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Örijinal araştırma (Original article)

Determination of *Puccinia striiformis* f.sp. *tritici* races of wheat in İzmir and Manisa provinces in Türkiye

İzmir ve Manisa illerinde buğdayda sarı pas ırklarının belirlenmesi

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ABSTRACT

Stripe rust, caused by *Puccinia striiformis* f. sp. *tritici* (Pst), is a major source of yield loss in wheat production in Türkiye. Field surveys were conducted between March and May 2021 to determine the prevalence of this disease in the provinces of İzmir and Manisa and to identify existing rust races. While no disease symptoms were found in 45 of the 71 wheat fields examined, yellow rust infection was detected in 26 fields. Twenty Pst isolates obtained from diseased leaves were subjected to characterisation studies following spore multiplication. Race analysis was performed using seedling stage tests and used differential set containing 19 Yr single genes. According to the findings, all isolates were found to be virulent on Yr2, Yr6, Yr7, Yr8, Yr17, Yr25 and Yr27 genes and avirulent on Yr1, Yr5, Yr10, Yr15, Yr24 and YrSp genes.

INTRODUCTION

Wheat is a staple crop essential for human nutrition and is among the most widely cultivated crops globally, owing to its broad adaptability and high yield potential. In this context, wheat plays an indispensable role not only as a staple food source but also ensuring the continuity of rural economies, maintaining agricultural stability, and supporting the sustainability of the global food supply. China, the EU, India, Russia and the US together account for 65% of global wheat production. Türkiye ranks 20th in the world in terms of production volume with 20 million tonnes (TUIK 2024). Türkiye has extensive cereal-producing areas, with wheat ranking first among them, producing 20.000.000 tonnes on a cultivated area of 70.238.078 da in 2024. The Aegean Region accounts for approximately 6.8% (1.372.531 tonnes) of this production. In our region, 85.911 tonnes of

wheat were produced on 250.059 da in İzmir province, while 216.089 tonnes of wheat were produced on 871.424 da in Manisa province. Rust diseases are the leading biotic factors causing yield and quality losses in wheat. Three rust species are commonly observed in wheat: yellow rust, leaf rust, and stem rust. Among these, the fungus *Puccinia striiformis* f. sp. *tritici* (Pst) is responsible for yellow rust, which typically occurs in regions with low temperature and high humidity. The disease can develop from the seedling stage to plant maturity and can cause significant yield and quality losses by triggering epidemics under favorable conditions (Chai et al. 2014). Although the disease is observed on all plant parts including leaves, stems and spikes, the typical symptoms are observed on leaves. Urediniospores of the pathogens are produced abundantly during the growing season and

dispersed by wind and rain (Zeybek and Yigit 2004). They can be transported from one geographically distant region to another, such as from America to Australia (Wellings 2007), from Europe to East Africa and West Asia, and from the Middle East to South Africa (Boshoff et al. 2002). These spores can cause significant yield and quality losses during epidemic years in the affected countries. Numerous investigations have been conducted to determine yellow rust races based on the reactions of wheat genotypes carrying different resistance genes, to identify resistance genes, and to characterize regional race profiles. A total of 78 yellow rust resistance genes were determined in bread and durum wheat varieties, as well as from wild relatives (Ölmez 2023). However, new virulent Pst races can overcome resistance genes, and genotypes that were previously resistant may lose their effectiveness and become susceptible to the disease. For instance, an epidemic occurred in 1991 as a result of infection by a new Pst race introduced from West Africa. At that time, it severely affected the 'Seri-82' variety, which was widely cultivated in the Çukurova region and known to carry the Yr9 resistance gene, causing a yield loss of approximately 7 million TL in today. This epidemic was also one of the reasons why the Seri-82 variety was removed from production programmes. Similarly, in 1998, cool and rainy weather in Central Anatolia led to widespread yellow rust infection, affecting 98% of production areas and resulting in yield losses ranging from 26.5% to 50% (Mamluk Çetin et al. 1997). In Türkiye race analysis of Pst began in the 1970s, followed by a limited number of studies. These studies reported that many resistance genes are ineffective (Çetin et al. 2000, Mert et al. 2012, Mert et al. 2016). Çat (2021) examined a total of 28 isolates, including 15 from the Mediterranean region and 13 from the Aegean region, and reported that the isolates were virulent at various frequencies on the resistance genes Yr1, Yr6, Yr7, Yr8, Yr9, Yr10, Yr17, Yr24, Yr27, Yr32, Yr43, Yr44, YrSp, and YrTr1. In addition, all isolates were avirulent on the Yr5 and Yr15 resistance genes. Ölmez (2023) determined that all isolates were virulent on Yr2, Yr3, Yr4, Yr6, Yr7, Yr8, Yr9, Yr10, Yr17, Yr25, Yr27, Yr32, and YrSp, while remaining avirulent on Yr5 and Yr15. The pathogen can spread over long distances via wind, rapidly adapt to different climatic environments, and give rise to new races. Therefore, it is crucial to determine yellow rust races, monitor resistance, and implement preventive measures against emerging races. This is particularly important for disease management, as it allows researchers to track changes in virulence and continuously monitor the effectiveness of resistance genes.

