advantage in interpreting data with visual graphics.

Genotype x environment interaction (GEI) is one of the important arguments to evaluate the stability of genotypes for plant breeders. Especially, determining the relationship between the performance of genotypes and ecological factors has been an important research subject of plant breeders and geneticists (Yan, 2001). Information about GEI is obtained through trials established in different ecological conditions. In addition, the yield performance of genotypes in different ecological conditions was determined by stability analyses (Kilic et al., 2003; Aydemir et al., 2019).

Yield is a complex feature that is directly or indirectly linked to many agricultural characteristics and is significantly affected by environmental factors. Therefore, growers prefer high-yielding and also stable varieties to ensure yield (Kendal and Dogan, 2015; Aydemir et al., 2019). The grain quality obtained from the unit area in bread wheat is also greatly important as well as the GY. Protein ratio (PR) and protein-related quality characteristics are among the important factors that make up the quality of wheat. PR is considered very high for 14-17%, 11-14% high, and 10-12% medium according to the change limits. In addition, it has been reported that PR is significantly affected by environmental effects (Grausgruber et al., 2000).

This study aims to test some different bread wheat varieties in terms of adaptability in high rainfall and drought-stressed conditions, and to determine the varieties that are superior in terms of GY, stability and other (Tables 4 and 5) examined characteristics.

2. Material and Methods

This research was carried out in the 2012-2013 and 2013-2014 growing seasons under the condition of Diyarbakır province of Türkiye (Figure 1).

Figure 1. Map of Türkiye showing the experiment area.

In the research, winter (Pehlivan and Tanya), alternative (Kate A-1), and spring type (Karatopak, Ceyhan-99, Nurkent, Cemre, Anapo, Tahirova 2000 and Dariel) bread wheat *(Triticum aestivum* L.*)* varieties were used.

Experiments were designed according to randomized complete blocks design in three replications using 10 bread wheat varieties. Seeds were planted (in the first week of november) with a 6-row parcel drill and 450 seed/m^2 sowing norm. Each parcel was sowed as 7.2 m^2 (1.2 m x 6 m) and 6 m^2 was harvested (1.2 m x 5.0 m). Harvest processes were done between 10-25 June.

In the trials, 60 kg ha^{-1} nitrogen (N) + 60 kg ha^{-1} phosphorus (P_2O_5) fertilizer was applied over the pure material at the planting, and 60 kg ha^{-1} N top fertilizer over the pure substance during the tillering period. A spraying procedure was done to control weeds (narrow and broadleaf weeds) and harvest was carried out with Hege 140 parcel combine harvester.

2.1. Climate properties of the experiment area

Growing day and degree day, precipitation, average temperature and maximum average temperature values based on growth stages for the 2012-2013 and 2013-2014 growing seasons, are given in listed (Table 1).

Defining the climatic conditions that occurred during the years of the experiment according to the critical plant development periods will facilitate the evaluation of the genotype performances. The average precipitation in the wheat development period in the first year is above the average for long years. The average temperatures were higher than the average for long years except for the tillering and-stem elongation stages. The first year of the experiment was defined as a high-temperature stress environment since the average maximum temperatures were also high during the entire development period. Since drought stress was not observed in any growing stage, genotypes were exposed to high heat stress this year. High temperature is one of the most important climatic factors affecting the yield and growth of the plant, and the exposure of field crops (wheat, barley, corn, etc.) to fluctuating high temperatures significantly affects plant metabolism (Saleh et al., 2007; Gürsoy et al., 2012).

Table 1. Rainfall and temperature values according to plant growth stages during two years of experiment

	Number of days		Total of Temperature (degree-day)		Precipitation (mm)			Average Temperature (°C)			Average Max Temperature (°C)		
Plant growth stages	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**	**Long Years**	**2013**	**2014**	**Long Years**	**2013**	**2014**	**Long Years**
Sowing-Emergence (GS00-10)	20.0	21.0	170.1	156.2	66.8	37.4	61.6	7.7	7.1	6.6	12.6	7.4	6.4
Emergence-Tillering (GS10-20)	18.5	38.9	77.1	25.8	94.0	30.8	69.7	4.5	0.7	2.9	8.8	3.7	2.6
Tillering- Stem elong. (GS20-30)	47.5	43.5	192.2	292.2	147.2	96.6	68.4	3.9	6.1	4.5	8.7	12.6	5.3
Stem elong.-Heading (GS30-50)	67.5	36.0	698.2	434.3	79.4	44.0	68.3	10.4	11.4	8.5	16.2	17.9	11.2
Heading- Phys. Matur (GS50-90)	57.5	50.5	1253.3	984.6	100.8	88.7	55.0	21.2	18.2	19.8	29.5	26.0	19.8
Total Average	211.0	189.0	2390.9	1893.1	488.2	297.5	323.0	9.54	8.70	9.04	15.16	13.52	9.08

