ENVIRONMENTAL EFFECT ON BIOTIC STRESS AND RESPONSE OF BREAD WHEAT (*Triticum aestivum* L.) GENOTYPES UNDER RAINFED CONDITION

İrfan Öztürk[1], Banu Tülek[1], Adnan Tülek[1], Kadir Akan[2], Remzi Avci[1]

[1]Trakia Agriculture Research Institute, Edirne, Turkey

[2]Ahi Evran University, Faculty of Agriculture, Department of Plant Protection, Kırşehir, Turkey

Abstract

Wheat is one of the most important crops in the world with the largest production of any crop owing to its ability to adapt to environmental conditions. Bread wheat, a major cereal crop, is subject to several biotic stresses. These stresses affect the crop's yield, quality and yield components. Different mechanisms have been adopted by plants to counter the wide range of biotic and abiotic stresses faced. Leaf rust (Puccinia triticina), stripe rust (Puccinia striiformis f. sp. tritici), septoria leaf blotch (Septoria tritici), and powdery mildew (Blumeria graminis f. sp. tritici) are mainly and widespread imported diseases of wheat in the Trakia region, Turkey. This research was established with 25 genotypes in RCBD with 4 replications, and four environments in the Trakia region, in the 2017-2018 growing seasons. According to the result, there were significant differences among genotypes for yield and biotic stress factors. The mean yield of the genotypes was 6161 kg ha^{-1}, the highest yield was determined in G21 (6807 kg ha^{-1}) and Köprü (6776 kg ha^{-1}). The lowest infection was observed in the Keşan location. G9 highly was tolerant or highly resistant to leaf rust across four environments. Genotypes G17, G19, and G24 were highly tolerant to LR showed 0-TR reaction across four environments. It was no observed any stripe rust infection in ten genotypes, and six genotypes showed a 0-TR reaction. Because of the lowest infection, there was almost no negative association between grain yield and leaf rust in Edirne and Keşan location but in Tekirdağ and in Lüleburgaz location there was a slightly negative relationship between grain yield and leaf rust. Stripe rust infection was low due to unfavourable environmental conditions and it was not observed in ten genotypes. G7 was tolerant to septoria leaf blotch and four genotypes (G7, G18, G19 and G25) were highly tolerant to powdery mildew across four environments under rainfed conditions.

Key words: *Bread wheat, genotypes, environment effect, biotic stress, grain yield*

1. INTRODUCTION

Biotic stresses of significance vary according to location and our major ones are the three rusts, karnal bunt with upcoming concern prevailing for powdery mildew, barley yellow dwarf and the new emergence of spot blotch (Mujeeb-Kazi et al. 2008). Rusts have remained very dynamic pathogens that have consistently existed as a major wheat-breeding objective globally. Currently, major attention is given to stem rust and yellow rust is a close second that should not be a reason to look at leaf rust with complacency. (McIntosh et al. 2003). Leaf rust (caused by *Puccinia triticina*) and yellow rust (caused by *Puccinia striformis*) however have the potential to affect production levels up to 60 and 43 million hectares respectively in Asia if susceptible cultivars were grown (Singh et al. 2004). Though fungicidal applications offer control their use is an added cost to farmers besides being unsafe environmentally. Hence growing resistant cultivars is the most effective and efficient control strategy (Rizwan et al. 2008). Wheat plants are suffering from many destructive diseases. Rusts are the most important diseases of wheat because of their ability to move for a long distance and their ability to form new virulent races causing serious losses (Yahyaoui et al., 2004). Leaf rust caused by Puccinia triticina is one of the most important and widespread diseases of common wheat (*Triticum aestivum* L.) worldwide. It is adapted to a wide range of environments that occurs wherever wheat is grown and can cause significant yield and economic losses (Wamishe and Milus, 2004). Susceptible wheat cultivars to leaf rust suffer from yield reductions between 5 to 60% (Smith, Lauren, 2008). The pathogen interferes with wheat plants at all developmental stages and serious yield losses of up to

62.7% have been reported in susceptible cultivars (Singh et al. 1998). Early infection of leaf rust usually causes higher yield losses of 60-70% depending on the susceptibility of the wheat varieties and the severity of epidemics (Appel et al., 2009). The disease can develop rapidly when free moisture is available and temperatures are near 20°C (Duveiller et al., 2012). Fungicides and different cultural practices can be used to reduce yield losses. However, the development of resistant cultivars is the most efficient, sustainable, and economic method to prevent leaf rust epidemics (Naz et al., 2008).

