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EVALUATION OF THE PHYSIOLOGICAL AND AGRICULTURAL PROPERTIES OF SOME OF BREAD WHEAT (*TRITICUM AESTIVUM* L.) GENOTYPES REGISTERED IN TURKEY USING BIPLOT ANALYSIS

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Abstract

This study was conducted over two years in the 2016-2017 and 2017-2018 growing seasons with 13 bread wheat varieties under rainfall condition of Diyarbakir province, Turkey. Trials were designed according to randomized blocks with three replications. Significant differences were determined in all investigated traits ($p \leq 0.01$). According to the results of correlation analysis, Grain yield (GY) had a significant positive relationship with heading time and plant height, and a significant negative relationship with protein rate, zeleny sedimentation, and wet gluten. The GGE-biplot analysis revealed the presence of six different sectors with the physiological properties and quality parameters being included in the same sector. It was remarkable that there was a significant negative relationship between hectoliter weight and chlorophyll content and normalized difference vegetation index. Dinc, Gelibolu, Kale, and Aday-12 were prominent genotypes in terms of GY. It was determined that the investigated genotypes showed better potential in the first year of the study, and Aday-12 was the most stable genotype for GY. Based on the results, flag leaf chlorophyll content (SPAD) and normalized difference vegetation index were revealed as important parameters to be considered in quality-based selection. It can be concluded that the genotypes Dinc, Gelibolu, Kale and Aday-12, having a high GY and acceptable quality values, could be recomended cultivated under farm conditions and used as parents in wheat breeding programs.

Key words: Wheat, SPAD, NDVI, quality, GGE-Biplot.

Introduction

Wheat is one of the main food sources in human nutrition and it will become more important in the future considering the consistent growth of the world population. The world wheat cultivation area is 219 million hectares, production rate 758 million tons, and avarage yield 3450 kg ha^{-1}. Turkey produce 21.5 million tons grain wheat in 7.7 million hectares and it's yield average is 2800 kg ha^{-1} (Anon., 2018; Anon., 2018). The effects of genotypes and the interaction between the environmental factors are of great importance for wheat breeders, growers and merchants (Vazquez *et al*., 2012; Kaya and Sahin, 2015). It has been reported that in the Southeast Anatolia region of Turkey, spring, facultative and winter wheat varieties are cultivated in an area of approximately 1.3 million hectares under different environmental conditions, therefore the primary objective of breeders is to determine stable and high adapted genotypes in terms of the grain yield and quality traits (Aktaş *et al*., 2010; Kılıç *et al*., 2010; Aktaş, 2016). In order to reveal the status of other topics of research regarding agricultural traits associated with productivity, researchers have used different statistical analyses, such as correlation and principal components analysis (PCA) and visualized the relationship between the investigated factors through a GGE biplot analysis (Asfaw *et al*., 2009; Kendal and Sayar, 2016; Oral, 2018). In recent years, considering the importance of multidisciplinary studies in breeding programs, conventional breeding methods and physiological studies are undertaken together. In addition, there is ongoing research to determine the physiological parameters to support GY and grain quality (Kizilgeci *et al*., 2017).

Since the quality of wheat is influenced by the genotype, environment, and the interaction between these two factors, it is always difficult to achieve consistent quality. It is necessary to clearly understand the effect of the environment and the environment*genotype interaction in order to meet the expectations of the wheat market, improve high yielding, stable genotypes with appriciate quality traits (Williams *et al*., 2008; Kaya and Sahin, 2015). It has been reported that the total chlorophyll content per unit area can be measured by a hand-held chlorophyll meter (SPAD-502) to easily determine different plant patterns (Uddling *et al*., 2007; Yildirim *et al*., 2012). In plants with nitrogen (N) deficiency, the leaves turn pale green. Since the SPAD-502 meter measures the flag leaf chlorophyll content per unit area, it also helps determine the N requirement of the plant based on the relationship between chlorophyll content and N. In addition, the Green Seeker crop sensing system is frequently used by researchers to predict plant biomass based on the normalized vegetation index (NDVI) (Osborne, 2002; Lakesh, 2015). This portable device emits high-intensity light at a wavelength of 660 to 780 nanometers (nm) and measures the light reflected from the investigated plant with the help of a photodiode (Yun-Wen, 2012).

The aim of the current study was to determine the relationship between some physiological and agricultural characters of 13 bread wheat varieties and determine which are superior in terms of the investigated traits. The relationship between these traits was visualized using the GGE-biplot analysis method.

Materials and Methods

This study was conducted with 13 bread wheat varieties registered and intensively cultivated in Turkey (Table 2). The trial was designed as a randomized block with three replications under rainfall conditions of Diyarbakir province, Turkey (37°93' N; 40°25' E; 599 m altitude) in the 2016-2017 and 2017-2018 growing seasons (Figs. 1 and 2). In the first year of the study, sowing was undertaken on November 10, 2016 and the crop was harvested on June 16, 2017, and in the second year, the dates of sowing and harvest were November 15, 2017 and June 11, 2018, respectively (Fig. 1). Each plot area was 6 m^2 (six rows, each rows 20 cm, length of each plot 5 m, width 1.2 m).