GS: determined according to the Zadoks growth scale (Zadoks *et al.* 1974).

In the second year, it is seen that the total precipitation in the development period is a little lower than the average precipitation for long years. Precipitation after the tillering stage is sufficient and higher than average for long years. The low rainfall from the sowing to the end of tillering stage shows that plants are exposed to early drought stress. When the plant loses water for any reason (drought, etc.), turgor pressure drops suddenly at first. Since drought stress will have a negative effect on the growth cells of the plant, there will be losses in germination ability due to the dispersion of membrane proteins and the decrease in chlorophyll content (Jaleel et al., 2009; Gürsoy et al., 2012). High temperatures occurring between the heading and physiological maturity period indicate that high-temperature stress is experienced in this period, in which grain yield is mainly determined. Long-term exposure to minus temperatures from emergence to starting of tillering indicates that cold and frost stress are experienced. In the second year, sudden frost damage was experienced between stem elongation and the heading stage and it caused necrosis in plants. When the plant is exposed to cold stress, the permeability of stem cell membranes is impaired. Even if there is water in the soil, water cannot be taken from the soil by the plant due to its low or lack of fluidity. If cold stress conditions continue for a long time, the leaves turn yellow as the first symptom and then the plants die (Taulavuori et al., 2005; Gürsoy et al., 2012).

When the second year is evaluated in general, it is seen as an environment where drought and cold stress are experienced in the early growing stages and moderately high-temperature stress is experienced in the later stages. The first year of the experiment was evaluated as high rainfall and high temperature stressed environment in the period when the yield and yield factors were determined, and the second year was considered a drought and cold stress environment for early growing stages (Table 1). On the other hand, the results of the analysis of the soil samples belonging to the field experiment area are given in listed (Table 2). The soil structure of the experiment area is clay-loam and slightly alkaline and has low organic material.

Table 2. Soil traits properties of the research experimental area

Soil Class	Total Salt (%)	pH	Lime $CaCO_3$ (%)	Phosphorus P_2O_5 (kg/da)	Organic Matter (%)	Saturation with Water (%)
Clay loam	0.245-0.246	7.75-7.81	6.26-8.50	1.28-1.30	0.676-0.680	77-65

Source: Anonymous (2014).

2.2. Data collection procedures for the investigated traits

GY of each parcel was determined by weighing the wheat grains obtained after harvesting the whole parcel on a 0.01 g scale and converting it to kg ha^{-1} (Pask et al., 2012). Heading time (HT) is determined as the days between the emergence and half of the spike (GS55) visible in 70% of the plants in each plot (Bell and Fischer, 1994). As a method in yield components, Kirtok et al. (1988)'s method has been taken into account. The number of spikes per square meter (SN): It was determined by counting the spike per square meter in each plot. The number of grains per spike (GN): The grains in 10 spikes taken from each plot were counted separately and averaged. Spike weight (SW): 10 spikes taken from each plot after physiological maturity were weighed separately on a 0.001 g scale. Then, the average weight of the spike was determined. Thousand grain weight (TGW): 1000 wheat grains representing each parcel were determined by weighing with a precision scale of 0.001 g (Pask et al., 2012).

Test weight (TW) and protein ratio (PR) were determined using the Near Infrared Model 6500 device (Anonymous, 1990).

2.3. Statistical analysis

The effects of genotype and environment on investigated traits were tested by using ANOVA. Genotype-traits and stability biplot graphics in visual properties were created using the GenStat 12th Edition program (GENSTAT, 2009). The differences between the means for each trait were examined by the least significant difference (LSD) test ($p < 0.01$ and $p < 0.05$) (Gomez and Gomez, 1984).

