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Genetics and Breeding

Assessment of bread wheat (*Triticum aestivum* L.) genotypes based on their agronomic characters and tolerance to biotic stress

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Abstract. *The aim of the study was to investigate the occurrence and severity of biotic stress factors, quality and agronomic parameters and its effect on yield and quality character of wheat genotypes. The experiment was conducted at Trakia Agricultural Research Institute, Edirne experimental area, during 2013-2015 cropping years. Grain yield, days of heading, plant height, 1000-kernel weight, test weight, protein ratio, leaf rust, stripe rust, Septoria leaf spot and relationship among these parameters were investigated. Based on a two years data, apart from protein content, other parameters showed significant difference ($p<0.05$). When compared to the mean yields in both cropping years, the genotypes Gelibolu and BBVD-3, BBVD-4, BBVD-9 genotypes were determined the better-adapted genotypes under target environment. Cultivar Aldane and TCI011322-8 line was detected as very tolerant to leaf rust and stripe rust in both years under the infection of field condition. Aldane had higher protein ratio, 1000-kernel weight and test weight. Grain yield was positively correlated with test weight and negatively correlated with foliar diseases. A highly significant negative correlation was determined between grain yield and plant height in both growing years. Leaf rust and Septoria tritici leaf disease had negative effect on protein ratio in both years. There was a significant positive relation between 1000-kernel weight and test weight. Results of the study indicated that based on biotic stress factors BBVD-6, BBVD-7 and TCI011322-8 are promising lines that need to be improved a bit further.*

Keywords: bread wheat, genotypes, yield, agronomic characters, biotic stress

Abbreviations: GY - Grain yield (kg ha^{-1}), TKW - 1000-kernel weight (g), TW - Test weight (kg), PRT - Protein ratio (%), DH - Days of heading, PH - Plant height (cm), LR - Leaf rust, SR - Stripe rust, SEPT - *Septoria tritici* (0-99).

Introduction

Bread wheat (*Triticum aestivum* L.) is the most important and widely produced cereal crop throughout the Thrace region of Turkey. Although the amount of the rainfall (589.1mm) 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; 2018). Environmental factors influence yield production and quality. For example, foliar diseases are a significant risk factor, which influences the quantity and quality of grain production under target environment. Wheat is susceptible to many foliar diseases, particularly rusts (*Puccinia spp.*) and *Septoria* leaf blotches (Prescott et al., 1986). Annually, global yield losses due to wheat diseases in the field or in storage are estimated to be 20% (Bockus et al., 2010). Foliar pathogens affect leaf physiological activities. As a result of these yield may decrease by reducing net photosynthesis and altering the formation of any of the yield components, depending on the crop developmental stage at which infection occurs and on the duration and severity of the epidemic (Robert et al., 2004). Management of these diseases should be based on the use of resistant varieties. To develop higher yielding new varieties with disease resistance and end-use, quality is a major objective of wheat breeding programs under target environment (Budak et al., 2003). Grain yield is an important trait as it measures the economic productivity in wheat. However, it is a complex polygenic quantitative trait, hence, selection based on the performance of grain yield alone, is usually not very efficient. Thus, identifying characters contributing to grain yield is important as it increases breeding efficiency; therefore, easily measurable characters having useful relationship with grain yield are of paramount importance to practise indirect selection for high yield (Zarei et al., 2013). Several researchers have reported a positive and significant correlation between grain yield and plant height, number of grains per spike, and 1000-kernel weight (Bhutto et al., 2016). Although grain yield is one of the major determinants of a farmer's income, grain protein content as a quality trait is very important for bread-making quality. However, it is known that grain protein is negatively correlated with grain yield in wheat (Abdipour et al., 2016). In addition to all these, the climate of the target region has pivotal importance affecting selection criteria.