Stripe rust (yellow rust), caused by Puccinia striiformis f. sp. tritici, is an important foliar disease of wheat. It occurs in wheat-growing areas of temperate, moist and cool regions in all continents except Antarctica (Chen 2005). Its wider prevalence is a global threat to wheat production inflicting about 30–100% grain losses besides affecting the quality of grain and forage (Chen 2005). Septoria leaf blotch (*Bipolaris sorokiniana*) limits wheat production in high rainfall areas across 10.4×106 hectares globally. Disease scoring is of a double-digit scale from 1-1 (resistant) to 9-9 (susceptible) and recorded over the three-grain development stages (watery, milky, and doughy) (Mujeeb-Kazi et al. 2000, 2001a). Resistances to septaria tritici blotch and septaria nodarum blotch appear to be more widely distributed among bread wheat (*Triticum aestivum*) cultivars with winter growth habits than among those with spring growth habits. Resistance has also been reported in several wild relatives of wheat (Brokenshire 1975; Williams and Jones, 1973; Wilson 1985). Symptoms vary according to cultivar, cultural practices, and geographic location (Cooke and Jones, 1970). Under Mediterranean conditions, where spring wheat is grown during the cool and rainy winter months (November May) of the year, S. tritici is most important. There are a limited number of resistant varieties available and new pathotypes that overcome the most widely deployed genes have arisen. Due to stripe rust grain yield losses of 10 to 70% have been reported depending upon the cultivar grown and the environmental conditions (Safar, 2015).

Wheat powdery mildew, caused by *Blumeria graminis* (DC.) (*Erysiphe graminis)*, is one of the most devastating diseases of common wheat that occurs in many areas, including China, Germany, Japan, Russia, United Kingdom, South and West Asia, North and East Africa, and the Southeastern United States. Yield losses range from 13-34% due to this disease (Griffey et al. 1993). The visual appearance of powdery mildew usually outweighs its damage potential, especially during autumn and winter. In very susceptible varieties, yield losses can be high (up to 20%) and early control can be very important. However, the disease generally causes much smaller yield losses (rarely exceeding 10%).

Biotic stress factors such as leaf rust, stripe rust, septoria leaf blotch, and powdery mildew are mainly biotic stress factors affecting wheat yield production in the Trakia region, Turkey. Environmental conditions are very important in these factors in the severity of infection. Genetic factor is also effective in infection level of time. Therefore; the objectives of the study was to determine and compare the effect of the biotic stress factors on yield in bread wheat genotypes under various environmental conditions. Also, some biotic stress factors and the relationship between these characters were investigated under rainfed conditions.

2. MATERIAL AND METHODS

The experiment was conducted in the 2017-2018 cycle in the Trakai region, Turkey, at four locations (Edirne, Burgaz, Tekirdağ and Keşan). Two locations are located in the coastal area in the region. Twenty-five winter wheat advanced genotypes were examined under rainfed conditions with randomized complete block design (RCBD) with four replications. Five local checks which are Pehlivan, Selimiye, Gelibolu, Saban and Köprü were tested in the experiment to compare with advanced lines. In the experiment, each plot was 6 meters long and had 6 rows, spaced 0.17 meters apart. Using a plot drill performed sowing and 500 seeds per square meter were used. Sowings were performed by using a plot drill in October and in November, and nitrogen was applied three times, and for weed, a chemical was used.

Data on grain yield and, leaf rust (*Puccinia triticina*), stripe rust (*Puccinia striiformis* f. sp. tritici), septoria leaf blotch (*Septoria tritici*), and powdery mildew (*Blumeria graminis* f. sp. tritici) was taken at heading stages (Z55).

Twenty-five advanced genotypes, evaluated under the rainfed condition and reaction types and levels scored using the Modified Cobb scale. Rusts severity is recorded as a percentage, according to the modified Cobb scale (Prescott et al., 1986). This recording process relies upon visual observations, and it is common to use the following intervals: Trace / 5 / 10 / 20 / 40 / 60 / 100 percent infection. This recording process relies upon visual observations at Z55 (heading stage) (Peterson et. al., 1948; Roelfs et al., 1992; Saari and Prescott, 1975; Stubbs et al., 1986; Prescott et al., 1986).

