ENVIRONMENT EFFECT IN BREAD WHEAT (*Triticum aestivum* L.) ON YIELD AND QUALITY PARAMETERS UNDER RAINFED CONDITIONS

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Abstract

The experiment was carried out to assess the environmental effect on the yield of bread wheat cultivars under rainfed conditions. A total of five bread wheat cultivars were tested across seven environments during the 2010-2011 and 2016-2017 growing cycle in Edirne location in the Trakia region, Turkey. Each year was considered as a single environment. The experiment was conducted in a randomized complete blocks design (RCBD) with four replications. Grain yield, days of heading, plant height, 1000-kernel weight, test weight, protein ratio, wet gluten content, gluten index and sedimentation value were investigated. The results of variance analysis revealed significant differences ($p<0.01$) among cultivars, environments and environments × cultivars interaction for yield. The lowest grain yield was 4454 kg ha^{-1} in 2015-2016 cycles in E6, and the highest was 8158 kg ha^{-1} in 2013-2014 growing cycle in environment E4. The highest grain yield was performed by cultivar Gelibolu (7234 kg ha^{-1}) and the lowest by Aldane (6485 kg ha^{-1}). Environment influenced the characters studied and very significant variation was found between environments. According to the environmental effect, the highest protein ratio, wet gluten content and sedimentation value were determined in environment E1. The highest 1000-kernel weight was determined in E4 and the test weight was in E2. While the Selimiye variety was the most stable in terms of yield, 1000-kernel weight and sedimentation value, the Pehlivan variety was the most stable in terms of test weight. The existence of different interactions between cultivars and environments showed the importance of genotype-environment interaction in breeding studies. The result of the study showed that for an effective selection of genotypes in breeding studies, studies should be carried out under different environmental conditions.

Key words: *Bread wheat, cultivar, yield, quality parameters, environment effect*

1. INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the most important and widely produced cereal crop throughout the Trakia region of Turkey. Although the amount of rainfall (589.1 mm) during the growing season is enough for wheat production, the distribution of this rainfall is not regular. This fluctuation of rainfall causes reducing grain yield and quality (Öztürk and Korkut, 2017; Öztürk and Korkut, 2018). Bread wheat (*Triticum aestivum* L.) is economically one of the most important cereal crops in the world. Genetic improvement in wheat yields in dry areas has not been as easy as in more favourable environments or where water is not a limiting factor (Richards et al., 2001). The identification and examination of key genetic and environmental components that affect the quality and G×E interactions have proven successful in breeding and cultivating good-quality crop cultivars. For example, in regions with excessive rainfall, breeders should pay greater attention to such traits as early maturity to avoid the rainy season in the early summer (Sun et al, 2010, Zhao et al, 2010). Improvement of end-use quality in wheat (*Triticum aestivum* L.) depends on a thorough understanding of the Influences of environment, genotype, and their interaction (Awulachew, 2019). Wheat quality is directly affected by diverse environmental factors. Environmental variables have important effects on wheat grain protein accumulation and processing quality, although wheat quality is a genotype-dependent trait. Moderately high temperature, proper soil moisture (resulting from rainfall and irrigation), and sufficient solar radiation may improve wheat quality. Wheat quality may be improved by breeding elite varieties, improving crop/farming management practices and exploiting the synergism between genotype and the environment (Awulachew, 2019). Increasing yield potential without affecting negatively the quality of the grain is difficult, mainly because increases in grain yield are generally

accompanied by a decrease in the grain's protein content, which is strongly associated with bread-making quality (Awulachew, 2019). Grain protein content in wheat varies between 8 and 17 percent, depending on genetic make-up and on external factors associated with the crop. The interactions of G×E significantly influence all quality traits, including grain protein content, sedimentation value, test weight, and mixing development time. Moreover, the interactions among environment, genotype and sowing time greatly influence the indicators of wheat end-use quality (Pan et al, 2005). Grain protein content, particularly gluten content, is positively correlated with Zeleny sedimentation value and stability time and is thus regarded as an important index for wheat quality (Shi et al, 2005, Weegels et al, 1996). One of the most effective pathways to meet global needs for the production of the wheat grain is to focus on the interactions of genotype × environment x crop management. The development of methods to screen genotypes for a variety of responses to combinations of environmental and management scenarios will allow breeders and farmers to make better use of the genetic potential of genotypes (Studnickia et al., 2016). This research provides to determine how the environment affects wheat yield and quality and facilitates further investigations of the environmental effect on grain yield and quality. Therefore, the objective of this study was to investigate yield and quality parameters of bread wheat genotypes and evaluate the relationship between environmental factors and wheat quality and thus accelerating the improvement of wheat quality.