Keeping in view all these, this study was designed to assess: (i) the occurrence and severity of wheat diseases in the region of South-East Trakia; (ii) to determine the suitable selection criteria in bread wheat and the most promising cultivars appropriate for the conditions of that region; (iii) based on correlation analysis between/among some quality parameters, grain yields and biotic stresses under field conditions in Edirne.

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Material and methods

Experimental design

The experiment was conducted in Trakia Agricultural Researches Institute (TARI) in Edirne, Turkey, which is located in geographic latitude of 41°40' N and longitude of 26°34' S. The experiment was carried out during 2013-2014 and 2014-2015 growing seasons. Twenty-five winter wheat genotypes, developed through extensive wheat breeding program at TARI, were grown for two sequential years and 12 genotypes were selected for further experiments, which sustained under field condition with randomized complete block design with four replications. Each plot was 6m long and had 6 rows, spaced 0.17m apart. A seed rate of 500 seeds/m^2 was used. Grain yield, quality parameters and rust diseases were assessed under rainfed conditions. The climatic conditions during both growing seasons are given in Table 1. Thousand-kernel weight (TKW), test weight (TW), and protein content (PRT) were determined as previously described (Buckley et al., 1990; Peterson et al., 1998; Köksel et al., 2000; Pena, 2008). Assessments of diseases were performed from the middle of April to late June ranging from growth stage 30 to growth stage 60, according to Zadoks scale (Zadoks et al., 1974).

Table 1. Climate conditions during 2013-2014 and 2014-2015 growing years in Edirne region

Months	Rainfall (mm)		Mean temperature (°C)		Min. temperature (°C)		Max. temperature (°C)	
	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015	2013-2014	2014-2015
September	8.8	105.0	21.1	20.9	8.3	7.3	33.2	31.2
October	30.7	121.8	12.8	15.4	-1.6	2.9	26.8	28.6
November	73.9	43.2	11.0	9.3	-2.4	-2.7	23.4	19.1
December	2.3	111.3	2.7	6.6	-5.6	-3.7	12.1	16.3
January	74.9	42.2	5.5	3.8	-4.2	-11.0	17.3	17.1
February	3.8	68.6	7.6	6.4	-4.4	-5.0	20.2	17.7
March	124.5	67.8	10.1	9.0	-1.4	-0.7	23.7	19.9
April	36.8	44.4	13.6	13.1	-0.1	0.2	25.5	25.7
May	61.7	45.2	18.6	20.4	4.0	10.3	32.1	33.3
June	68.8	31.0	22.9	22.5	10.3	12.1	33.6	35.3
Total/mean	486.2	680.5	12.6	12.7	0.3	1.0	24.8	24.4

Visual assessment of disease severity

Foliar disease assessments were made at growth stage (GS) GS60 in each cropping season. Incidence was calculated by using the number of plants infected and expressed as percentage of the total number of plants assessed. Severity was scored visually using the modified Cobb's scale (Peterson et al., 1948) for rusts, and the double-digit scale (00-99) for Septoria leaf blotch (Eyal et al., 1984).

Statistical analysis

To evaluate significant differences between genotypes, the analysis of variance (ANOVA) was performed. The differences between genotype means of parameters were tested by the L.S.D (0.05) test. Letter groupings were generated by using a 5% level of significance. Data were analyzed statistically for analysis of variance by the method described by Gomez and Gomez (1984). The significance of differences among means was compared by using L.S.D test (Kalaycı, 2005).

Results and discussion

To define effective selection, criteria for identifying the better-adapted genotype(s) under target environment are required. In this study, we have assessed the occurrence and severity of wheat diseases in South-East Trakia region and determined both the suitable selection criteria in bread wheat to implement breeding programs and the most promising cultivars appropriate for the environmental conditions of that region based on correlation analysis between/among some quality parameters, grain yields and biotic stresses under rainfed conditions in Edirne.

