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Comparison of Two and Six-rowed Barley (*Hordeum vulgare* L.) Genotypes under Rainfed Conditions for Yield, Quality and Biotic Stress Tolerance

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ABSTRACT

Barley is an essential crop in the Trakya region and it grows for feed and malting in the region. The experiments were carried out in the 2016-2017 growing cycle and composed of 36 two-rowed and 36 six-rowed barley genotypes in alpha-lattice blocks with three replications. The characters such as grain yield, net blotch, scald, plant height, days of heading, 1000-kernel weight (TKW), test weight (TW) and protein ratio and relationship among them were investigated in the study. The genotypes were screened for scald and net blotch under natural epidemic conditions. According to the results, there were significant differences among genotypes for the parameters investigated in the study. The means of grain yield for two-rowed and six-rowed genotypes were 8576 kg ha^{-1} and 8454 kg ha^{-1} respectively. In two-rowed genotypes mean 1000-kernel weight was 51.2 g, test weight 72.9 kg and protein ratio 11.6%. In six-rowed genotypes mean TKW was 37.0 g, TW 69.5 kg and protein ratio 10.8%. In two-rowed genotypes based on double-digit scores, a total of 11 barley genotypes highly tolerant to Net blotch (*Pyrenophora teres*) scored between 11 and 33. Net blotch effect on grain yield, 1000-kernel weight, test weight and protein ratio were slightly negative for two-rowed genotypes. Scald leaf disease negatively affected 1000-kernel weight (r=-0.391*) and test weight (r=-0.482**). Scald leaf disease also negatively affected grain yield. In the study, 5 genotypes from the 2-rowed experiments and 2 genotypes from a 6-rowed experiment were selected for breeding studies based on parameters investigated.

Keywords**:** Barley, genotype, grain yield, quality parameter, biotic stress

Introduction

Barley is the main field crop in the Trakya region of Turkey. Environmental effects such as temperature, humidity and rainfall cause biotic and abiotic stress factors and constraint yield and quality in barley (Öztürk et al., 2018). Barley genotypes are classified as 2-row or 6-row according to the structure of the spike and has been used as animal feed, as a source of fermentable material for beer and certain distilled beverages, and as a compound for a variety of health foods (Marwat et al., 2012). Since two-row barley produces larger seeds with a higher test weight and seed weight than six-row barley, two-row barley is very likely to produce more useful quality forage than six-row barley (Reid et al., 2001). Understanding the potential grain yield of the 2 and 6 rows and the ways to get their yield can be helpful to the plant breeder. Grain filling, the final process associated with yield performance, is a very important determinant of grain yield in cereals products. In addition, abiotic stresses such as, drought and high temperature during the grain-filling phase of barley limit barley productivity Gouis, 1992; Przulj and Momcilovic, 2012).

According to the spike morphology, the two and six-rowed genotypes of barley usually differ in their end-use. Six-row barley is mainly used as feed due to its higher grain protein content and less uniform grain size and weight compared to two-row barley (Kandic et al., 2019; Zwirek et al., 2019; Lang et al., 2013). Two-row barley is used more often as a malting material in brewing and produces higher malt extract than six-row barley (Gupta et al., 2010). The two-row barley genotypes generally had a higher absolute grain filling rate. Another benefit of two-row barley over six-row barley is the earliness. This is essential mechanism for the future climate scenario to avoid high temperatures and low rainfall during grain filling (Kandic et al., 2018). Grain yield and yield components in barley are complicated characters relying on a large number of genotypes, and environmental, agronomic and physiological characteristics. Based on the barley row type, there are various results concerning grain yield across stress environment conditions. Two-rowed barley genotypes generally had more 1000-kernel weight, test weight, protein ratio and grain uniformity than six-rowed genotypes under non-stress environment conditions. Another advantage of two-row barley over six-row barley is the earlier heading time. This is essential to avoid high temperatures and low precipitation during the grain-filling phase (Öztürk, 2019).