Fig. 1. A photograph of the study area.

In this study, 140 kg ha^{-1} N and 60 kg ha^{-1} (P_2O_5) phosphorus (pure form) were used for fertilization. Half of the N was applied with sowing and the remaining at the end of the tillering period. All of the phosphorus was applied with sowing. The soil composition of the experimental area was clayey, the total salt content was 0.034, soil pH (concentration) 8.10 (alkaline), lime 8.64% (moderately calcareous), phosphorus 28.6 $kg.ha^{-1}$ (very low), organic matter 0.98 (very low), and water saturation 75.9% (Anonymous, 2018). In both growing seasons of the study, the precipitation (453.0 mm-462.0 mm) was below the long-term average (484.0 mm) (Table 1), and the distribution of rainfall was irregular within each growing season.

Statistical analysis of data: Harvested grains of each plot were weighed and the data were converted to the hectare unit to obtain the GY in kg ha^{-1}. The heading time (HT) (day) and plant height (PH) (cm) were examined according to the method described by Bell and Fischer (1994). NDVI (Normalized Difference Vegetation Index) was measured in ZGS70 and ZGS80 stages by Trimble Green Seeker hand-held device and flag leaf chlorophyll content (SPAD) in ZGS70 and ZGS80 stages by Minolta SPAD-502, Osaka, Japan (Zadoks, 1974). The chlorophyll content was measured from the exact center of the flag leaves of randomly selected 10 plants.

In order to determine the thousand grain weight (TGW), 400 seeds were counted and weighed, and the value obtained was multiplied with 2.5. Seed protein content (PR) and wet gluten ratio (WGR) were determined by NIT 6500 perten device, and the zeleny sedimentation (ZS) was measured according to the method recommended by the International Association for Cereal Science and Technology (Anon., 2008). The variance analyse was made by JMP 8.0 and GGE-biplot graphics were obtained using Genstat 12th Edition (Genstat, 2009) statistical analysis programs. The significance of differences between the average values of the examined traits was analyzed using the LSD test at $p \leq 0.01$ and $p \leq 0.05$ levels.

Table 2. Origin of bread wheat genotypes used in the study.

Varieties	Origin
Aldane	Directorate of Trakya Agricultural Research Institute, Turkey
Bereket	Directorate of Trakya Agricultural Research Institute, Turkey
Gelibolu	Directorate of Trakya Agricultural Research Institute, Turkey
Kopru	Directorate of Trakya Agricultural Research Institute, Turkey
Saban	Directorate of Trakya Agricultural Research Institute, Turkey
Selimiye	Directorate of Trakya Agricultural Research Institute, Turkey
Tekirdag	Directorate of Trakya Agricultural Research Institute, Turkey
Yuksel	Directorate of Trakya Agricultural Research Institute, Turkey
Aday-12	GAP International Agricultural Research And Training Center, Turkey
Cemre	GAP International Agricultural Research And Training Center, Turkey
Dinc	GAP International Agricultural Research And Training Center, Turkey
Kale	GAP International Agricultural Research And Training Center, Turkey
Tekin	GAP International Agricultural Research And Training Center, Turkey

Table 1. Climate data for the 2017-2018 growing season.

Months	Average of temperature (ºC)			Precipitation (mm)		
	2016-2017	2017-2018	Long-Term	2016-2017	2017-2018	Long-Term
September	24.2	26.8	24.8	5.2	0.0	4.1
October	18.8	17.2	17.2	13.6	22.0	34.7
November	8.2	10	9.2	52.0	21.2	51.8
December	2.4	5.8	4.0	135.6	12.8	71.4
January	1.5	5.2	1.8	20.6	86.4	68.0
February	1.5	7.6	3.5	3.8	86.2	68.8
March	9.4	12.4	8.5	90.2	12.8	67.3
April	12.8	15.9	13.8	98.8	48.6	68.7
May	18.8	19.4	19.3	30.6	157.6	41.3
June	26.9	26.6	26.3	2.6	14.4	7.9
Total				453.0	462	484.0

Fig. 2. Map of Turkey showing the location of the experiment.