Agronomic parameters

Wheat yield potential in the target region changed due to varying rainfall conditions in two years. The results of the experiment showed statistical difference between genotypes based on grain yield (Table 2). According to the acceptance of farmers, grain yield is a measure of the economic productivity in wheat (Zarei et al., 2013). The highest grain yields were determined in TCI011322-8 line with 8991 kg ha^{-1} in 2013-2014 and in TE5793-2 line with 8267 kg ha^{-1} in 2014-2015 growing year, respectively. On the other hand; based on mean yield, Gelibolu was the highest yielding cultivar with 8351 kg ha^{-1} and the mean yield of the genotypes was 7811 kg ha^{-1} (Table 2).

Rainfall data given in Table 1 showed that the rainfall fluctuation was variable in the monitored region. According to these results, the line of TCI011322-8 gave the highest grain yield under low rainfall condition, while the line of TE5793-2 gave the highest grain yield under higher rainfall condition. When comparing both cropping years, the highest loss of yield was observed in TCI011322-8 with a ratio of 23% and it was followed by Selimiye (22.61%) and Pehlivan (20.46%), respectively. As known, stability of grain yield and quality traits through locations and years are im-

Table 2. Mean value of grain yield of the genotypes in 2013-2014 and 2014-2015 growing years

Entry No	Genotypes	Years		Mean
		2013-2014	2014-2015	(kg ha^{-1})
1	Aldane	7601^{e}	6583^{c}	7092^{cd}
2	TE5793-2	7709de	8267^{a}	7988^{ab}
3	TE6217-3	8694^{abc}	7823^{ab}	8259^{ab}
4	BBVD-4	8159^{a-e}	8238^{a}	8198^{ab}
5	Selimiye	8560^{a-d}	6625^{c}	7593^{bcd}
6	BBVD-6	7543^{e}	7976^{ab}	7759^{abc}
7	BBVD-7	8242^{a-e}	7885^{ab}	8064^{ab}
8	TCI011322-8	8991^{a}	6923^{bc}	7957^{ab}
9	BBVD-9	8378^{a-e}	8012^{a}	8195^{ab}
10	Bereket	7816^{cde}	6289^{c}	7052^{d}
11	Pehlivan	8045^{b-e}	6399^{c}	7222^{cd}
12	Gelibolu	8768^{ab}	7934^{ab}	8351^{a}
	Mean (kg ha^{-1})	8209	7413	7811
	LSD (0.05)	92.8	105.1	68.7
	CV (%)	7.8	9.5	8.8
	F value	2.22*	4.46**	3.65**
	P value	p=0.030	p=0.0004	p=0.0005

Note: Significance at *p<0.05, **p<0.01; CV- Coefficient of variation; Letter groupings were generated by using a 5% level of significance and letters indicate statistical significance.

portant (Tayyar, 2008). If the rainfall fluctuation in this region was taken into consideration, the lines of BBVD-7, BBVD-9, BBVD-4 and BBVD-6 were determined as the better-adapted cultivars with the loss/increase of yield approximately between 4% and 6% under target environment comparing both cropping years. Earliness is one of the important traits in wheat in the investigated region because rainfall fluctuation causes lowering yield and grain quality in the production area. There was statistical difference among genotypes for earliness and Aldane, TCI011322-8 and BBVD-6 were early genotypes in the research (Table 3).

Susceptibility of the lodging in genotypes for cereal production is one of the priority problems in Trakia region. Stem structure and short plant together with root disease are the crucial issues for lodging resistance in wheat. Plant height is a very important trait to evaluate genotypes especially for lodging resistance, as well. In our study, plant height ranged from 90.5cm up to 108.5cm and the mean was 100.6cm. The lowest plant height was determined in TE6217-3 and BBVD4 genotypes. 1000-kernel weight and test weight of all genotypes were significantly varied (p<0.05) between the two growing years (Table 3).