Due to changing environmental conditions, there are variations in yield, quality and leaf diseases depending on environmental factors in genotypes with 2 and 6 rows. In addition, biotic stress factors are also influential due to rainy and humidity conditions during the shooting and heading phase. Because of the favourable environmental factors such as precipitation and temperature, high yields can be obtained in barley in the region. However, the change between some years and locations may occur high infection of leaf disease and cause a decrease in yield. In addition, the low temperature of the booting and heading stages causes cold damage and sterility in the spike. For this reason, genotypic differences are also important for adapting to different environmental conditions in barley. The study aimed was to investigate and comparison of 2 and 6-rowed barley genotypes yield, quality and biotic stress factors such as scald and net blotch under rainfed conditions.

Materials and Methods

The study was carried out in the 2016-2017 growing season as two experiments that composed of 36 two-rowed and 36 six-rowed barley genotypes. Experiments were set up in alpha-lattice blocks design with three replications. Experiments were conducted in the Edirne location (latitude 41° 38′ 57″ N, longitude 26° 35′ 59″ E and altitude 41 m), Trakya region, Türkiye. The plot area was 6 m^{-2}, 6 meters long and 6 rows, spaced 0.17 meters apart. A seed rate of 500 seeds m^{-2} was used. In the study, grain yield (GY), plant height (PH), days of heading (DH), 1000-kernel weight (TKW), test weight (TW) and protein ratio (PRT) were investigated. Scald (*Rhynchosporium commune*) (RHY) and Net blotch (*Pyrenophora teres* f.sp. *teres*) (PYR) leaf diseases were screened under natural epidemic conditions at heading stages (Z75). Plots were naturally infected by *Pyrenophora teres* and *Rhynchosporium commune*. Disease assessments were made in Zadoks 75 growth stage of development (GS75) (Zadoks et al., 1974) using a 0-9 scale described by Saari and Prescott (1975) and Couture (1980).

Statistical Analyses

Data were analysed statistically for analysis of variance the method described by Gomez and Gomez (1984). The significance of differences among means was compared by using the Least Significant Difference (L.S.D. at a 5%). Pearson correlation coefficients were calculated between significant variables measured in this study and the results were plotted.

Cluster Analysis

Cluster analysis was performed on the barley genotypes using the seven measured parameters in clustering of the studied accessions (Chiu et al., 2001; Bacher et al., 2004). Hierarchical Cluster analysis with Ward's clustering method (Ward, 1963) based on Squared Euclidean Distances was performed to construct a cluster tree (Dendogram).

Temperature, monthly precipitation and mean humidity in 2016-2017 in the experimental area are given in Table 1. In the experimental area, the amount of precipitation was 417.2 mm less than a long year. The mean humidity was 71.2%. Rainfall in November and December was very low compared with the long year (Table 1).

Results and Discussion

According to the results, there were significant differences among genotypes for the parameters investigated in two-rowed genotypes. The mean grain yield in two-rowed genotypes was 8576 kg ha^{-1}. The highest grain yield was performed by G3 (9603 kg ha^{-1}) and followed by Yaba, G21 and G22. The minimum and maximum days of heading were 100 (G4) and 118 (G18 and G36). Plant height is an important component as it can cause lodging in rainy conditions and flat areas. In addition, tall varieties are preferred in arid regions. In the study, plant height varied from the shortest 85 cm (Yaba) to and tallest 109 cm (G25). In barley genotypes, TKW and TW vary according to genotype, environmental factors and cultural practices. Precipitation during the grain-filling period is the most important determining factor. In two-rowed genotypes mean 1000-kernel weight was 51.2 g and the test weight was 72.9 kg. Genotypes G17, G23 and G24 had the highest 1000-kernel weight. The highest test weight was determined in G14, G12 and G13. The ratio of protein is much related to the amount and time of nitrogen fertilization. Nitrogen fertilization, especially in the pre-heading period, contributes to the increase in protein in the grain. In the study, the mean protein ratio was 11.6%. The highest protein ratio was determined in G8 and G12 (12.8%) and the lowest in G33 (10.5%).