3. Results and Discussion

The ANOVA analysis revealed statistically significant differences in the mean GY and other traits ($p \le 0.01$ and $p \le 0.05$) (Table 3).

Table 3. ANOVA results for investigated traits, mean squares and significance levels of each variable

		Mean Squares							
Resources	DF	HT	SN	GN	SW	GY	TW	TGW	PR
Y	1	4352**	1100^{NS}	376**	18.7**	2138560**	214.4**	2325**	676**
R[Y]	4	3.8	1654	46.8	0.1	11313	0.5	6.3	1.8
C	9	49.4*	5855**	118.9**	0.3*	12245.7**	16.3**	45.7**	3.2^{NS}
Y x C	9	1.7^{NS}	4788**	58.1*	0.2^{NS}	4279.3^{NS}	3.5^{NS}	3.2^{NS}	0.9**
CV(%)		0.7	5.1	10.7	12.6	15.1	1.8	5.9	6.6
LSD (0.05)		1.2	44.7	5.8	0.4	73.9	1.7	2.2	1.1

R: Replication, Y: Year, C: Cultivar, CV: Coefficient of variation, DF, Degree of freedom, HT: Heading time, SN: Number of spike per square meter, GN: Number of grain per spike, SW: Spike weight, GY: Grain yield, TW: Test weight, TGW: Thousand-grain weight, PR: Protein ratio, NS: not significant, * Significant level, P<0.05, ** Significant level, P<0.01.

Genotype x environment interaction has been reported to be effective on grain yield, test weight, and thousand-grain weight in studies of bread wheat (Beleggia et al., 2013; Rozbicki et al., 2015; Sakin et al., 2015). Although different results were obtained in this study, it was seen that the YxC interaction was significant in the yield components (SN and GN) and the PR. This shows that cultivars are affected at different levels by environmental conditions in terms of SN, GN, and PR properties.

Table 4. Mean values of the first and second year of trial for the trait of HT, SN and GN

Cultivars	HT (day)			SN (spike m^{-2})			GN (grain $spike^{-1}$)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Karatopak	136.67	119.67	128.17	470.00	456.67	463.33	53.20	44.80	49.00
Ceyhan-99	136.00	117.67	126.83	446.67	443.33	445.00	48.50	47.50	48.00
Nurkent	135.33	116.67	126.00	371.67	441.67	406.67	47.70	49.70	48.70
Pehlivan	136.67	120.33	128.50	403.33	463.33	433.33	37.20	35.50	36.30
Cemre	136.67	121.33	129.00	445.00	391.67	418.33	48.50	42.90	45.70
Anapo	128.67	112.00	120.33	352.33	396.67	374.50	46.00	40.50	43.20
Tanya	138.67	121.33	130.00	486.67	428.33	457.50	49.80	39.30	44.60
Tahirova 2000	138.67	122.33	130.50	450.00	341.67	395.83	44.50	46.00	45.30
Dariel	134.67	118.33	126.50	393.33	365.00	379.17	49.50	47.20	48.30
Kate A-1	135.67	117.67	126.67	431.67	436.67	434.17	62.30	43.80	53.00
Means	135.77	118.73	127.25	422.85	416.50	420.78	48.7	43.7	46.20
CV (%)	0.6	0.9	-	9.1	8.9	-	10.2	11.3	-
LSD (0.05)	1.6**	1.8**	-	67**	63.9**	-	8.5**	NS	-

HT: Heading time, SN: Number of Spike per square meter, GN: Number of grains per spike, ** Significant level, $P<0.01$.

The heading time in the first year was prolonged due to the high precipitation during the tillering-heading stages and also because tillering- stem elongation period was cooler than the mean of long years. In the study, it was determined that the earliest cultivar was Anapo, and Tahirova 2000 was the latest heading time. In early growing genotypes, because of the long grain filling time, more dry matter accumulates in the grain and causes to increase in GY (Sharma, 1994).

Temperature stress in the location where the experiment is conducted is one of the important abiotic stress factors that limit GY. Early heading genotypes have the advantage of providing stable GY through the stress-escaping mechanism in the years when the high-temperature stress is observed. Due to the above-mentioned reasons, the high yield potential of the "Anapo" cultivar may be due to the earliness feature. Although there were differences in precipitation and temperature in both years during the development stage in which the number of the tiller is determined, the total number of the spike was similar. This case showed that there was a high genetic effect in the formation of spike numbers related to tillering. It had been reported that the number of spikes per square meter was influenced by genetic and environmental factors (Sakin et al., 2015).