Table 3. Mean value of the genotypes related with agronomic and quality parameters

Entry No.	Genotypes	DH	PH	TKW	TW	PRT
1	Aldane	114.0^{c}	100.0^{bc}	46.5^{a}	80.8^{a-d}	12.5^{a}
2	TE5793-2	119.0^{ab}	101.0^{bc}	39.7^{abc}	77.9^{de}	11.1^{a-e}
3	TE6217-3	116.0^{bc}	90.5^{e}	42.7^{ab}	82.0^{ab}	11.4^{a-d}
4	BBVD-4	119.0^{ab}	93.0^{de}	41.2^{ab}	80.9^{a-d}	11.7^{abc}
5	Selimiye	117.0^{abc}	100.0^{bc}	46.1^{ab}	82.6^{a}	10.9^{b-e}
6	BBVD-6	114.5^{c}	99.0^{cd}	38.7^{bc}	80.3^{a-d}	11.5^{a-d}
7	BBVD-7	119.5^{a}	103.5^{abc}	43.3^{ab}	81.9^{ab}	10.8^{b-e}
8	TCI011322-8	114.5^{c}	102.0^{bc}	32.4^{c}	76.8^{e}	11.9^{ab}
9	BBVD-9	119.0^{ab}	100.0^{bc}	38.9^{bc}	78.7^{cde}	10.2^{de}
10	Bereket	115.5^{c}	108.5^{a}	39.7^{abc}	79.3^{b-e}	10.4^{cde}
11	Pehlivan	117.0^{abc}	105.5^{ab}	46.8^{a}	81.4^{abc}	11.1^{a-e}
12	Gelibolu	115.0^{c}	104.0^{abc}	43.2^{ab}	80.4^{a-d}	9.8^{e}
	Mean	116.7	100.6	41.6	80.2	11.1
	LSD (0.05)	1.2	2.8	8.1	1.8	5.8
	CV (%)	3.1	6.3	7.5	3.2	1.4
	F value	4.15*	5.95**	2.95*	2.94*	2.64ns
	P value	0.013	0.003	0.043	0.043	0.060

Note: Significance at *p<0.05, **p<0.01, ns- non-significant; CV- Coefficient of variation, TKW- 1000-kernel weight (g), TW- Test weight (kg), PRT- Protein ratio (%), DH- Days of heading, PH- Plant height (cm); Letter groupings were generated by using a 5% level of significance and letters indicate statistical significance.

These results revealed that the variation of both environment and the two growing years could contribute to the differences of wheat grain weight among genotypes. In addition, the interaction between wheat genotypes and growing environment was also significant for both traits. 1000-kernel weight ranged from 32.4 to 46.8g among genotypes and the mean value was 41.6g. Aldane cultivar had the highest 1000-kernel weight and was followed by Selimiye. There were significant differences among genotypes based on test weight. Test weight (TW) varied in genotypes from 76.8kg to 82.6kg and the mean value of the test weight was 80.2kg. Selimiye had the highest test weight (Table 3). Protein quality and quantity are the most important components of wheat grain governing end-use quality (Pena, 2008; Niu et al., 2010). However, environmental factors, such as rainfall and temperature during the period of grain filling influence protein content. Table 3 shows mean and range of variations for protein ratio in all genotypes evaluated across two years and protein ratio varied from 9.8% to 12.5% in the genotypes. The highest protein ratio was determined in Aldane cultivar.

Foliar disease assessment

Wheat leaf rust is the most destructive and widespread disease in South-East Trakia region and susceptible cultivars leading to serious yield losses. Foliar disease assessments were made each growing season at GS60 (heading stage). All evaluated data for all diseases are provided in Table 4.