Results and Discussion

In this study, significant differences were determined between the bread wheat genotypes ($p \leq 0.01$ for all traits) (Tables 3 and 4). In addition, genotype x environment interaction were found significant for all examined traits. This shows that, response of genotypes were different across environmens. Grain yield and quality parameters of wheat genotypes are affected by genotype and environmental interaction (Barutcular *et al*., 2016; Kizilgeci, 2019). The mean of heading day (HT) was 119.0 days, ranging from 113 days (Tekin variety) to 124.8 days (Kopru variety). In the second year, HT was observed to be shorter throughout the growing season due to the higher temperature compared to the first year (Tables 1 and 5). In addition, the mean plant height (PH) was found to be 77.9 cm, higher plant height was observed in Tekin and the shortest in Saban varieties. In a previous study, GY and plant phenology were reported to be associated with HT, PH, and physiological maturity time (Lopes & Reynolds, 2012). The genotypes with the highest and lowest average NDVI values in ZGS70 were noted as Tekirdag and Aday-12, respectively (Table 5). For the ZGS80 stage, NDVI average was 0.470, with the highest value being observed in Cemre and the lowest in Tekin. In another study conducted with 10 bread wheat varieties in Diyarbakir conditions, a significant positive relationship was found between GY and the NDVI values in the booting (ZGS45) stage, but no correlation was observed between GY and NDVI in the ZGS70 stage (Karaman *et al*., 2014). Similarly, in the current study, correlation between NDVI readings (ZGS70 and ZGS80) and GY was not signigicant. Concerning the chlorophyll content, the average of ZGS70 SPAD was 47.0. In the ZGS70 stage, the highest average SPAD was obtained from the Yuksel variety (51.8) and the lowest in the Aday-12 (42.0). In terms of the average SPAD values of the ZGS80 stage, the Yuksel variety was the most prominent (45.5) and the Tekin variety (29.6) ranked last (Table 6). In studies on winter bread and durum wheat, a significant relationship was reported between GY and the SPAD values determined in the heading (ZGS50) and grain filling stage (ZGS70-ZGS80) (Bavec & Bavec, 2001; Jiang *et al*., 2004; Yildirim *et al*., 2009; Yildirim *et al*., 2011). However, in another study conducted in Diyarbakır conditions, no relationship was observed between GY and the SPAD readings during the stages of flowering and milk development (Karaman *et al*., 2014). Similarly, we found that GY was not related to SPAD values obtained from the ZGS70 and ZGS80 stages.

In the current study, average of GY was 5804 kg ha^{-1}. The highest average GY was obtained from Dinc (7036 kg ha^{-1}) and the lowest value from Aldane (4911 kg ha^{-1}) (Table 7). GY was lower in the second year of the study despite the higher total precipitation compared to the first year. This is considered to be due to the plants being exposed to drought stress caused by the lower amount of precipitation until the ZGS30 stage, the irregular distribution of rainfall based on months, and the consequent weakness of the plant entering the generative stage (ZGS30). It has been suggested that genetic potential alone is not sufficient to explain GY in wheat since agronomic factors (soil structure, depth, fertilization, amount of rain and it's distribution etc.) and other factors, such as biotic and abiotic stress have an effect on this trait, and therefore in attempts to increase the potential of GY, in addition to improving the genetic structure, it is necessary to enhance biotic and abiotic factors (Costa *et al*., 2012).

Table 3. Variance analysis table.

Resources	Squares mean						
	DF	HT	PH	ZGS70 NDVI	ZGS70 SPAD	ZGS80 NDVI	ZGS80 SPAD
Year	1	6183.72**	29835.3**	0.00388**	9.13277**	0.02302	88.4909*
Replication [Year]	4	0.35577	6.04808	0.00008	0.28355	0.00592**	5.65401
Genotype	12	75.2233**	92.8221**	0.00421**	52.8376**	0.03809**	131.622**
Year* Genotype	12	10.6239**	65.9471**	0.00042**	6.27843**	0.00366**	44.1047**
Error	48	1.946	6.63	0.000144	1.1539	0.000917	3.1654
CV (%)		1.2	3.3	1.6	2.3	6.4	5.1

Table 4. Variance analysis table.

Resources	Squares mean						
	DF	GY	HW	TGW	PR	ZS	WGR
Year	1	1524398**	7.75846	128.462*	252.001**	7115.71**	1280.21**
Replication [Year]	4	12222.9**	2.69179*	6.96551*	0.87321**	10.4103	4.04128*
Genotype	12	18950.1**	15.2222**	25.6411**	2.88543**	124.459**	14.224**
Year* Genotype	12	21008.5**	11.2257**	19.0371**	5.13607**	85.6774**	25.7482**
Error	48	2559.8	0.9204	1.9768	0.4192	5.674	1.0834
CV (%)		8.7	1.2	4.4	4.0	5.8	3.1

Table 5. Average values and formed groups.