2. MATERIAL AND METHODS

The experiment was conducted during the 2010-2011 and 2016-2017 growing years in the Edirne location (41° 38′ 52′′ N and 26° 36′ 07′′ N, 40 m elevation) in the Trakia region, Turkey. Each year was considered as a single environment. A total of 5 bread wheat cultivars were tested across seven environments. The experiment was laid out in a randomized complete block design (RCBD) with four replications. In the study, grain yield (GY), days of heading (DH), plant height (PH), 1000-kernel weight (TKW), test weight (TW), protein ratio (PRT), wet gluten content (GLT), gluten index (IND) and sedimentation value (SED) were investigated. In the experiment, each plot was comprised of 6 rows of 6 m, spaced 0.17 meters apart. Using a plot drill was performed for sowing and 500 seeds per square meter were used. In the research, 1000-kernel weights and test weight (Blakeney et al., 2009), protein ratio, grain hardness, wet gluten content, gluten index, and sedimentation value (Perten H. 1990; Anonymous, 2002; Anonymous, 1990) were determined. The quality analysis of the Zeleny sedimentation test and wet gluten content was determined according to ICC standard methods No. 116/1 and 106/2, respectively (Anonymous, 1972; Anonymous, 1984).

Statistical analysis

Data were analyzed statistically for analysis of variance in the method described by Gomez and Gomez (1984). To evaluate significant differences between genotypes, the analysis of variance (ANOVA) was performed. Letter groupings were generated by using a 5% level of significance. Finlay and Wilkinson's joint regression model (1963) and Eberhart and Russel's method (1966) were applied and the regression coefficient (b), determination coefficients of the regression equations (R2) were calculated (Pintus, 1973, Finlay and Wilkinson, 1963; Eberhart and Russell, 1966 and 1969; Tai, 1971). The correlation coefficient was also used to detect the relationship between yield and disease progresses correlations among parameters were determined by Pearson's correlation analysis.

Total precipitation during the growing season is given in Table 1 and there was a significant difference among years. Accumulated the highest rainfall was 614.9 mm in the 2012-2013 growing season, which occurred between October and June. The lowest precipitation was in the 2010-2011 cycle with 331 mm. The heading and grain filling period in wheat takes place in May and early June. The amount and distribution of precipitation in this period and the effect of temperature are important in determining yield and some quality parameters (Table 1).

Table 1. Precipitation from 2010-2011 up to 2016-2017 growing cycle in the experimental field of the institute.

Months	Rainfall Long year	2010-2011(E1)	2011-2012 (E2)	2012-2013 (E3)	2013-2014 (E4)	2014-2015 (E5)	2015-2016 (E6)	2016-2017 (E7)
October	52.9	68.5	95.0	46.1	30.7	121.8	52.6	44.4
November	72.4	39.7	1.4	12.4	73.9	43.2	26.2	3.2
December	61.7	34.4	71.4	165.8	2.3	111.3	0.3	3.2
January	48.1	34.4	108.8	134.6	74.9	42.2	114.8	67.8
February	46.9	45.8	43.4	104.5	3.8	68.6	91.4	43.4
March	52.2	16.0	4.6	62.9	124.5	67.8	54.8	51.0
April	51.0	47.4	55.7	51.0	36.8	44.4	116.1	65.6
May	56.0	12.4	104.6	11.0	61.7	45.2	81.4	85.0
June	41.5	32.4	0.4	26.6	68.8	31.0	10.2	44.4
Total	482.7	331.0	485.3	614.9	477.4	575.5	547.8	408.0

3. RESULTS AND DISCUSSION

Results of analysis of variance (ANOVA) for the effects of experimental factors genotype (G) and environment (E) on yield and quality parameters of mean square and F ratio were given in Table 2. The combined ANOVA revealed significant differences ($P<0.01$ and $P<0.05$) among environments for all traits (Table 2). There was also a significant difference among genotypes except for grain yield (GY), test weight (TW) and hardness (HARD).