Table 4. Mean value of the genotypes related with disease incidence

Entry No.	Genotypes	Leaf rust		Stripe rust		*Septoria tritici (0-99)*	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
1	Aldane	TR	TR	5R	0	53	22
2	TE5793-2	10MR	60S	10MR	TR	99	44
3	TE6217-3	5R	10MR	TR	0	78	55
4	BBVD-4	TR	10MR	10MR	TR	55	56
5	Selimiye	10MS	60S	10MR	TR	66	44
6	BBVD-6	TR	TR	10MR	0	45	44
7	BBVD-7	0	0	20MR	10MR	55	66
8	TCI011322-8	0	TR	0	0	0	55
9	BBVD-9	40S	20S	0	0	33	45
10	Bereket	60S	100S	100S	100S	45	35
11	Pehlivan	40S	80S	10MR	0	89	45
12	Gelibolu	40S	60S	10MR	0	44	56

Note: TR- Trace, MR- Medium resistance, MS- Medium susceptible, S- Susceptible, R- Resistant, *Septoria tritici* (0-99): 0- Resistant, 99– Susceptible.

Due to suitable environmental conditions disease severities on susceptible varieties reached 100% in leaf rust and 99 in *Septoria tritici,* respectively. There were differences between growing years because of fluctuation in rainfall conditions in the point of leaf rust *(Puccinia recondita)* infection. A high incidence and severity of wheat leaf rust occurred in 2014-2015 growing season. Aldane, BBVD-6, BBVD-7 and TCI011322-8 genotypes were found tolerant or resistant to leaf rust under field conditions throughout two years. There was generally observed low or moderate incidence of stripe rust. Except Bereket cultivar, all other genotypes were detected tolerant to stripe rust in both growing cycles under rainfed condition. Bereket was observed as the most susceptible cultivar to both rust diseases. This result is in agreement with the fact that Bereket cultivar gave the lowest grain yield in the 2014-2015 year among the genotypes. The severity of *Septoria tritici* infection was detected almost the same during both growing years.

Correlation analysis

Correlation coefficients based on the investigated parameters were determined by Pearson's correlation analysis. Correlation coefficient analysis among the tested characters in all genotypes was done in both growing years (Tables 5 and 6). A negative correlation between grain yield (GY) and leaf rust (LR), and stripe rust (SR) in both growing years was confirmed with a loss of grain yield about 9.7% in 2014-2015 seasons, although it was quite rainy (Tables 1 and 2). This supports the view that the incidence of foliar diseases in plants increases under favourable environments such as wet conditions. Grain yield was positively slightly correlated with test weight and thousand-kernel weight in both years. Grain yield is one of the primary determinants of a farmer's income (Abdipour et al., 2016). Thus, for a trait to be considered a selection criterion in plant breeding, it must be contributed in grain yield directly or indirectly (Zarei et al., 2013). Leilah and Al-Khateeb (2005) and Mohammadi et al. (2012) reported that the positive correlation between grain yield and 1000-kernel weight, and test weight, respectively. A significant positive correlation was also determined between test weight and thousand-kernel weight in both growing years (r= 0.599*; r= 0.918**), which are known mainly as quality factors by the milling industry (Boz et al., 2012). Plant height is a major agronomic metric in wheat breeding because of its association with lodging, seedling growth capacity, and weed control. Highly significant negative correlation between grain yield and plant height was found in 2014-2015 (r= -0.777**) growing year. The slightly negative association between plant height and net blotch leaf diseases was revealed in this study (Tables 5 and 6).

Grain protein content is among the key determinants affecting both end use and market value in wheat. However, it

was reported that grain protein is negatively correlated with quality parameters (Abdipour et al., 2016). This result was confirmed in our study. The negative correlation between foliar diseases and grain protein rate was detected in the presented study and the rate of the obtained negative correlation has been determined to increase in proportion to the severity of diseases (Tables 5 and 6). These results indicate that, the rate of photosynthesis decreases depending on the severity of the foliar diseases, as a result of this the quality parameters, such as grain protein content, are negatively affected. A highly significant negative correlation was found between protein content and leaf rust in 2013-2014 (r= -0.746**) and a moderate correlation was found in 2014-2015 (r= -0.554) growing years.