Genotypes	HT (day)			PH (cm)			ZGS70 NDVI		
	Year* Genotype			Year* Genotype			Year* Genotype		
	1. Year	2. Year	Average	1. Year	2. Year	Average	1. Year	2. Year	Average
Aldane	126.5 bc	113.5 fgh	120.0 c	107.0a	55.5 fg	81.3 abc	0.700 ab	0.707 kl	0.703 h
Bereket	127.5 bc	112.8 ghı	120.2 c	91.5 cd	58.0 f	74.8 e	0.737 cde	0.750 e-h	0.743 e
Gelibolu	127.0 bc	107.0 l	117.0 de	98.5 b	63.0 e	80.8 abc	0.717 def	0.710 jkl	0.713 gh
Kopru	134.0 a	115.5 f	124.8 a	99.0 b	58.0 f	78.5 cd	0.727 eh	0.740 ghı	0.733 ef
Saban	127.5 bc	112.5 ghı	120.0 c	88.5 d	53.0 gh	70.8 f	0.737 fgh	0.757 d-g	0.745 de
Selimiye	128.5 b	111.0 ıj	119.8 c	104.5 a	58.0 f	81.3 abc	0.710 hı	0.740 ghı	0.725 fg
Tekirdag	126.5 bc	109.7 jk	118.1 d	94.0 c	58.0 f	76.0 de	0.787 hı	0.770 bcd	0.778 a
Yuksel	134.5 a	114.5 fg	124.5 a	92.5 cd	50.5 h	71.5 f	0.760 ıj	0.757 d-g	0.758 cd
Aday-12	125.5 cd	106.5 lm	116.0 e	95.0 bc	63.0 e	79.0 c	0.697 jk	0.707 kl	0.702 h
Cemre	132.5 a	112.0 hı	122.3 b	98.5 b	65.5 e	82.0 ab	0.767 jkl	0.780 abc	0.773 ab
Dinc	126.5 bc	104.5 mn	115.5 e	95.5 bc	55.5 fg	75.5 e	0.750 jkl	0.790 a	0.770 abc
Kale	123.5 de	108.0 kl	115.8 e	95.5 bc	58.0 f	76.8 de	0.747 kl	0.780 abc	0.763 bc
Tekin	122.5 e	103.5 n	113.0 f	107.5 a	63.0 e	85.3 a	0.710 l	0.740 ghı	0.725 fg
Means	127.9	110.1	119.0	97.5	58.4	77.9	0.734	0.748	0.741
Min-Max.	122.5-134.5	103.5-115.5	113.0-124.8	88.5-107.5	50.5-65.5	70.8-85.3	0.697-0.787	0.707-0.790	0.702-0.778
LSD$_{(0.05)}$	2.29**		1.62**	4.23**		2.99**	0.02*		0.014**

Table 6. Average values and formed groups.

Genotypes	ZGS70 SPAD			ZGS80 NDVI			ZGS80 SPAD		
	Year* Genotype			Year* Genotype			Year* Genotype		
	1. Year	2. Year	Average	1. Year	2. Year	Average	1. Year	2. Year	Average
Aldane	45.9 jkl	47.5 g-j	46.7 ef	0.460 hk	0.490 e-h	0.475 cd	27.7 mn	33.5 hıj	30.6 g
Bereket	47.0 g-k	47.3 g-j	47.2 de	0.450 hk	0.480 fgh	0.465 d	27.2 n	34.6 f-j	30.9 fg
Gelibolu	50.2 bcd	48.5 d-h	49.3 bc	0.457 hk	0.427 jkl	0.442 d	36.6 efg	34.5 f-j	35.5 d
Kopru	51.7 ab	49.4 cf	50.5 b	0.470 g-j	0.460 hk	0.465 d	33.6 hıj	31.8 jkl	32.7 ef
Saban	48.4 e-h	47.8 f-ı	48.1 cd	0.537cde	0.590 ab	0.563 a	34.2 g-j	40.5 cd	37.3 cd
Selimiye	48.5 d-h	48.1 e-ı	48.3 cd	0.447 h-k	0.457 hk	0.452 d	33.4 hıj	33.2 ıjk	33.3 e
Tekirdag	48.7 d-g	49.7 cde	49.2 c	0.547 bcd	0.590 ab	0.568 a	41.6 bc	40.8 cd	41.2 b
Yuksel	52.9 a	50.6 bc	51.8 a	0.527 cf	0.477 ghı	0.502 bc	47.1 a	44.0 b	45.5 a
Aday-12	40.2 p	43.8 no	42.0 h	0.337 mn	0.430 ıjk	0.383 e	30.0 lmn	32.5 jkl	31.3 efg
Cemre	40.7 p	44.0 mno	42.3 h	0.567 abc	0.597 a	0.582 a	40.8 cd	35.8 e-ı	38.3 c
Dinc	44.7 lmn	46.5 ıjk	45.6 f	0.510 dg	0.537 cde	0.523 b	38.3 de	37.3 ef	37.8 c
Kale	42.8 o	45.7 j-m	44.2 g	0.307 no	0.417 kl	0.362 e	30.4 klm	36.1 e-h	33.3 e
Tekin	45.4 k-n	46.8 h-k	46.1 ef	0.270 o	0.380 lm	0.325 f	22.5 o	36.7 efg	29.6 g
Means	46.7	47.4	47.0	0.453	0.487	0.470	34.1	36.2	35.2
Min-Max.	40.2-52.9	43.8-50.6	42.0-51.8	0.270-0.567	0.380-0.597	0.325-0.582	22.5-47.1	31.8-44.0	29.6-45.5
LSD$_{(0.05)}$	1.76**		1.25**	0.05**		0.04**	2.92**		2.07**

Table 7. Average values and formed groups.