Table 2. Mean square and F ratio for yield, quality and morphological parameters measured in durum wheat genotypes across seven environments.

Parameters	Genotypes (G)		Environment (E)	
	MS	F ratio	MS	F ratio
GY	5000.75	1.53ns	64084.54	19.65**
TKW	45.69	5.07**	127.22	14.12**
TW	2.49	2.10ns	17.89	15.13**
PRT	4.09	6.78**	12.93	21.46**
GLT	110.72	11.70**	174.11	18.40**
IND	1398.53	15.84**	279.06	3.16*
HARD	17.03	1.63ns	45.05	4.32**
SED	408.31	18.88**	490.71	22.69**
DH	41.76	28.02**	453.23	304.08**
PH	185.31	28.67**	690.52	106.82**

*, ** Significant at $p<0.05$ and $p<0.01$ respectively. ns: non-significant, MS: mean of square, GY: Grain yield (kg ha^{-1}), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Wet gluten content (%), IND: Gluten index (%), HARD: Hardness, SED: Sedimentation value (ml), DH: Days of heading, PH: Plant height (cm).

In the experiment, five bread wheat cultivars were used in this study with red grain and are widely produced in various regions. The red-grained wheat is preferred for cultivation in Trakia regions due to tolerance to sprouting characteristics. There was no significant difference among cultivars for grain yield. The highest yield was determined in Gelibolu (7088 kg ha^{-1}) while the lowest was in cultivar Aldane (6398 kg ha^{-1}). The mean test weight of the genotypes was 82.0 kg and the lowest test weight was 81.5 kg (cv. Bereket) and the highest was 82.7 kg (cv. Selimiye). There were significant differences among genotypes for 1000-kernel weight. The highest 1000-kernel weight was weighted for Pehlivan (45.8 g) while the lowest was in cultivar Bereket (39.7 g). Days of the heading of the genotypes ranged from 114.3 to 120.1 and the mean value was 117.7 days. Variations in plant height of cultivars ranged from 98.6 cm (cv Gelibolu) to 110.9 cm in cv Bereket. Due to the fluctuation of rainfall mid-early genotypes generally are favourable in bread wheat in the Trakia region (Table 3).

Table 3. Mean performance and standard deviation of genotypes for parameters investigated

Cultivars	GY	TKW	TW	DH	PH
Aldane	6398±848^{b}	43.6±4.8^{ab}	81.6±2.0^{ab}	114.3±9.8^{c}	104.0±13.0^{b}
Selimiye	6866±142^{ab}	42.1±5.7^{bc}	82.7±2.1^{a}	117.7±8.7^{b}	101.1±12.3^{c}
Bereket	6791±134^{ab}	39.7±3.9^{c}	81.5±2.2^{b}	120.1±9.4^{a}	110.9±12.3^{a}
Pehlivan	6571±137^{ab}	45.8±5.7^{a}	82.6±2.0^{ab}	120.0±10.3^{a}	108.9±11.5^{a}
Gelibolu	7088±115^{a}	40.0±7.8^{c}	81.7±2.2^{ab}	116.7±9.6^{b}	98.6±10.6^{c}
Mean	6743	42.2	82.0	117.7	104.7
LSD $_{(0.05)}$	62.80	3.89	1.40	1.58	3.29
CV (%)	8.5	7.1	1.3	1.0	2.4

GY: Grain yield (kg ha^{-1}), TKW: 1000-kernel weight (g), TW: Test weight (kg), Days of heading, PH: Plant height (cm).