Table 5. Correlation coefficients among tested characters in 2013-2014 growing year

Traits	GY	LR	SR	SEPT	DH	PH	TKW	TW
LR	-0.457							
SR	-0.472	0.595*						
SEPT	-0.081	0.010	-0.043					
DH	-0.012	0.107	0.082	0.405				
PH	-0.553	0.666*	0.531	-0.218	-0.075			
TKW	0.082	0.278	0.043	0.274	-0.128	0.338		
TW	0.496	-0.043	0.084	0.048	-0.192	0.092	0.599*	
PRT	0.038	-0.746**	-0.375	0.236	-0.250	-0.452	-0.217	-0.104

Note: Significance at *p<0.05, **p<0.01; GY- Grain yield (kg ha^{-1}), TKW- 1000-kernel weight (g), TW- Test weight (kg), PRT- Protein ratio (%), DH- Days of heading, PH- Plant height (cm), LR- Leaf rust, SR- Stripe rust, SEPT- *Septoria tritici* (0-99).

Table 6. Correlation coefficients among tested characters in 2014-2015 growing year

Traits	GY	LR	SEPT	SR	DH	PH	TKW	TW
LR	-0.546							
SEPT	0.631*	-0.257						
SR	-0.459	0.558	-0.286					
DH	0.523	-0.004	0.498	-0.281				
PH	-0.271	0.512	- 0.145	0.461	-0.322			
TKW	0.107	0.186	-0.061	-0.250	0.267	-0.194		
TW	0.102	0.021	0.032	-0.250	0.350	-0.482	0.918**	
PRT	-0.255	-0.554	-0.324	-0.110	-0.336	-0.278	-0.298	-0.149

Note: Significance at *p<0.05, **p<0.01; GY- Grain yield (kg ha^{-1}), TKW- 1000-kernel weight (g), TW- Test weight (kg), PRT- Protein ratio (%), DH- Days of heading, PH- Plant height (cm), LR- Leaf rust, SR- Stripe rust, SEPT- *Septoria tritici* (0-99).

Environmental factors play a main role in the expression of genotype characteristics (Peterson et al., 1998). In accordance with this view; grain yield, leaf diseases and other investigated parameters were found to be affected by rainfall fluctuations during both growing years. For example, the highest significant association was measured between test weight and 1000-kernel weight in 2014-2015 growing year. On the other hand, negative association was detected between grain yield and leaf rust, grain yield and lodging resistance, and protein content and leaf rust. Blakeney et al. (2009) reported that protein content in mature grain was largely affected by both environment and farm management factors and agronomic practices.

Conclusion

The ideal cultivar for high grain yields and quality should express its genetic potential in different environmental factors during its growing. The results of the presented experiment showed that there was statistical difference among genotypes based on yield under two different environment conditions in Edirne region. Based on two years' data, apart from grain protein content, other traits examined showed significant difference. When compared to the mean yields in both cropping years, Gelibolu and BBVD-3, BBVD-4, BBVD-9 were determined the better-adapted cultivars under target environment. Cultivar Aldane and TCI011322-8 line were detected very tolerant to leaf rust and stripe rust in both years under the infection of field conditions. Aldane, BBVD-6, BBVD-7 and TCI011322-8 were found tolerant to leaf rust and genotypes Aldane, TE6217-3, TCI011322-8 and BBVD-9 were tolerant to stripe rust under rainfed conditions in both growing years. The highest protein ratio was determined in Aldane cultivar. Grain yield was positively correlated with 1000-kernel weight and negatively correlated with foliar diseases. A highly significant negative correlation was determined between grain yield and plant height in both growing years. Leaf rust was negatively correlated with protein ratio in both years. Results indicated that Gelibolu is a promising line for yield potential, Aldane for the quality and leaf disease and TCI011322 for all leaf diseases that needs to be improved a bit further.

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