Net blotch caused by *Pyrenophora teres* f. sp. teres and scald caused by *Rhynchosporium commune* are major foliar diseases of barley and often epidemics occur in the same region. In two-rowed genotypes based on double-digit scores, a total of 11 barley genotypes highly tolerant to Net blotch (*Prenophora teres*) scored between 11 and 33. A total of 10 genotypes were susceptible to Net blotch leaf disease. It has been determined that *Prenophora teres* leaf disease generally causes moderate and low epidemics in genotypes.

Scald (*Rhynchosporium commune*) is one of the important biotic stress factors in barley. Scald leaf disease negatively affected 1000-kernel weight (r=-0.391*) and test weight (r=-0.482**). Scald leaf disease also negatively affected grain yield. In the study, 5 genotypes from the 2-rowed experiments and 2 genotypes from a 6-rowed experiment were selected for breeding studies. In 2-rowed genotypes, protein ratio was positively associated with plant height and 1000-kernel weight. Genotypes with short plant height had higher yield potential. Net blotch (*Pyrenophora teres*) is one of the essential biotic stress factors associated with precipitation and humidity during plant growth stages. Correlation coefficients among tested characters in two-rowed genotypes were given in Table 3. Net blotch negatively slightly affected grain yield, TKW, TW and protein ratio. There was also a negative association between grain yield with plant height (r=-0.410*), days of heading, TKW, and protein ratio (Table 3).

Correlation coefficients among tested characters in six-rowed genotypes were given in Table 5. Scald (*Rhynchosporium commune*) leaf disease is one of the important biotic stress factors in barley and reduces grain yield and quality. Scald leaf disease negatively significantly affected and reduced 1000-kernel weight (r=-0.391*) and test weight (r=-0.482**). Scald leaf disease also negatively affected grain yield. In the study in six-rowed genotypes, grain yield was negatively and significantly associated with days of heading (r=-0.500**), TKW (r=-0.458**) and protein ratio (r=-0.554**). There was also a positive association between grain yield and test weight (r=0.369*), 1000-kernel weight and protein ratio (r=0.569*) (Table 5).

The mean grain yield in six-rowed genotypes was 8454 kg ha^{-1}. Genotype G22 had a higher yield (10086 kg ha^{-1}) and followed by G24 (9864 kg ha^{-1}), G12 (9774 kg ha^{-1}), and G21 (9652 kg ha^{-1}). In barley, 6-rowed genotypes are more sensitive to drought and heat stress due to the high number of grains per spike. For this reason, the grain weight of barley is affected the most by drought and high temperatures. In the research, while the earliest genotypes were G23, G22 and G24, the latest variety was Lord. Plant height with stem strength is an essential characteristic for lodging resistance. In the study, the shortest plant was 82 cm (G15) and the tallest was 118 cm (G9). In six-rowed barley genotypes, while the average TKW was 37.0 g, the lowest was 28.6 g (cv. Yaprak) and the maximum was 45.3 g (G26). The mean test weight was 69.5 kg. Genotype Lord had the highest TW (73.6 kg) and G3 and G3 had the lowest 64.1 kg. The protein ratio in barley varies depending on genotype, environment and agronomic practices such as nitrogen amount and time. The mean protein ratio was 10.8%. The higher protein ratio was established in G11 and followed by cultivar Martı. While 2 barley genotypes were highly tolerant to scald leaf disease in 6-row genotypes, 22 barley genotypes were found to be very sensitive. In six-rowed genotypes, scald negatively slightly affected grain yield, and significantly negatively affected 1000-kernel weight and protein ratio.