Table 4. Mean performance and standard deviation of genotypes for quality parameters

Cultivars	PRT	GLT	IND	HARD	SED
Aldane	12.9±1.3^{a}	37.0±4.3^{a}	90.8±5.5^{a}	47.0±5.6^{b}	60.9±7.3^{a}
Selimiye	12.0±0.7^{b}	37.0±7.0^{a}	82.8±8.4^{a}	50.7±3.1^{a}	50.7±11.3^{b}
Bereket	11.3±2.1^{bc}	31.9±7.7^{b}	87.1±10.7^{a}	48.4±3.4^{ab}	45.4±11.4^{c}
Pehlivan	11.4±0.9^{bc}	36.3±5.3^{a}	57.7±20.0^{b}	50.6±2.9^{a}	41.7±11.4^{c}
Gelibolu	11.0±2.1^{c}	28.0±7.5^{c}	92.2±4.2^{a}	49.6±5.1^{ab}	44.0±9.1^{c}
Mean	11.7	34.0	82.1	49.3	48.5
LSD $_{(0.05)}$	1.01	3.99	12.20	4.20	6.05
CV (%)	5.9	8.8	11.4	6.5	9.5

PRT: Protein ratio (%), GLT: Wet gluten content (%), IND: Gluten index (%), HARD: Hardness, SED: Sedimentation value (ml).

There was a significant difference among cultivars for quality parameters except for grain hardness (Tables 2 and 4). The highest protein ratio (12.9%) and wet gluten content (37.0%) were determined for cultivars Aldane while the lowest was in cultivar Gelibolu. Four cultivars had a higher gluten index

except for cultivar Pehlivan. Sedimentation values in genotypes varied from a minimum of 41.7 ml (Pehlivan) to 60.9 ml in Aldane (Table 4).

In terms of grain yield, Gelibolu was the most stable, while Aldane was the most unstable varieties. It was determined that all cultivars were close to each other in terms of stability according to other parameters except gluten index. There were significant differences in the standard deviation according to the gluten index in the cultivars. It was determined that the minimum standard deviation was in Gelibolu (4.2) and the highest was in cultivar Pehlivan (20.0). While it was the most stable variety that was Gelibolu least affected by environmental conditions in grain yield, Aldane was the most stable variety that was least affected by environmental changes according to quality parameters investigated. According to the evaluation made in seven different environments, there was a highly significant difference among environments for grain and all other parameters. The minimum grain yield was 4454 in E6 and a maximum of 8158 in E4. This difference showed how important the effect of the environment on grain yield (Table 5). Except for the gluten index, no significant difference was observed in the standard deviation value in terms of environmental effect in other parameters. A very significant difference was observed in the standard deviation value in terms of environmental effect in the gluten index value. While the lowest standard deviation in gluten index value was determined in environment E4 (1.4), the highest standard deviation was in E6 (24.9). This result shows that among the quality parameters, the environmental effect is very important in the gluten index compared to other parameters.

Table 5. Mean performance and standard deviation for yield, quality and morphological parameters across environment

Environment	GY	TKW	TW	DH	PH
E1	6552±465^{b}	34.3±5.2^{c}	82.5±1.6^{bc}	131.2±3.3^{a}	117.8±8.1^{a}
E2	6967±912^{b}	46.4±3.8^{a}	85.2±0.8^{a}	121.6±2.6^{c}	91.6±5.7^{c}
E3	7272±357^{b}	44.2±2.6^{ab}	80.1±0.5^{d}	114.8±1.6^{d}	117.2±5.8^{a}
E4	8158±493^{a}	47.2±3.1^{a}	80.4±0.8^{d}	108.4±2.1^{e}	115.4±3.4^{a}
E5	6766±667^{b}	41.6±3.8^{b}	81.3±1.8^{cd}	123.2±2.6^{b}	92.4±4.6^{c}
E6	4454±648^{c}	36.5±2.6^{c}	83.7±0.8^{b}	103.4±3.5^{f}	100.4±3.4^{b}
E7	7029±414^{b}	45.4±4.5^{ab}	80.9±1.3^{d}	121.8±2.6^{bc}	98.0±7.0^{b}
Mean	67430	42.2	82.0	117.7	104.7
LSD $_{(0.05)}$	74.40	3.29	1.19	1.34	2.78
CV (%)	8.5	7.1	1.3	1.0	2.4

GY: Grain yield (kg ha^{-1}), TKW: 1000-kernel weight (g), TW: Test weight (kg), DH: Days of heading, PH: Plant height (cm).