The number of spikes per square meter ranged between 374.50-463.33 spikes m^{-2}. Karatopak cultivar had the highest number of ears per square meter (463.33 spikes m^{-2}). It had been reported that spike density per unit area in wheat was one of the most important yield components that determine GY (Kadum et al., 2019). The number of grains in wheat is potentially determined starting from the stem elongation and reaches its final limit during the flowering period. The decline in grain number potential in the second year was caused by drought during stem elongation and heading stages and the shortening of these stages (Table 4). To guarantee the number of grains, which are important yield factors, it will be beneficial to make irrigation when drought occurs in the pre-heading period. Exposure of plants to chilling stress due to sudden temperature drop at the booting stage in the 2nd year of the experiment was able to damage the flower primordium and decrease the number of grains.

The GN varied from 36.30 to 53.00 among genotypes and Kate A-1 had the highest GN. GN ranged from 31.20 to 44.90 in a study conducted in Türkiye (Aydogan and Soylu, 2017). Although the varieties used in our study were different from theirs, close values were obtained in GN. Depending on the drought season in the 2nd year, a drastic decrease in GN of Kate A-1, Tanya, and Karatopak cultivars negatively affected the yield potential. Pehlivan and Ceyhan-99, which had stable grain yield in the environment in which the study was carried out, had similar GN in both years, indicating that grain number is important in genotype stability.

There was a significant difference between the varieties for SW and it ranged between 2.00-2.70 g, while the Cemre cultivar (2.70 g) had the highest value (Table 5). Spike weight (SW) was found to be significantly higher in the first year due to high precipitation and humidity. In the first year, the time between stem elongation and physiological maturity was as long as 40 days compared to the 2nd year, which led to both good developments of spike before heading time and high dry matter accumulation at grain filling duration. Despite the high temperature occurring throughout the whole season in the first year, the high production of the dry matter showed that wheat in high rainy conditions turned the temperature increase into an advantage.

In the second year, in which the growing stages were shortened and early period drought stress occurred, SW decreased by approximately 40%. The highest reduction in SW was observed in the Kate A-1 cultivar with 50%. The most resistant cultivar was the Nurkent with a 22% reduction. Test weight (TW) ranged from 77.00-82.47 kg hl^{-1} and the highest test weight was obtained from Tahirova 2000 (82.47 kg hl^{-1}) cultivar. In the study conducted by Karaman et al. (2017) with bread wheat at the same location as our study, similar results were obtained with this study and it was reported that TW varied between 78.2 and 82.7 kg hl^{-1}. TGW, ranged from 28.91-38.37 g among cultivars, and Pehlivan (38.37 g) had the highest TGW (Table 5). Considering that TGW is largely under the control of genetic factors, it would be more useful to examine the decreases in the stressful year instead of grading the varieties from large to small. In the 2nd year, there was less reduction in TGW in comparison to SW and the last decrease was in the Nurkent cultivar. In the second year, the Nurkent cultivar had the lowest decrease for SW and GN characteristics as well as TGW, and it can be accepted as a strong stable cultivar for spike characteristics.

Table 5. Mean values of the first and second year of trial for the trait of SW, TW, TGW and PR