Genotypes	GY (kg ha^{-1})			HW (kg hl^{-1})			TGW (g)		
	Year* Genotype			Year* Genotype			Year* Genotype		
	1. Year	2. Year	Average	1. Year	2. Year	Average	1. Year	2. Year	Average
Aldane	5455 fg	4367 ı-m	4911 e	79.8 abc	75.8 h-k	77.8 bcd	29.9 g-k	30.5 f-ı	30.2 de
Bereket	6457 de	5382 fg	5919 bc	76.4 f-j	80.2 ab	78.3 bc	28.8 ı-l	39.1 a	33.9 ab
Gelibolu	7165 bcd	5297 fgh	6231 b	77.1 e-h	80.0 ab	78.5 b	28.0 jkl	31.1 fgh	29.6 ef
Kopru	7315 bc	4470 h-k	5893 bc	74.2 k	75.8 h-k	75.0 f	31.4 efg	34.9 bc	33.1 b
Saban	7462 bc	3582 m	5522 cd	77.8 def	77.0 e-ı	77.4 cd	32.1 d-g	34.4 bc	33.3 b
Selimiye	5870 ef	4701 g-j	5285 de	77.4 efg	80.2 ab	78.8 b	30.8 f-ı	35.1 bc	32.9 bc
Tekirdag	7308 bc	4931 g-j	6120 b	75.4 ıjk	77.1 e-h	76.2 e	30.5 f-ı	35.6 bc	33.1 b
Yuksel	6722 cd	3711 klm	5216 de	72.3 l	77.7 def	75.0 f	27.8 kl	32.0 efg	29.9 de
Aday-12	7573 b	4428 ı-l	6001 bc	75.4 jk	76.6 f-j	76.0 ef	33.5 cde	36.6 b	35.1 a
Cemre	7330 bc	3710 klm	5520 cd	77.8 def	76.1 g-j	76.9 de	34.4 bcd	31.3 efg	32.8 bc
Dinc	9110 a	4962 ghı	7036 a	79.1 bcd	78.3 cde	78.7 b	31.8 efg	28.0 jkl	29.9 de
Kale	8497 a	4123 j-m	6310 b	79.6 bc	77.7 def	78.6 b	27.5 l	28.9 h-l	28.2 f
Tekin	7357 bc	3610 lm	5483 cde	81.3 a	79.2 bcd	80.2 a	30.3 f-j	32.5 def	31.4 cd
Means	7202	4406	5804	77.2	77.8	77.5	30.5	33.1	31.8
Min-Max.	5455-9110	3582-5382	4911-7036	72.3-81.3	75.8-80.2	75.0-80.2	27.5-34.4	28.0-39.1	28.2-35.1
LSD (0.05)	83.06**		58.73**	1.57**		1.11**	2.31**		1.63**

Table 8. Average values and formed groups.

Genotypes	PR (%)			ZS (ml)			WGR (%)		
	Year* Genotype			Year* Genotype			Year* Genotype		
	1. Year	2. Year	Average	1. Year	2. Year	Average	1. Year	2. Year	Average
Aldane	15.4 j-k	17.9 def	16.7 abc	32.0 hı	56.0 a	44.0 b	31.4 gh	37.1 c	34.2 c
Bereket	16.2 g-j	16.9 f-ı	16.5 bc	40.0 e	50.0 bc	45.0 ab	33.1 efg	34.7 de	33.9 cd
Gelibolu	13.5 mn	16.5 ghı	15.0 e	30.0 ıjk	51.7 b	40.8 cd	27.1 jk	33.9 def	30.5 g
Kopru	12.9 n	18.5 bcd	15.7 de	27.7 kl	39.0 ef	33.3 e	25.7 k	38.2 c	31.9 ef
Saban	14.2 lm	19.5 ab	16.8 ab	28.0 jkl	59.7 a	43.8 b	28.6 ıj	40.4 a	34.5 bc
Selimiye	16.2 g-j	17.1 efg	16.7 abc	34.7 gh	59.0 a	46.8 a	33.1 efg	35.2 d	34.1 c
Tekirdag	15.9 ı-j	17.0 e-h	16.5 bc	33.0 ghı	44.0 d	38.5 d	32.5 fg	35.0 d	33.7 cd
Yuksel	16.0 hıj	18.7 bcd	17.3 a	26.0 l	36.0 fg	31.0 e	32.6 fg	38.6 bc	35.6 ab
Aday-12	12.9 n	18.0 de	15.4 de	29.7 ı-l	56.0 a	42.8 bc	25.7 k	37.2 c	31.5 fg
Cemre	14.8 kl	19.9 a	17.3 a	30 ıjk	51.0 b	40.5 cd	29.9 hı	41.6 a	35.7 a
Dinc	13.8 lmn	18.3 cd	16.0 cd	31.7 hıj	46.7 cd	39.2 d	27.7 j	37.9 c	32.8 de
Kale	13.7 mn	18.4 cd	16.1 cd	32.7 ghı	46.7 cd	39.7 d	27.5 j	38.1 c	32.8 de
Tekin	13.8 lmn	19.3 abc	16.6 bc	30.0 ıjk	58.0 a	44.0 b	27.8 j	40.1 ab	34.0 cd
Means	14.5	18.1	16.3	31.2	50.3	40.7	29.4	37.5	33.5
Min-Max.	12.9-16.2	16.5-19.9	15.0-17.3	26.0-40.0	36.0-59.7	31.0-46.8	25.7-32.6	33.9-41.6	30.5-35.7
LSD(0.05)	1.06**		0.75**	3.91**		2.77**	1.71**		1.21**