Table 6. Mean performance and standard deviation for quality parameters across environment

Environment	PRT	GLT	IND	HARD	SED
E1	14.6±1.4^{a}	43.4±5.1^{a}	86.7±11.4^{ab}	54.6±1.1^{a}	64.8±10.1^{a}
E2	12.2±0.9^{b}	37.2±6.2^{b}	79.5±17.5^{bc}	51.6±2.7^{ab}	43.4±8.1^{bc}
E3	10.5±0.9^{de}	29.3±3.9^{de}	80.8±16.6^{bc}	47.0±3.5^{c}	42.6±10.8^{bc}
E4	9.6±1.2^{e}	25.4±6.7^{e}	93.3±1.4^{a}	45.8±1.6^{c}	40.0±7.3^{c}
E5	12.3±1.0^{b}	34.7±3.8^{bc}	87.2±14.4^{ab}	49.4±1.1^{bc}	59.8±6.1^{a}
E6	11.0±1.1^{cd}	31.5±3.7^{cd}	71.3±24.9^{c}	47.6±2.7^{bc}	40.6±10.3^{c}
E7	11.7±0.6^{bc}	36.7±3.9^{b}	75.9±19.7^{bc}	48.8±6.9^{bc}	48.6±7.6^{b}
Mean	11.7	34.0	82.1	49.3	48.5
LSD $_{(0.05)}$	0.84	3.37	10.30	3.54	5.10
CV (%)	5.9	8.8	11.4	6.5	9.5

PRT: Protein ratio (%), GLT: Wet gluten content (%), IND: Gluten index (%), HARD: Hardness, SED: Zeleny Sedimentation value (ml)

There were significant differences among environment based on 1000-kernel weight (TKW) and test weight (TW) ($p<0.01$). 1000-kernel weight ranged from 34.3 g in E1 to 47.2 g in E4 among environment and the mean value was 42.2 g across seven locations. Although the number of grain spikes in wheat has predominant importance over kernel weight with regard to grain yield, kernel weight is well documented to be a major yield component. The lowest standard deviation was determined at E3 and E6. Test weight of seven environments indicated that the highest TW was 85.2 kg in E2, whereas, the lowest test weight was determined in E3 (80.1 kg). Changes in environmental factors caused significant differences in plant height and day of the head. There was a significant difference between the environments according to the days to heading. The earliest days to heading was in environment E6 with 103.4 days, while the latest was in E1 with 131.2 days. Plant height can vary according to environmental and cultural factors such as precipitation and temperature, fertilization and planting frequency, as well as genetic factors. The shortest plant was measured in E2 at 91.6 cm and the tallest was 117.8 cm in environment E1 (Table 5). Protein quantity is influenced by environmental factors, while the quality of the protein is genetically determined. Protein ratio and wet gluten content are important quality parameters that are affected by environmental factors as well as genetic factors. There was a significant difference among environments for protein content. The maximum and lowest protein ratio varied from 9.6% in E4 to 14.6% in E1. In the study, wet gluten content ranged from the lowest 25.4% to the highest 43.4% in the environment. A very significant difference was observed in terms of environmental effect in the gluten index value. While the lowest index value was determined in E6 (71.3%), the highest was in E4 (93.3%). Zeleny sedimentation was another important quality parameter significant affected by environmental factors such as climate and agronomic practices. The lowest Zeleny sedimentation value was in E4 and E6, and the highest sedimentation was in E1 (64.8%) (Table 6).