Septoria leaf blotch scored with a double-digit 00-99 scale. Double-digit (00-99) scale representing the vertical disease progress (first digit) and severity estimate (second digit) (Eyal et al., 1987). Powdery mildew disease evaluation was made based on a double-digit (00-99) scale (Saari-Prescott 0-9 scale, double-digit 00-99 scale).

Table 1. Rainfall, humidity and mean temperature scored across four locations in 2017-2018

Months	Edirne location			Keşan location			Tekirdağ location			Burgaz location		
	RF	RH	MT	RF	RH	MT	RF	RH	MT	RF	RH	MT
October 2017	135.2	77	13.6	98.3	71	14.1	111.2	77	14.9	9.6	75	13.8
November 2017	71.6	75	9.5	63.7	65	10.5	85.2	83	11.7	5.8	88	9.7
December 2017	119.6	85	7.4	95.1	64	9.8	94.8	80	9.5	32.6	88	7.8
January 2018	55.6	88	4.3	103.2	68	5.9	76.5	85	6.6	72.0	92	4.7
February 2018	101.8	89	5.7	143.3	67	6.8	95.3	86	7.2	52.8	93	5.9
March 2018	145.6	88	8.9	112.5	68	11.4	63.7	86	10.2	30.0	91	9.2
April 2018	3.0	61	16.6	6.4	80	15.9	10.6	76	14.0	2.8	73	14.8
May 2018	18.8	64	20.3	17.3	74	20.2	19.3	77	19.1	22.0	77	18.8
June 2018	148.4	66	22.6	49.2	65	23.2	75.4	73	22.4	16.6	74	22.1
Total/Mean	799.6	77	12.1	689.0	69	13.1	632.0	80	12.8	244.2	83	11.9

RF: Rainfall (mm), RH: Relative humidity (%), MT: Mean temperature (^{o}C)

Statistical analysis

The statistical analyses of measurement data were performed by using a statistics program and the differences among the means were compared with L.S.D at a 5% significant level (Kalaycı, 2005). To evaluate significant differences between genotypes, the analysis of variance (ANOVA) was performed. Letter groupings were generated by using a 5% level of significance. Data were analyzed statistically for analysis of variance in the method described by Gomez and Gomez (1984). The regression equations were calculated according to Finlay and Wilkinson (1963), and Eberhart and Russell (1969). Regression graphs were used to predict the adaptability of genotypes. 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.

3. RESULTS AND DISCUSSION

Leaf rust (*Puccinia triticina*) is a vital disease that causes significant yield losses in wheat production. Infection severity of biotic stress factor also changes due to changing environmental conditions such as rainfall, temperature, and humidity. The infection and severity of the biotic stress factor can cause

and reduce the various levels of yield and quality in bread wheat. Leaf rust, caused by *Puccinia triticina* and stripe rust caused by *(Puccinia striiformis* f. sp. *tritici) are* important diseases of wheat in the Trakia region, Turkey. In the study, bread wheat genotypes were chosen to show different levels of field resistance against leaf rust and stripe rust infection. Due to the changes in environmental conditions from one location to another, leaf rust and stripe rust epidemic was varied and showed various degrees. Variation in disease severity was noticed among genotypes and the environment. Data in Table 2 revealed that leaf rust incidence in Burgaz and Tekirdağ locations was higher than in the other locations (Edirne and Keşan) due to genotype and environmental effects.

Table 2. Leaf rust and stripe rust disease infection of the genotypes across four environments