Cluster analysis

Genotypes were classified according to cluster analysis in terms of the traits examined. (Figure 1). Based on cluster analyses there was a significant difference classified of the 2 and 6- rowed genotypes. The first and second clusters included 36 accessions composed of 2 and 6-rowed barley genotypes. While the 2-row genotypes showed a different distribution according to the cluster analysis, most genotypes were in 1 subgroup. The clustering analyses in six-rowed genotypes were divided into seven subclusters (Figure 1 and 2). Genotypes G19 and G29 were the closest to each other, while G1 and G36 were the most distant genotypes in terms of the traits examined in the two-row genotypes. G15 and G18 were the closest to each other in terms of the investigated characteristics in the six-row genotypes, while G1 and G23 were the most different genotypes.

Conclusions

These results showed that the two-row genotypes had better performance under rainy conditions in terms of yield and some quality parameters. As expected, grain yield, 1000 grain weight and test weight of the two-row barley genotypes were higher than those of the six-row barley genotypes. Unexpectedly, the fact that the protein ratio of the two-row genotypes was found to be higher than the six-row genotypes also means that they may be more suitable for use as feed. The fact that *Pyrenophora teres* disease for two-row genotypes and *Rhynchosporium secalis* leaf disease for 6-row genotypes were observed to cause more adverse effects with the effect of environmental factors confirms that the genotypic susceptibility factor is the determinant. These adverse effects were on grain yield, TKW, TW and protein ratio for two-row barley and grain yield for six-row barley. The 11 two-rowed barley genotypes and 2 six-rowed barley genotypes showed high tolerance to Net blotch (*Pyrenophora teres*) and scald leaf disease respectively. In the study, 5 2-rowed genotypes and 2 6-rowed genotypes were selected to use as a parent in breeding studies.

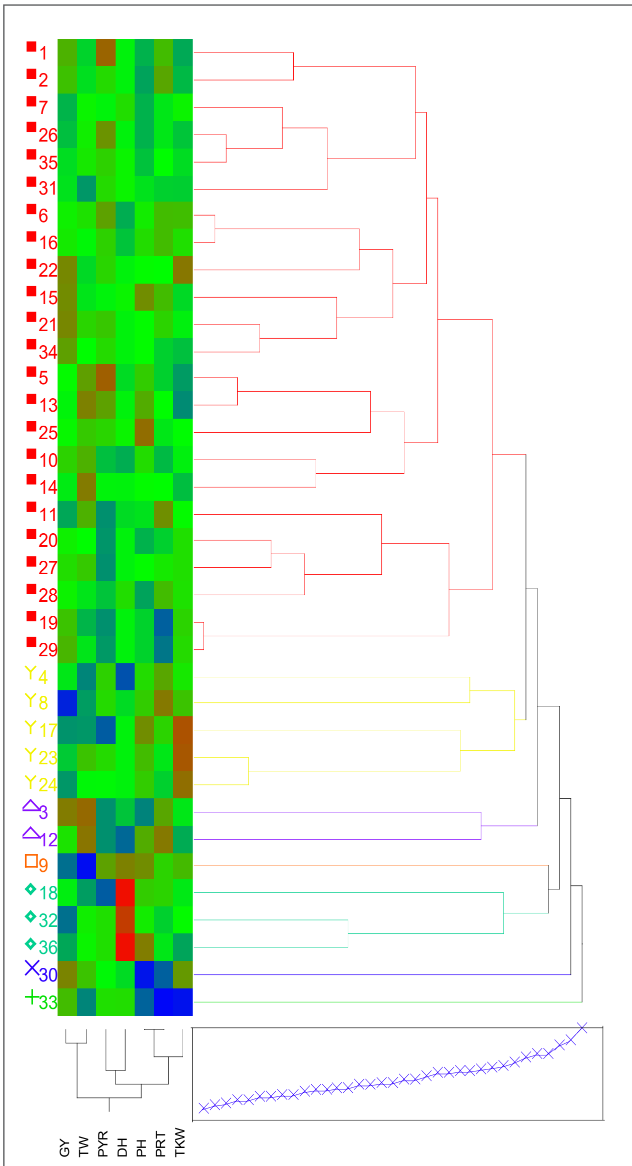

Figure 1. Dendrogram of 2-rowed 36 barley genotypes using the Hierarchical Ward's clustering method based on seven measured parameters.