Table 7. Estimates of stability parameters for yield and quality parameters of the genotypes across seven environments

	Grain yield (GY)					Test weight (TW)				
Cultivar	X	R^2	b	S^2d	a	X	R^2	b	S^2d	a
Aldane	6398	0.86	0.69	1541.6	172.5	81.6	0.61	0.84	2.38	13.00
Selimiye	6866	0.98	1.25	503.7	-154.5	82.7	0.82	1.03	1.23	-1.63
Bereket	6791	0.83	1.07	4575.2	-45.0	81.5	0.83	1.05	1.24	-4.58
Pehlivan	6571	0.89	1.14	3078.5	-110.9	82.6	0.91	1.03	0.54	-1.83
Gelibolu	7088	0.70	0.85	5943.5	137.9	81.7	0.80	1.06	1.53	-4.97
	Thousand kernel weight (TKW)					Protein ratio (PRT)				
Cultivar	X	R^2	b	S^2d	a	X	R^2	b	S^2d	a
Aldane	43.6	0.64	0.77	12.57	11.27	12.9	0.90	0.79	0.27	3.68
Selimiye	42.1	0.83	1.03	8.26	-1.33	12.0	0.89	1.15	0.62	-1.53
Bereket	39.7	0.81	0.69	4.29	10.72	11.3	0.97	1.29	0.19	-3.81
Pehlivan	45.8	0.84	1.04	7.58	2.06	11.4	0.72	0.49	0.36	5.71
Gelibolu	40.0	0.93	1.48	6.46	-22.71	11.0	0.96	1.28	0.27	-4.04
	Sedimentation value (SED)					Hardness (HARD)				
Cultivar	X	R^2	b	S^2d	a	X	R^2	b	S^2d	a
Aldane	60.9	0.88	0.69	9.67	27.49	47.0	0.35	1.10	30.07	-7.31
Selimiye	50.7	0.96	1.13	7.46	-3.98	50.7	0.76	0.92	3.52	5.60
Bereket	45.4	0.95	1.13	8.87	-9.29	48.4	0.84	1.04	2.81	-2.81
Pehlivan	41.7	0.63	0.73	46.61	6.21	50.6	0.78	0.87	2.81	7.95
Gelibolu	44.0	0.96	1.33	11.64	-20.43	49.6	0.41	1.08	22.78	-3.43
	Wet gluten content (GLT)					Gluten index (IND)				
Cultivar	X	R^2	b	S^2d	a	X	R^2	b	S^2d	a
Aldane	37.0	0.94	0.71	1.67	12.85	90.8	0.22	0.34	36.19	62.44
Selimiye	37.0	0.92	1.14	5.63	-1.73	82.8	0.43	0.74	60.01	21.95
Bereket	31.9	0.81	1.18	17.33	-8.10	87.1	0.44	0.94	95.82	9.55
Pehlivan	36.3	0.66	0.73	14.08	11.41	57.7	0.95	2.61	28.48	-156.81
Gelibolu	28.0	0.95	1.25	4.07	-14.43	92.2	0.41	0.36	15.19	62.87

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

In the breeding study genotype (G) environment (E) interaction is the main issue in improving high-yielding and stable genotypes across variable environments. The stability parameters of the parameters investigated are presented in Table 7. Based on grain yield, cultivars Gelibolu and Bereket were more stable than the other cultivars. For the test weight cultivar, Pehlivan showed good performance across seven environments. Cultivar Pehlivan had a higher mean test weight and determination coefficient

and, the lowest deviation from regression. It had also a suitable regression coefficient. Due to these characteristics, it has been the most stable variety for TW. According to all stability parameters except intercept value, Selimiye had a more stable cultivar for test weight than the other cultivars. Selimiye had a higher test weight (TW) and determination coefficient (R^2), optimum regression coefficient (b) value, and lowest deviation from regression (S^2d). Protein ratio and wet gluten content are essential quality parameters in bread wheat and Aldane was a very stable variety according to all stability parameters. For sedimentation value, cultivars Selimiye and Aldane were more stable according to all stability parameters. For grain hardness Cultivar Bereket is more stable than the other according to determination coefficient (R^2), optimum regression coefficient (b) value, and lowest deviation from regression (S^2d) (Table 7).

Correlation coefficients among investigated parameters were determined by Pearson's correlation analysis (Table 8). Analysis based on the mean data of the environment showed that the correlation coefficients between the parameters for grain yield and other parameters changed. Grain yield was positively correlated with 1000-kernel weight (r=0.717) and gluten index (r=0.723). Grain yield also positively correlated with plant height and days of heading. Grain yield was negatively correlated with test weight (r=-0.537), and slightly negatively correlated with protein ratio (r=-0.224). It was found highly positive relation between protein ratio with gluten value (r=0.976**), hardness (r=0.968**), sedimentation (r=0.862*), and days of heading (r=0.847*).