No	Genotype	Leaf rust (Location)				Stripe rust (Location)			
		Edirne	Burgaz	Tekirdağ	Keşan	Edirne	Burgaz	Tekirdağ	Keşan
1	Pehlivan	10S	60S	60S	0	0	0	0	0
2	G2	30S	60S	40S	0	0	0	0	0
3	G3	0	30S	5R	0	TR	TR	0	0
4	G4	0	40S	10MR	0	5R	50S	10S	0
5	Selimiye	10S	60S	60S	0	0	0	0	0
6	G6	10S	60S	60S	0	20S	20S	TR	0
7	G7	0	TR	10MR	0	20S	TR	10S	0
8	G8	5R	20MR	10MR	0	40S	TR	0	0
9	G9	0	0	0	0	100S	100S	100S	60S
10	Gelibolu	40S	10MR	40S	0	0	TR	0	0
11	G11	40S	TR	TR	0	0	TR	0	0
12	G12	5R	TR	10MR	0	0	0	0	0
13	G13	30S	TR	10MR	10S	5R	0	0	10S
14	G14	10MR	TR	30MR	TR	0	0	0	0
15	Saban	20S	30S	80S	20S	0	20S	TR	0
16	G16	5R	TR	0	0	0	TR	0	0
17	G17	TR	TR	0	0	0	0	10S	0
18	G18	0	TR	20MR	0	0	0	0	0
19	G19	0	0	TR	TR	0	TR	TR	0
20	Köprü	TR	TR	TR	0	TR	0	TR	0
21	G21	5R	TR	0	0	0	TR	0	0
22	G22	5R	0	10MR	0	0	0	0	0
23	G23	30S	10MR	40S	40S	0	0	0	0
24	G24	0	TR	0	0	0	0	0	0
25	G25	0	TR	20MR	TR	0	0	0	0

Severe epidemics and losses can occur when the flag leaf is infected before anthesis. Disease severity of local check was assessed in the study. It was seen that cultivars Pehlivan, Selimiye and Gelibolu were susceptible to leaf rust but there was no observed any symptom of stripe rust under rainfed condition. Most of the studied genotypes were tolerant to stripe rust under rainfed condition. Genotype

G9 was very susceptible to stripe rust disease across four locations. Among advanced lines G9, G17, G16, G19, G21 and G24 highly tolerant to leaf rust.

Data in Tables 3 indicated that all tested genotypes showed different septoria leaf blotch severity. Almost all genotypes excepted G7 and G12 had moderately or highly susceptible to septoria leaf blotch (*Septoria tritici*). Powdery mildew is not a major disease in the Trakia region. With the effect of climatic factors such as temperature, rainfall and relative humidity, the disease has caused a low epidemic. Infection of powdery mildew was higher in Tekirdağ location, in other locations there was almost no infection.

Table 3. Septoria leaf blotch and powdery mildew disease infection of the genotypes across four environments

No	Genotype	Septoria tritici (00-99) (Location)				Powdery mildew (00-99) (Location)			
		Edirne	Burgaz	Tekirdağ	Keşan	Edirne	Burgaz	Tekirdağ	Keşan
1	Pehlivan	55	55	67	47	33	22	44	0
2	G2	55	46	67	67	0	34	55	0
3	G3	65	56	55	57	0	21	47	0
4	G4	66	34	57	45	0	45	57	0
5	Selimiye	66	66	57	56	0	22	68	55
6	G6	76	45	55	67	0	21	55	0
7	G7	33	0	22	33	0	0	11	0
8	G8	65	11	55	57	0	0	45	0
9	G9	78	0	56	56	0	0	57	0
10	Gelibolu	67	45	54	67	44	0	57	0
11	G11	45	34	57	45	55	0	56	0
12	G12	33	0	56	33	32	0	34	0
13	G13	78	22	67	58	0	0	44	0
14	G14	67	23	34	57	0	0	53	0
15	Saban	54	23	56	46	0	0	24	0
16	G16	68	34	54	57	0	0	43	0
17	G17	68	34	66	58	0	0	43	0
18	G18	56	22	54	22	0	0	22	0
19	G19	65	0	55	57	0	0	22	0
20	Köprü	57	32	55	44	0	0	68	0
21	G21	68	55	45	68	0	0	56	0
22	G22	56	57	22	78	22	0	24	0
23	G23	53	57	78	57	22	0	46	0
24	G24	57	22	32	55	0	0	34	0
25	G25	54	34	44	44	0	0	11	0

In the evaluation made according to the diseases cultivar Köprü was highly tolerant of both leaf and stripe rust diseases under four locations. It is necessary to take into consideration yield performance because a high yielding genotype with high leaf rust tolerance will have a greater value for wheat

breeders and producers. Genotypes Köprü, G21 and G25 are perfect parents for crossing with other slow-rusting lines that have better resistance to achieve high yield potential with a high level of resistance to leaf rust disease.

The analysis of variance for yield was performed and given in Tables 4 and 5. The results of variance analyses showed that there were significant differences (P<0.01) among genotypes, location and its interaction for yield (Table 4 and 5).