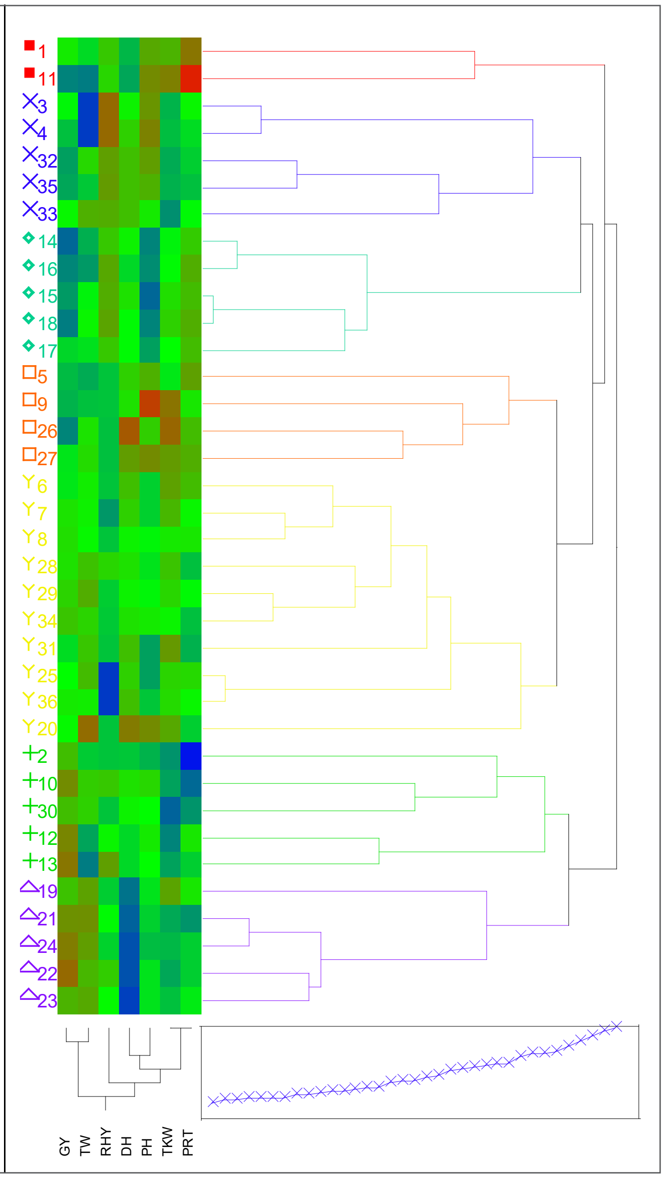

Figure 2. Dendrogram of 6-rowed 36 barley genotypes using the Hierarchical Ward's clustering method based on seven measured parameters.

Table 1. Rainfall, mean humidity and temperature in Edirne location in 2016-2017 growing year.

Months	Rainfall Long Year	Rainfall (mm)	Humidity (%)	Temperature (°C)		
				Min.	Max.	Mean
September 2016	34.0	9.2	57.5	5.0	33.8	20.8
October 2016	52.9	44.4	69.5	1.3	28.8	14.3
November 2016	72.4	3.2	72.9	-9.9	15.4	0.7
December 2016	61.7	3.2	72.9	-9.9	15.4	0.7
January 2017	48.1	67.8	83.7	-17.0	8.4	-1.9
February 2017	46.9	43.4	80.0	-8.4	20.6	5.3
March 2017	52.2	51.0	73.0	-1.9	25.5	10.2
April 2017	51.0	65.6	63.1	-1.6	28.6	12.5
May 2017	56.0	85.0	65.4	4.4	30.0	17.9
June 2017	41.5	44.4	74.4	12.9	40.0	21.2
Total/Mean	516.7	417.2	71.2	-17.0	40.0	10.2

Table 2. Mean grain yield quality and other parameters investigated in two-rowed barley genotypes in 2016-2017 cycles.