The average HW was calculated as 77.5 kg hl^{-1}. The highest HW was obtained from Tekin (80.2 kg hl^{-1}) and lowest from Kopru and Yuksel (75.0 kg hl^{-1}). It has been reported that HW varies according to the seed shape, volume and density of grain and it is also affected by the plant's ability of adaptation to the environment (Costa *et al.*, 2013). In the current study, there were significant differences between the investigated varieties in terms of HW, and the irregular distribution of rainfall based on months despite the similar total precipitation resulted in different plant reactions, indicating the importance of the effect of environment*genotype interaction. Environment and pests significantly affect the hectoliters weight (Deivasigamani, 2018). The selection of genotypes that give high hectolitre weight is important in terms of economic profitability (Conley & John, 2013: Deivasigamani, 2018).

TGW varied between 28.2 g and 35.1 g, with an average of 31.8 g for the whole trial. The highest TGW value was measured for Aday-12 (35.1 g) and the lowest for Kale (28.2 g) (Table 7). According to the results of correlation analysis undertaken by Anwar *et al.*, (2009), there was no correlation between TGW and, GY, HT and PH in bread wheat. Similarly, in the current study, no correlation was observed between TGW and GY in the correlation analysis. However, TGW was significantly and negatively correlated with HT and PH. The two studies differed in this respect.

Significant differences were determined between the varieties in terms of PR. The average of PR was 16.3%, with the highest value being detected in Yuksel (17.3%) and Cemre (17.3%) and the lowest in Gelibolu (15.0%). In a study conducted with 13 bread wheat genotypes, PR was reported to vary between 12.49% and 13.44%, with an average value of 12.91% (Kaya & Şahin, 2015). Our PR values were higher both on an individual basis and based on the trial average. This is considered to be caused by the environmental conditions in the study area and the differences in the plant materials that used in current study. We calculated the average ZS value as 40.7 ml, which ranged from a maximum of 46.8 ml in the Selimiye variety to a minimum of 31.0 ml in the Yuksel variety (Table 8).

Table 9. The correlation coefficients showing the relationship between the investigated features and significance levels.

Features	GY	HW	TGW	PR	ZS	WGR	HT	PH	ZGS70 NDVI	ZGS70 SPAD	ZGS80 NDVI
HW	0.07										
TGW	-0.22	0.19									
PR	-0.89**	-0.09	0.16								
ZS	-0.74**	-0.16	0.34*	0.76**							
WGR	-0.89**	-0.09	0.16	0.99**	0.76**						
HT	0.72**	-0.35*	-0.31*	-0.72**	-0.83**	-0.73**					
PH	0.78**	-0.07	-0.39**	-0.80**	-0.78**	-0.80**	0.86**				
ZGS70 NDVI	-0.09	-0.06	-0.06	0.35*	-0.04	0.35*	-0.18	-0.28*			
ZGS70 SPAD	-0.13	-0.30*	-0.11	0.14	-0.01	0.13	0.07	-0.17	0.09		
ZGS80 NDVI	-0.13	-0.29*	0.14	0.31*	0.08	0.31*	0.00	-0.25	0.55**	0.32*	
ZGS80 SPAD	-0.13	-0.36**	0.02	0.28*	0.01	0.27	-0.03	-0.26	0.59**	0.37**	0.62**

In the literature, the sedimentation value is commonly used to evaluate the quality of wheat protein and wheat flour (Makawi *et al*., 2013). Ali (2017) reported that sedimentation value to ranged from 44.0 ml to 60.7 ml, while Kaya & Akcura (2014) calculated this range as 24 ml to 33 ml. These differences in the sedimentation values between the studies can be attributed to the effect of environmental conditions and the genetic structure of the genotypes used.

In this research, the average WGR value for the all trial was 33.5%, with the highest and lowest values being obtained from the genotypes Cemre (35.7%) and Gelibolu (30.5%), respectively. WGR is not only among the most important parameters in measuring the quality of wheat, but it is also a key trait in determining the area of use of wheat considering that gluten strength is taken into account in the classification of wheat to be used in the production of bread, pasta and cakes (Módenes *et al*., 2009). In bread wheat, WGR was reported to range from 27.3 to 32.2% with an average value of 29.5% (Ali, 2017). In the current study, consistent with the literature, the WGR values varied between 30.5% and 35.7%, and the trial average was calculated as 33.5%.