Table 4. Combined analysis of variance for 25 genotypes for grain yield

Source of variation	**DF**	**SS**	**MS**	**F Ratio**
Location	3	1.003	3341691	422.577**
Replication	12	94894.6	7907.88	
Genotypes	24	774935.0	32288.9	16.007**
Location × Genotypes	72	423678.0	5884.42	2.917**
Error	288	580932.0	2017	
C. Total	399	11899512.0		

DF: Degrees of freedom; SS: Sum of square, MS: Mean of square; *, ** Significant at p<0.05 and p<0.01 respectively

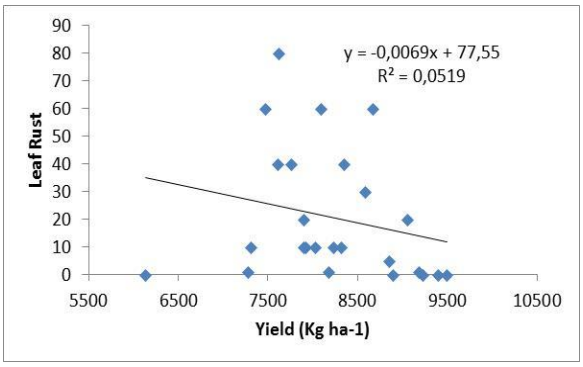
Table 5. Mean grain yield of the genotypes across four environments in 2017-2018 cycle

No	Genotypes	Locations				Mean yield (kg ha^{-1})
		Edirne	Burgaz	Tekirdağ	Keşan	
1	Pehlivan	7704	4954	7477	5004	6285 b-e
2	G2	6765	3918	7763	4396	5711 hı
3	G3	7295	5312	8858	4900	6591 ab
4	G4	7610	4494	7923	4951	6244 c-f
5	Selimiye	6990	4630	8090	4770	6120 d-g
6	G6	7474	5011	8671	4566	6430 bcd
7	G7	6593	4428	7904	3859	5696 ı
8	G8	6879	4830	7310	4415	5858 ghı
9	G9	6124	3769	6137	3023	4763 j
10	Gelibolu	7543	4955	8346	4868	6428 bcd
11	G11	6864	4608	7281	3930	5671 ı
12	G12	6715	4544	8028	4213	5875 ghı
13	G13	7354	4413	8235	3862	5966 f-ı
14	G14	6560	4319	8583	3930	5848 ghı
15	Saban	7576	5175	7628	4830	6302 b-e
16	G16	7142	5277	9226	4562	6552 abc
17	G17	7210	5538	8899	4654	6575 ab
18	G18	7259	4449	7903	4475	6021 e-h
19	G19	7511	4867	8183	4958	6380 bcd
20	Köprü	7781	5334	9182	4808	6776 a

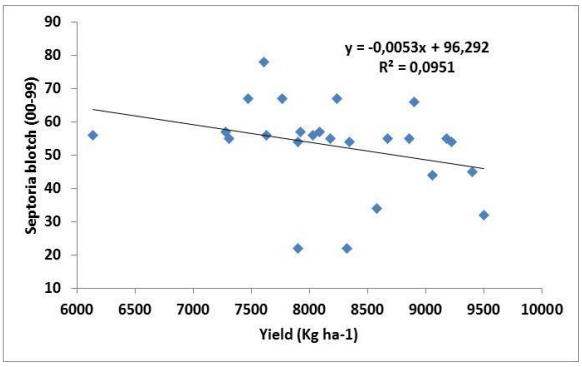
21	G21	7702	5533	9400	4593	6807 a
22	G22	6782	4511	8323	4630	6061 efg
23	G23	7554	4268	7611	4379	5953 f-ı
24	G24	7329	4644	9498	4609	6520 abc
25	G25	6992	5418	9059	4865	6584 ab
Mean (kg ha^{-1})		7172	4768	8221	4482	6161
LSD (0.05)		65.8	56.3	74.8	53.3	31.1
C.V (%)		6.5	8.3	6.5	8.4	7.3
F		3.37**	5.78**	8.69**	6.03**	16.01**