Table 8. Correlation coefficients among investigated parameters across seven environments

Parameter	GY	TKW	TW	PRT	GLT	IND	HARD	SED	DH
TKW	0.717								
TW	-0.537	-0.266							
PRT	-0.224	-0.622	0.392						
GLT	-0.230	-0.509	0.449	0.967**					
IND	0.723	0.198	-0.433	0.010	-0.157				
HARD	-0.143	-0.510	0.519	0.968**	0.952**	0.031			
SED	-0.015	-0.554	-0.043	0.862*	0.758*	0.322	0.743		
DH	0.273	-0.178	0.065	0.847*	0.842*	0.254	0.832*	0.834*	
PH	0.300	-0.196	-0.509	-0.092	-0.206	0.423	-0.083	0.014	-0.065

*, ** Significant at $p<0.05$ and $p<0.01$ respectively. GY: Grain yield (kg ha^{-1}), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Wet gluten content (%), IND: Gluten index (%), HARD: Hardness, SED: Sedimentation value (ml), DH: Days of heading, PH: Plant height (cm).

Correlation coefficients among investigated parameters for cultivars were determined and given in Table 9. Analysis based on the mean data of the genotypes showed that the correlation coefficients between the parameters for grain yield and other parameters varied. Grain yield was negatively correlated with 1000-kernel weight (r=-0.732), protein value (r=-0.729) and gluten value (r=0.759). 1000-kernel weight positively correlated with gluten value (r=0.752) and negatively correlated with gluten index (r=-0.766). Test weight and grain hardness were positively associated (r=0.836). Grain protein ratio was positively and significantly correlated with sedimentation value (r=0.952*). Due to the different effects of genotype and environment on yield and quality, different results were obtained in the investigated parameters. While grain yield was positively related to thousand-grain weight according to environmental factors, a negative correlation was determined according to genotypes.

Table 9. Correlation coefficients according to mean values in cultivars

Parameter	GY	TKW	TW	PRT	GLT	IND	HARD	SED	DH
TKW	-0.732								
TW	-0.011	0.580							
PRT	-0.729	0.404	-0.024						
GLT	-0.759	0.752	0.553	0.736					
IND	0.332	-0.766	-0.706	0.209	-0.439				
HARD	0.479	0.183	0.836	-0.546	0.016	-0.589			
SED	-0.555	0.132	-0.259	0.952*	0.504	0.495	-0.684		
DH	0.211	-0.012	0.325	-0.689	-0.102	-0.611	0.549	-0.816	
PH	-0.495	0.236	-0.083	-0.089	0.247	-0.485	-0.166	-0.233	0.658

*, ** Significant at $p<0.05$ and $p<0.01$ respectively. GY: Grain yield (kg ha^{-1}), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%), GLT: Wet gluten content (%), IND: Gluten index (%), HARD: Hardness, SED: Sedimentation (ml), DH: Days of heading, PH: Plant height (cm).

4. CONCLUSIONS

The objective of this study was to investigate yield and quality parameters of bread wheat genotypes and evaluate the relationship between environmental factors and wheat quality and thus accelerating the improvement of wheat quality. The results of variance analysis revealed significant differences among cultivars, environments and environments × cultivars interaction for yield. Due to the different effects of genotype and environment on yield and quality, different results were obtained in the investigated parameters. The lowest mean grain yield was in 2015-2016 (E6) cycle and the highest was in 2013-2014 (E4) growing cycle. The highest grain yield was performed by cultivar Gelibolu and the lowest by cultivar Aldane. Environment influenced the characters studied and very significant variation was found between environments. According to the environmental effect, the highest protein ratio, gluten value and sedimentation were determined in environment E1. The highest 1000-kernel weight was in E4 and the test weight was in E2. While the Selimiye variety was the most stable in terms of yield, 1000-kernel weight and sedimentation value, the Pehlivan variety was the most stable in terms of test weight.

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