Considering the significance levels of the relationship between the examined traits in the current study, GY had a positive and significant relationship with HT and PH, and a negative and significant relationship with PR, ZS, and WGR (Table 9). Furthermore, it was determined that ZGS70 NDVI was positively and significantly correlated with PR and WGR and negatively and significantly correlated with PH. In addition, ZGS80 NDVI and ZGS80 SPAD had a negative and significant relationship with HW and a positive and significant relationship with PR (Table 9). Kizilgeci (2019) reported positive and significant relationship between grain yield and thousand grain weight and SPAD. In our study, no relation was detected (Table 9).

Determination of genotype-trait relationship using GGE-biplot analysis: GGE-Biplot analysis has been reported to be of great importance for plant breeders because it visually presents the relationship between different traits (Kendal, 2015; Kendal *et al.*, 2016; Oral, 2018). According to the biplot graph showing the relationship between genotype and traits, there were six different main sectors (Sector to Sector), and PR, WGR, ZGS70 SPAD, ZGS80 SPAD, ZGS70 NDVI, ZGS80 NDVI, and HT were included in the same sector and group (Figs. 3 and 4).

In addition, as shown in the figures (Figs. 3 and 4), PH and HW being included in the same sector (Sector 5) and the same group indicate the positive correlation between these two traits. A previous study determined that genotypes and environments included in the same sector had a positive relationship and those emerging in different sectors had a negative relationship (Islam *et al*., 2014). In the current study, the most prominent genotypes were found to be Tekirdag, Yüksel, Saban and Cemre for ZGS70 SPAD, ZGS80 SPAD, ZGS70 NDVI, ZGS80 NDVI, WGR, PR and TGW; Aldane and Selimiye for ZS; and finally Tekin for HW and PH.

Comparison of genotypes regarding GY stability using GGE-biplot analysis: GGE-biplot analysis method is an analysis method that visually presents the stability and performance of GY and other properties (Goyal *et al*., 2011; Oral, 2018). According to the GGE-biplot graphs showing the GY stability of the genotypes over the two-year averages (Figs. 5 and 6), it can be stated that the genotypes had better potential better in the first growing year because it was located just above the stability line on the far right**.** Genotypes, which are located closest to the *x* axis and also to the right of the *y* axis, are desirable genotypes (Farshadfar *et al*., 2013; Aktas, 2017; Karaman, 2020). It was also determined that Dinc, located on the far right of the stability line, was the best genotype in terms of GY. Kale, Aday-12 and Saban were other prominent genotypes concerning GY. The most stable genotype was Aday-12 with its highest GY and location directly above the stability line and Aldane and Selimiye were the lowest-performing genotypes for this trait (Figs. 5 and 6). Different researchers have reported that the biplot ranking model facilitated the visual comparison of multiple factors, demonstrated the stability and adaptability of genotypes, and provided support for the interpretation of data (Ahmadi *et al*., 2012; Mortavazian *et al*., 2014). The GGE-biplot analysis method was recommended for investigators as an excellent method of analysis to demonstrate the differences between the genotypes selected (Pržulj & Momčilović, 2012).

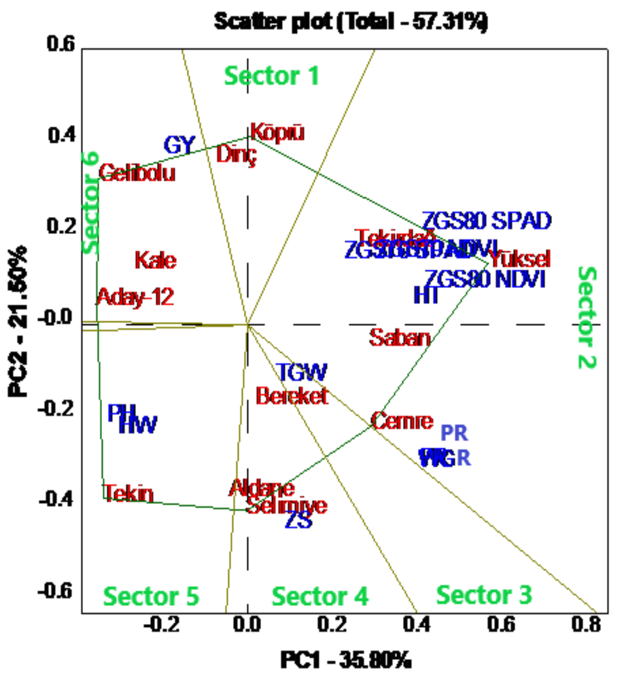

Fig. 3. GGE-Biplot graph showing genotype-trait correlation and sector.