Significance at *: P<0.05; **: P<0.01

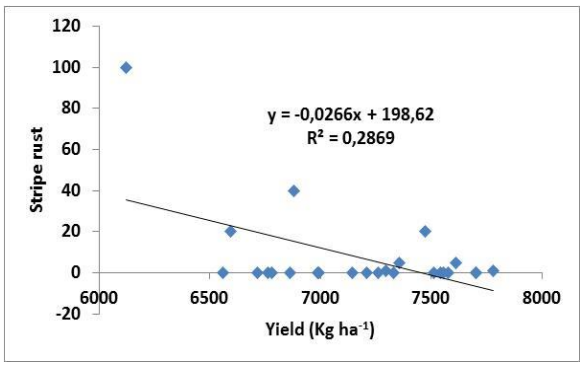
Analysis of variance showed a highly significant difference (P<0.01) among genotypes for grain yield except for Burgaz location. The mean yield of the genotypes was 6161 kg ha^{-1}, the highest yield was determined in G21 (6807 kg ha^{-1}) and Köprü (6776 kg ha^{-1}). Location Tekirdağ and Edirne had higher yield potential. Based on location genotype effect the highest grain yield performed in Edirne location from cultivar Köprü (7781 kg ha^{-1}), in Burgaz location from G17 (5538 kg ha^{-1}), in Tekirdağ location from G24 (9498 kg ha^{-1}), and Keşan location from Pehlivan (5004 kg ha^{-1}) (Table 5).



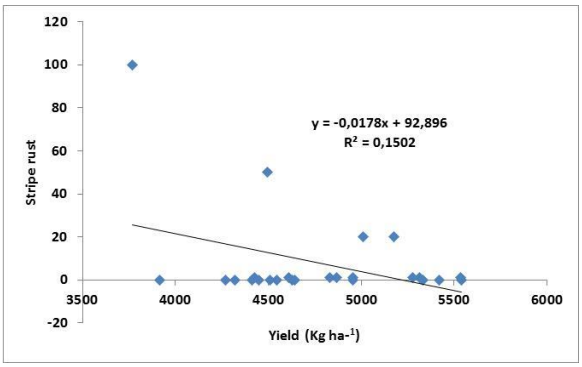
Grain yield and leaf rust in Tekirdağ location



Grain yield and septoria blotch in Tekirdağ location



Grain yield and stripe rust in Edirne location



Grain yield and stripe rust in Burgaz location

Fig. 1. Relationship between grain yield and diseases infection in various environments

The genotypes and environmental interactions varied by genotypic traits and climate conditions. As expected there was a slightly negative relationship between grain yield and rusts and other diseases. The relationship between yield and biotic stress factors was investigated. Leaf rust in the Tekirdağ location had a negatively effect on grain yield. A negative slight relation was found between grain yield and septoria leaf blotch in the Tekirdağ location. Stripe rust in Edirne (R^2=0.286) and Burgaz location (R^2=0.150) negatively affected and reduced grain yield (Figure 1).

Correlations among parameters were determined by Pearson's correlation analysis. It was found various relations among biotic stress factors and grain yield due to various environmental conditions and various levels of disease infection. Stripe rust significantly negatively affected and reduced grain yield across four environments. There was a significant negative relation between grain yield and leaf rust in the Edirne location (r=-0.536**), in Tekirdağ (r=-0.550**), in Keşan (r=-0.695**), and negative moderate relation in Burgaz location (r= -0.387). Leaf rust slightly negative affected grain yield across four locations. Powdery mildew disease effect on yield was low due to the higher temperature in the late development period. It was also found a significant positive relation between powdery mildew and leaf rust in Edirne (r=0.600**) and Burgaz (r=0.832**) location. Powdery mildew is also a positive association with stripe rust in Tekirdağ (r=0.424*) and Burgaz location (r=0.415*).

Table 6. Correlation coefficients among parameters across four locations in 2017-2018

Parameter Edirne	GY	LR	SR	STR	Parameter Burgaz	GY	LR	SR	STR
LR	0.096				LR	-0.063			
SR	-0.536**	-0.210			SR	-0.387	0.063		
STR	0.176	-0.032	0.312		STR	0.268	0.493*	-0.292	
PM	0.012	0.600**	-0.192	-0.404*	PM	-0.160	0.832**	0.204	0.415*
Parameter Tekirdağ	GY	LR	SR	STR	Parameter Keşan	GY	LR	SR	STR
LR	-0.228				LR	-0.031			
SR	-0.550**	-0.213			SR	-0.695**	-0.041		
STR	-0.308	0.266	0.030		STR	0.093	0.019	0.059	
PM	-0.051	0.080	0.155	0.424*	PM	0.129	-0.069	-0.048	0.046