Genotypes	SW (g)			TW (kg hl^{-1})			TGW (g)			PR (%)		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Karatopak	2.80	1.87	2.30	83.19	79.46	81.33	35.42	22.67	29.04	11.45	18.28	14.87
Ceyhan-99	3.00	1.54	2.30	82.74	75.77	79.26	38.08	25.00	31.54	10.45	17.26	13.86
Nurkent	2.90	2.27	2.60	82.81	79.65	81.23	37.67	26.67	32.17	10.05	15.97	13.01
Pehlivan	2.70	1.81	2.20	82.80	81.02	81.91	45.92	30.83	38.37	10.75	16.93	13.84
Cemre	3.20	2.20	2.70	82.95	79.53	81.24	39.83	25.75	32.79	10.86	17.82	14.34
Anapo	3.00	1.75	2.40	83.95	80.44	82.19	38.75	26.00	32.38	10.28	15.97	13.13
Tanya	2.50	1.46	2.00	79.57	74.43	77.00	34.00	23.83	28.91	10.59	18.15	14.37
Tahirova2000	2.80	1.94	2.40	83.55	81.39	82.47	38.33	27.00	32.67	11.00	19.20	15.10
Dariel	3.20	1.85	2.50	82.24	77.40	79.82	35.42	23.17	29.30	10.94	17.64	14.30
Kate A-1	3.40	1.71	2.60	82.10	78.98	80.54	36.92	24.92	30.90	9.96	16.28	13.12
Means	2.95	1.84	2.40	82.59	78.81	80.70	38.03	25.58	31.81	10.63	17.35	13.99
CV (%)	9.5	17.6	-	0.8	2.5	-	5.5	6.5	-	8.8	5.3	-
LSD(0.05)	0.4*	NS	-	1.1**	3.3**	-	3.6**	2.9**	-	NS	1.6**	-

SW: Spike weight, TW: Test weight, TGW: Thousand grain weight, PR: Protein ratio, Av.: Average, NS: not significant, ** Significant level, $P<0.01$.

TGW is one of the important technological quality parameters as well as being the main component of GY. Our TGW findings were in line with the study, which ranged from 25.49 g to 37.51 g, and were carried out under similar conditions (Kizilgeci et al., 2019b). The PR is one of the important quality parameters for flour and pasta making. The PR of cultivars ranged from 13.01 to 15.10% and Tahirova 2000 cultivar had the highest value (15.10%). The PR of a study conducted in Diyarbakir conditions of Türkiye had been reported to vary between 14.36 and 16.48% (Kizilgeci et al., 2019b). Their results are similar to those obtained in our study. Although the PR has generally high heritability (Mckendry et al., 2011), this feature is highly affected by environmental factors such as soil nitrogen content, location of the field and climate components. Significant differences were observed for GY, between the varieties at $p\leq0.01$ level and it changed between 3414-4638 kg ha^{-1} (Fig 2). Kate A-1 cultivar gave the highest GY (4638 kg ha^{-1}). The GY of bread wheat is a complex feature and is under the influence of genetic and environmental conditions. GY is considered the most basic feature used directly in the selection of genotypes in breeding programs (Forgone, 2009; Kizilgeci et al., 2019b).

3.1. Evaluation of the features examined with The GGE biplot model

The relationship between cultivars and examined traits is given visually (Figure 3). The figure is interpreted as follows; there is a positive correlation if the angle between the vectors of the two traits is less than 90^0, negative if greater than 90^0, and no relationship if equal to 90^0. In addition, if the vector of one trait is longer than the other vectors, the variation between the genotypes is high in this traits, and if the vector is short, the variation among the genotypes is low (Yan et al., 2000; Yan and Tinker, 2006; Kendal et al., 2019). According to this explanation, there is a strong positive relationship among GY, TW and TGW; among PR, SN and HT and a negative relationship between TGW and GN (Figure 3). The long vectors of TGW, SW and GN mean that there is a large variation between the varieties for these properties (Figure 3). Variation between varieties is low in GY, SN, TW, PR and HT properties with short vectors. The relationship between variety and traits represents 60.67% of the total variation (Figure 3 and 4). Kate A-1, Pehlivan, Anapo and Nurkent varieties were associated with GY, Pehlivan with TGW, Tahirova 2000, Karatopak and Tanya with PR (Figure 3 and 4).

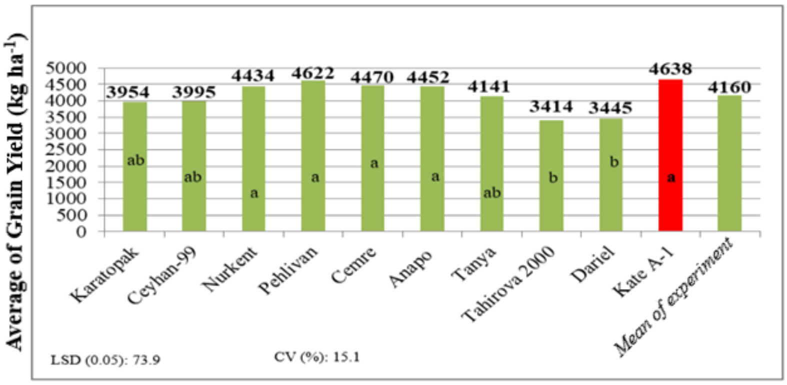

Figure 2. Average grain yield of varieties over two years of experiment results.