G No.	Genotypes	GY	PYR	DH	PH	TKW	TW	PRT
1	Sladoran (G1)	9175	78	107	95	47.5	72.2	11.9
2	G2	9059	53	107	94	48.2	72.4	12.0
3	G3	9603	22	105	92	50.2	75.4	12.0
4	G4	8391	55	100	102	52.2	70.9	12.0
5	Bolayır (G5)	8614	79	106	103	46.9	74.5	11.4
6	G6	8687	65	104	101	54.0	73.4	11.9
7	G7	7988	43	109	95	51.7	73.1	11.5
8	G8	6843	53	106	103	53.8	71.3	12.2
9	G9	7449	65	113	107	54.2	68.9	11.8
10	Harman (G10)	8924	32	104	102	50.6	74.2	11.3
11	G11	7889	22	106	98	51.4	74.2	12.1
12	G12	8789	22	101	105	47.6	75.2	12.2
13	G13	8491	65	107	105	46.2	75.0	11.6
14	G14	8426	43	107	100	48.4	75.1	11.6
15	Hasat (G15)	9479	43	108	107	49.6	72.5	11.9
16	G16	8740	55	105	102	52.6	72.8	11.9
17	G17	7729	11	107	107	58.7	71.2	11.8
18	G18	8446	11	118	103	50.3	71.3	11.8
19	G19	9041	22	107	97	53.1	71.7	10.9
20	Pınar (G20)	8688	23	107	95	52.6	72.9	11.4
21	G21	9517	57	107	100	50.6	73.6	11.8
22	G22	9508	54	107	100	57.1	72.3	11.6
23	G23	8162	53	107	104	58.5	73.9	11.5
24	G24	7760	44	107	103	57.5	72.8	11.4
25	G25	8633	54	108	109	51.1	73.8	11.5

Continuing table 2

G No.	Genotypes	GY	PYR	DH	PH	TKW	TW	PRT
26	G26	8077	68	107	95	48.7	73.2	11.5
27	G27	8843	22	107	100	52.6	73.8	11.7
28	G28	8677	33	109	94	52.5	72.5	11.9
29	G29	9148	24	107	97	52.8	72.5	11.0
30	Yaba (G30)	9535	44	106	85	55.6	73.9	10.9
31	G31	8353	53	108	98	49.1	71.2	11.4
32	G32	7457	52	116	101	51.4	73.2	11.4
33	G33	9096	52	109	90	40.9	70.9	10.5
34	G34	9316	53	107	100	48.5	72.9	11.4
35	G35	8313	55	108	96	49.7	73.3	11.6
36	G36	7886	52	118	108	47.3	73.1	11.5
	Mean	8576	45	108	100	51.2	72.9	11.6

GY: Grain yield (kg/ha^{-1}), PYR: Net blotch (0-99), DH: Days of heading, PH: Plant height (cm), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%).

Table 3. The correlation coefficient among parameters in 2-rowed barley genotypes.

Parameters	GY	PYR	DH	PH	TKW	TW
PYR	-0.072					
DH	-0.319	-0.024				
PH	-0.410*	0.066	0.164			
TKW	-0.232	-0.264	-0.107	0.159		
TW	0.278	-0.066	-0.299	-0.066	-0.172	
PRT	-0.217	-0.013	-0.192	0.364	0.134	0.076

*: P<0.05, **: P<0.01; GY: Grain yield (kg/ha^{-1}), PYR: Net blotch (00-99), DH: Days of heading, PH: Plant height (cm), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%).