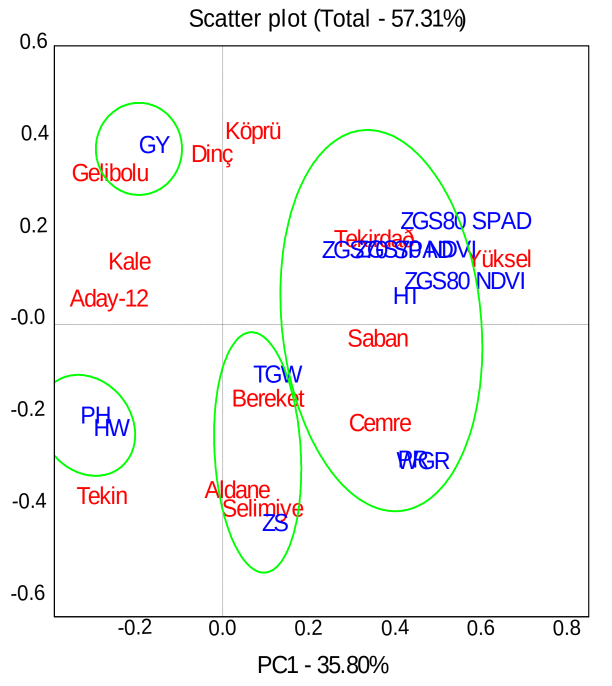

Fig. 4. GGE-Biplot graph showing genotype-trait group.

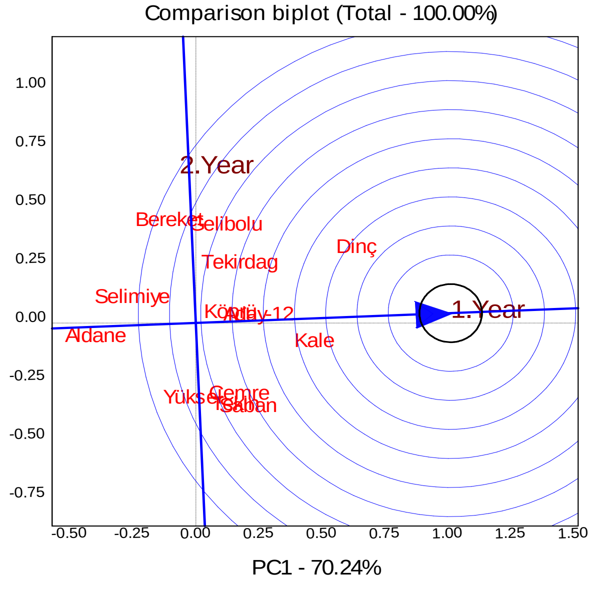

Fig. 5. Comparative GGE-Biplot graph showing grain yield.

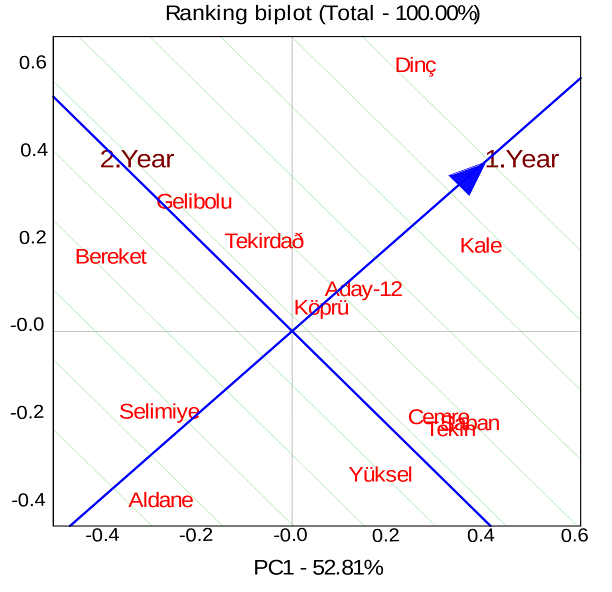

Fig. 6. Ranking GGE-Biplot graph showing grain yield and stability.

Conclusion

The analysis results of the two-year data of 13 bread wheat varieties revealed a positive relationship between PR, WGR, ZGS70 and ZGS80 SPAD, ZGS70 and ZGS80 NDVI, and HT. Furthermore, TGW and ZS were included in the same group and PH and HW in another group, and these pairs of traits had a positive and significant relationship. GY was negatively and significantly correlated with quality characteristics (PR, ZS and WGR), and positively and significantly correlated with HT and PH. In addition, it is noteworthy that the SPAD and NDVI values had a negative and significant relationship with HW and positive and significant relationship with PR and WGR. However, there was no relationship between GY and the ZGS70 and ZGS80 SPAD and NDVI values.

It was determined that the investigated physiological characters were associated with quality parameters, and SPAD and NDVI values can be used in selection of high quality genotypes. The genotypes with high GY values were Dinc, Gelibolu, Kale, and Aday-12, and the most stable genotype was Aday-12. Based on the acceptable quality values of the mentioned genotypes, it is concluded that they coluld be used as a parent in breeding programs to improve grain yield of new bread wheat genotypes.

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