3.2. Polygon view of the GGE biplot

Genotypes at the top of the sectors (on the diagonal of the polygon) in the GGE biplot polygon graph are the most preferred genotypes of that sector (Yan and Tinker, 2006; Erdemci, 2018).

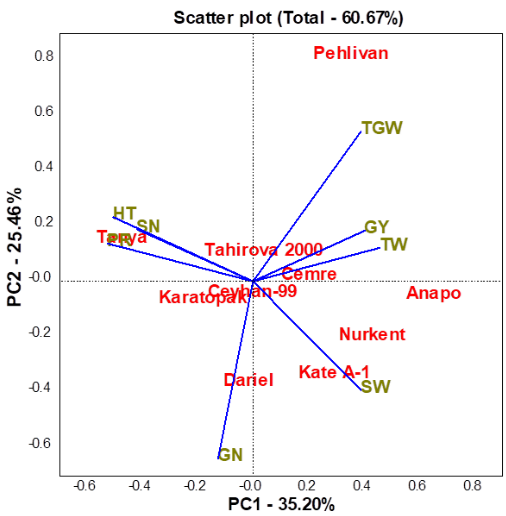

Figure 3. GGE biplot graph showing the cultivar traits relationship.

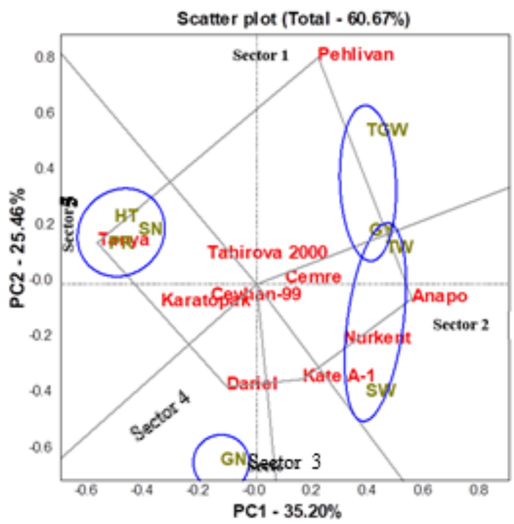

Figure 4. Which-won-where for cultivar and traits.

The cultivars in the diagonal of the polygon in the sector are considered to be a good cultivars in terms of properties close to the diagonal. According to the rule of being on the diagonal of the polygon; Pehlivan was the best variety for TGW and GY properties, Anapo varieties for GY and TW properties, and Tanya varieties were the best varieties for HT, PR and SN properties (Figure 4). According to the GGE biplot graph, five different sectors were created and they are grouped in a blue circle (Figure 4). The traits in the same sector are positively related to each other. According to the sectoral evaluation, TW contributed the most to the increase in grain yield.

3.3. Mean performance and stability of genotypes

In this study, according to the ranking biplot graph, PC1 represented 83.67% of the total variation, PC2 16.33% and both (PC1 + PC2) 100% (Figure 5). Genotypes showing high PC1 and low PC2 (close to zero) had been reported to be highly efficient and stable genotypes (Yan and Hunt, 2001). Accordingly, the biplot graph (Figure 5 and 6), consisting of PC1 and PC2 components, were sufficient to clearly determine the grain yield stability of cultivars and ideal genotypes. If a genotype is to the right of the PC1 axis, the grain yield is above the experimental mean, whereas the grain yield of the genotypes to the left of the axis is lower than the mean of the experiment. In addition, while the varieties close to the stability line are evaluated as stable varieties, the varieties that are far from the stability line are considered as a variable (unstable) for grain yield (Figure 5). According to this evaluation, Kate A-1 had both high grain yield and high stability (Figure 5).