Significance at *: P<0.05; **: P<0.01; GY: Grain yield (kg ha^{-1}), LR: Leaf rust, SR: Stripe rust, STR: Septoria blotch, PM: Powdery mildew

4. CONCLUSION

Different mechanisms have been adopted by plants to counter the wide range of biotic and abiotic stresses faced. Leaf and stripe rust, septoria leaf blotch and powdery mildew are mainly diseases of wheat. According to the result, there were significant differences among genotypes for yield and biotic stress factors. Genotype G21 and Köprü had the highest yield. The lowest infection was observed in the Keşan location. G9 highly was tolerant or highly resistant to leaf rust across four environments. G17, G19, and G24 were highly tolerant to LR showed 0-TR reaction across four environments. It was no observed any stripe rust infection in ten genotypes, and six genotypes showed a 0-TR reaction. Because of the lowest infection, there was almost no negative association between grain yield and leaf rust in Edirne and Keşan locations but in Tekirdağ and in the Burgaz location there was a slightly negative relationship between grain yield and leaf rust. Stripe rust infects the region depending on environmental conditions. Stripe rust infection was low due to unfavourable environmental conditions

and it was not observed in ten genotypes. G7 was tolerant to septoria blotch and four genotypes (G7, G18, G19 and G25) were highly tolerant to powdery mildew across four environments under rainfed conditions. Cultivar Köprü was highly tolerant of both leaf and stripe rust diseases under four locations. It is necessary to take into consideration yield performance because a high yielding genotype with high leaf rust tolerance will have a greater value for wheat breeders and producers. Genotypes Köprü, G21 and G25 are perfect parents for crossing with other slow-rusting lines that have better resistance to achieve high yield potential with a high level of resistance to leaf rust disease. Septoria tritici was the mainly biotic stress factor reducing grain yield in wheat genotypes across four environments. Therefore, when selecting high-yielding bread wheat genotypes, particular attention should be paid to the environmental conditions.

ACKNOWLEDGMENTS

This research was supported by Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies. Project name is "Bread Wheat Breeding Research in Trakia-Marmara Region"

REFERENCES

Appel JA, DeWolf E, Bockus WW, and Odd TT 2009, 'Preliminary 2009 Kansas wheat disease loss estimates' Kansas cooperative plant disease survey report.

Brokenshire T 1975, 'The role of graminaceous species in the epidemiology of Septaria tritici on wheat' Plant Pathol. 24:33-38.

Chen XM 2005, 'Epidemiology and control of stripe rust on wheat (*Puccinia striiformis* f. sp. tritici) on wheat' Can J Plant Pathol. 27:314-337

Cooke BM and jones DG 1970, 'The effect of near-ultraviolet irradiation and agar medium on the sporulat ion of Septaria nodorum and S. tritici' Trans. Br. Mycol. Soc. 54:221-226.

Duveiller E, Singh PK, Mezzalama M, Singh RP, Dababat A 2012, 'Wheat Diseases and Pests: A Guide for Field Identification (2nd Edition)' CIMMYT. Mexico, D.F., Mexico.

Eberhart SA and Russell WA 1966, 'Stability parameters for comparing varieties' Crop. Sci.6: 36-40.

Eyal Z, Scharen AL, Prescott JM, and van Ginkel M 1987, 'The Septoria Diseases of Wheat: Concepts and methods of disease management' Mexico, D.F.: CIMMYT.

Finlay KW and Wilkinson GN 1963, 'The Analysis of Adaptation in a Plant Breeding Programme' Aust. J. Agric.Res., 14: 742-754.

Gomez KA and Gomez AA 1984, 'Statistical Procedures for Agricultural Research' 2nd Ed. John Willey and Sons, Inc. New York. 641.

Griffey CA, Das MK, Stromberg EL 1993, 'Effectiveness of adult-plant resistance in reducing

grain yield loss to powdery mildew in winter wheat, Plant Dis 77:618–622

Kalaycı M 2005, 'Örneklerle Jump Kullanımı ve Tarımsal Araştırma için Varyans Analiz Modelleri' Anadolu TAE. Yayın No: 21. Eskişehir. (Example for Jump Use and Variance Analysis Model for Agricultural Research. Anatolia Agr. Res. Inst, Pub. No: 21 Eskişehir, Turkey).