Table 4. Mean grain yield quality and other parameters investigated in six-rowed barley genotypes in 2016-2017 cycles.

G No.	Genotypes	GY	RHY	DH	PH	TKW	TW	PRT
1	Martı (G1)	8669	78	104	107	41.1	68.5	11.8
2	G2	9161	53	105	90	31.2	68.1	9.2
3	G3	8371	99	109	109	33.0	64.1	10.9
4	G4	7768	99	111	111	33.5	64.1	10.6
5	G5	7717	53	111	106	35.8	67.2	11.5
6	G6	8200	53	112	93	42.1	70.0	11.3
7	G7	8752	43	111	93	40.9	69.9	10.9
8	G8	8807	53	109	97	38.2	69.7	11.0
9	G9	7634	53	110	118	44.5	67.8	11.0

Continuing table 4

G No.	Genotypes	GY	RHY	DH	PH	TKW	TW	PRT
10	Hazar (G10)	9701	78	110	102	32.0	70.9	9.8
11	G11	7107	75	103	110	43.9	65.9	12.4
12	G12	9774	68	106	100	30.4	67.0	11.0
13	G13	9944	87	106	98	32.0	65.9	10.5
14	G14	6798	78	109	85	36.4	67.3	11.2
15	G15	7361	84	110	82	38.8	69.2	11.3
16	G16	7136	85	106	86	36.8	66.7	11.4
17	G17	8010	78	108	88	37.0	68.7	11.3
18	G18	7043	86	108	85	39.5	69.8	11.4
19	G19	9110	55	100	95	41.9	72.1	11.0
20	Lord (G20)	8516	53	116	110	41.7	73.6	10.5
21	G21	9652	65	99	93	32.4	72.6	10.1
22	G22	10086	77	98	95	32.3	71.5	10.5
23	G23	9278	67	97	95	33.7	71.9	10.7
24	G24	9864	56	98	91	33.2	72.2	10.5
25	G25	8456	22	111	88	39.3	71.4	11.1
26	G26	7131	52	118	103	45.3	70.3	11.3
27	G27	8177	52	114	110	42.4	70.5	11.4
28	G28	8777	75	110	95	40.2	71.2	10.4
29	G29	8929	55	109	97	39.2	71.8	10.8
30	Yaprak (G30)	9156	53	109	98	28.6	70.8	10.1
31	G31	8073	53	112	88	42.5	71.1	10.3
32	G32	7416	87	112	108	32.5	70.6	10.5
33	G33	8531	84	112	100	31.0	71.7	10.8
34	G34	9079	54	110	100	37.6	70.7	10.4
35	G35	7489	88	112	106	32.8	68.0	10.4
36	G36	8673	22	112	92	39.0	70.0	10.9
	Mean	8454	66	108	98	37.0	69.5	10.8

*: P<0.05, **: P<0.01; GY: Grain yield (kg/ha^{-1}), RHY: Scald (00-99), DH: Days of heading, PH: Plant height (cm), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%).

Table 5. The correlation coefficient among parameters in 6-rowed barley genotypes.

Parameters	GY	RHY	DH	PH	TKW	TW
RHY	-0.210					
DH	-0.500**	-0.160				
PH	-0.060	0.142	0.251			
TKW	-0.458**	-0.391*	0.333*	0.081		
TW	0.369*	-0.482**	-0.071	-0.252	0.127	
PRT	-0.554**	0.043	0.073	0.093	0.569**	-0.304

*: P<0.05, **: P<0.01; GY: Grain yield (kg/ha^{-1}), PYR: Net blotch (00-99), DH: Days of heading, PH: Plant height (cm), TKW: 1000-kernel weight (g), TW: Test weight (kg), PRT: Protein ratio (%).

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