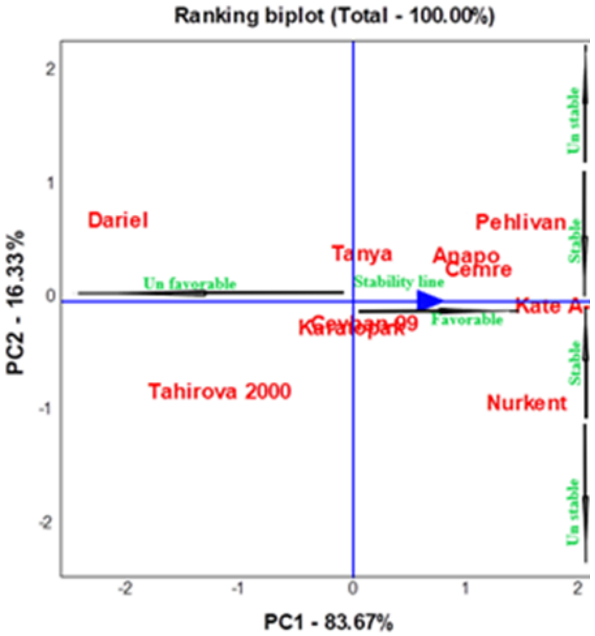

Figure 5. Grain yield stability graph with a ranking biplot.

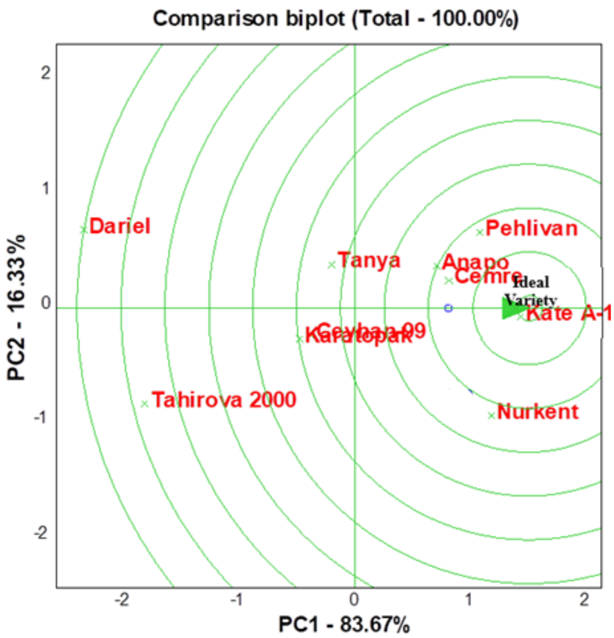

Figure 6. Presentation of the ideal genotype with the comparison biplot graph.

Different methods are used by researchers to determine the stability of genotypes. However, it is stated that the GGE biplot model shows the adaptation of genotypes to different environments easily and more understandably (Hassanpanah, 2011; Mortazavian et al., 2014). In addition, the grain yields of Tanya, Ceyhan-99, Karatopak, Tahirova 2000, and Dariel varieties were below the experiment mean and classified as undesired varieties.

3.4. Evaluation of genotypes based on the ideal genotype

The ideal genotype is defined as the most stable cultivar that has the highest grain yield in test environments and whose yield does not vary much from environment to environment (Yan and Kang, 2003). In Figure 6, there are many circles with the same centers. The cultivar in the smallest circle in the center of these circles is the ideal cultivar. Therefore, the varieties close to where the ideal cultivar is located are considered desired varieties. On the contrary, the suitability of varieties for any environment decreases as they move away from the central circle. When Figure 6 was evaluated, it was seen that the Kate A-1 cultivar was located very close to the center of the first circle. This showed that Kate A-1 was the most ideal cultivar compared to other varieties in terms of grain yield.

Conclusion

It was determined that Kate A-1, Pehlivan, Anapo, and Nurkent varieties had high yield potential. In addition to the highest grain yield, Kate A-1 was the most stable cultivar. Anapo cultivar was suitable for environments where terminal heat stress is experienced due to the mechanism of escaping from heat caused by earliness. Although the grain yield of Tahirova 2000 was below the experiment mean, it had the highest grain quality. It has been concluded that Kate A-1 will be the most suitable cultivar for the producer in terms of grain yield, and it will be beneficial to use Kate A-1 and Tahirova 2000 varieties as a parent in breeding programs for grain yield and quality improvement, respectively.

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