Mujeeb-Kazi A, Gilchrist LI, Villareal RL, Delgado R 2000, 'Registration of ten wheat germplasm lines resistant to Septoria tritici leaf blotch' Crop Sci 40:590-591.

Mujeeb-Kazi A, Cano S, Rosas V, Cortes A, Delgado R 2001, 'Registration of five synthetic hexaploid wheat and seven bread wheat germplasm lines resistant to wheat spot blotch' Crop Sci 41:1653-1654.

Mujeeb-Kazi A, Gul A, Farooq M, Rizwan S, Ahmad I 2008, 'Rebirth of synthetic hexaploids with global implications for wheat improvement' Aust J Agric Res 59:391-398.

McIntosh RA, Yamazaki Y, Devos KM, Dubcovsky J, Rogers WJ, Appels R 2003, 'Catalogue of gene symbols for wheat. In: Pogna NE, Romano M, Pogna EA, Galterio G (eds) Proceedings of the 10th International Wheat Genetics Symposium, Vol. 4, associated CD-Rom, pp 1-34.

Naz AA, Kunert A, Lind V, Pillen K, Leon J 2008, 'AB-QTL analysis in winter wheat: II. Genetic analysis of seedling and field resistance against leaf rust in a wheat advanced backcross population' Theor Appl Genet (2008) 116:1095-1104

Peterson R, Campbell AB, Hannah AE 1948, 'A diagrammatic scale for estimating rust intensity on leaves and stems of cereals' Can. J. Res., 2: 496-500.

Prescott JM, Saari EE, and Dubin HJ 1986, 'Cereal Disease Methodology Manual' CIMMYT, Mexico, 46 p.

Rizwan S, Ahmad I, Ashraf M, Mirza JI, Sahi GM, Rattu AR, Mujeeb-Kazi A 2008, 'Evaluation of synthetic hexaploid wheats and their durum parents for stripe rust resistance, Rev Mex Fitopatol 25:152-160.

Roelfs AP, Singh RP, and Saari EE 1992, 'Rust Diseases of Wheat: Concepts and Methods of Diseases Management, 81 P., Mexico.

Saari EE, and Prescott JM 1975, 'A scale for appraising the foliar intensity of winter wheat diseases. Plant Dis. Rep., 595: 337-380

Safar AS 2015, 'Effects of yellow rust on yield of race-specific and slow rusting resistant wheat genotypes, J. Crop Prot. Vol. 4 (3). DOI: 10.13140/RG.2.1.4594.8647.

Singh RP, Mujeeb-Kazi A, Huerta-Espino J 1998, 'Lr46: A gene conferring slow-rusting resistance to leaf rust in wheat' Phytopathology 88:890-894.

Singh RP, William HM, Huerta-Espino J, Rosewarne G 2004, 'Wheat rust in Asia: meeting the challenges with old and new technologies' New dimensions for a diverse planet, Proceedings of the 4th International Crop Science Congress, 26 Sep-1 Oct 2004, Brisbane

Smith Lauren M 2008, 'Mapping of drought tolerance and leaf rust resistance in wheat' Master of Science, Biology, Genetics, Department of Agronomy, Kansas State University.

Stubbs RW, Prescott JM, Saari EE, and Dubin HJ 1986, 'Cereal Disease Methodology Manual. CIMMYT: Mexico, D.F. 46 pp.

Wamishe YA and Milus EA 2004, 'Seedling resistance genes to leaf rust in soft red winter wheat' Plant Dis. 88:136-146.

Williams JR and Jones DG 1973, 'Infection of grasses by Septaria nodorum and S. tritici' Trans. Br. Mycol. Soc. 60:355-358.

Wilson RE 1985, 'Inheritance of resistance to Septaria tritici in Wheat' Pp. 33-35 in A.L. Scharen, ed. Septoria of Cereals. Proc. Workshop, August 2-4, 1983, Bozeman, MT. USDA-ARS Publ. No. 12. 116 pp.

Yahyaoui AH, Hovmoller M, Brahim Ezzahiri, Ahmed Jahoor, Maatougui MH, Asmelash Wolday 2004, 'Survey of barley and wheat diseases in the central highlands of Eritrea, Phytopathologia Mediterranea, 43(1):39-43.

Zadoks J, Chang T, Konzak C 1974, 'A decimal code for the growth stages of cereals' Weed research 14: 415-421.