This study aimed to reveal the status of yellow rust disease in wheat production areas of İzmir and Manisa provinces and

to determine the existing yellow rust races in these regions. Surveys were conducted in both provinces, and isolates obtained from diseased samples were inoculated onto susceptible wheat plants, then race analyses of this isolates were carried out phenotypically.

MATERIALS AND METHODS

Fungal material

The fungal material used in this study consisted of yellow rust isolates from symptomatic wheat plants.

Plant material

Wheat plants infected with yellow rust were collected from cultivated fields and used as experimental material. Additionally, the Morocco wheat variety was used as a susceptible host for rust spore multiplication, and a set of wheat genotypes was employed for race analysis.

Other materials

Other materials used in the study included envelopes for diseased plant samples, plastic Petri dishes, blotting paper, cryotubes, aluminium foil, filters, Novex 7100 mineral oil, maleic acid, pressurised spray devices, desiccators, silica gel, pots, peat, fertiliser, humidity control devices, labels, plastic containers, and climate chambers.

Field survey and isolate collection and spore multiplication

Surveys were carried out in the wheat cultivation areas of İzmir and Manisa provinces at different periods in 2021 (March-May). According to the systematic sampling method, at least 0.1% of the total wheat cultivation area was surveyed by stopping at 20 km intervals along the route (Aktas 2001). Infected leaves of wheat plants were collected from the fields (Figure 1). A total of 26 isolates, 20 from Manisa province and 6 from İzmir were collected.

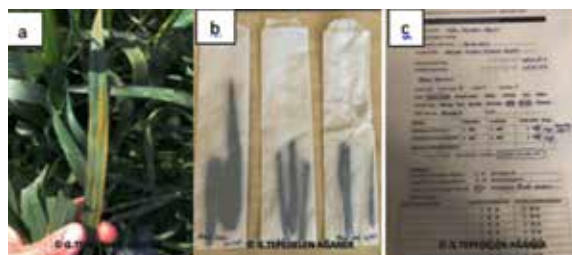


Figure 1. Collection of diseased leaf samples (a), paper envelopes in which leaf samples were placed (b) Global Cereal Rust Disease Observation Form (c)

Cultivation of susceptible wheat crop

The susceptible wheat variety 'Morocco' was used for spore multiplication (Rizwan et al. 2010, Ali et al. 2017). For this purpose, initially, 5-7 Morocco seeds were sown in pots

(Figure 2). Then, the plants were placed to climate chamber at 18-20 °C. Plants were generally inoculated when 12 days old.



Figure 2. Cultivation of Morocco wheat variety

Spore multiplication

Leaf material washed under running water and then placed in petri dishes containing Whatman filter paper and 2 ml of sterile distilled water was added to each Petri dish and kept at room temperature followed by incubation for 2-3 hours. For each field, 1 Petri dish was prepared and 2-3 plant leaves were placed in each Petri dish. After sporulation (approximately 2-3 hours), inoculation process were carried out by rubbing onto the susceptible Morocco wheat variety. Each Petri (2 leaves) was applied to a pot of plants (5-7 plants). After inoculation, the infected plants were incubated at 9-10 °C and 100% humidity for 24 hours in dark conditions. After the incubation process, the plants were taken to the climate-controlled room with temperature and humidity control and kept at 15-18 °C for approximately 12-15 days (Hovmoller et al. 2017). Urediniospores of each isolate were collected. This re-production process was repeated several times for each isolate until a sufficient spore quantity was obtained

for race analyses. Collected spores were passed through a small sieve and placed in cryo tubes and dried and kept in a desiccator at 4 °C for 4 days. Then samples were stored in -80 °C deep freezer until inoculation into the differential sets (Çat 2021).

Race analyses

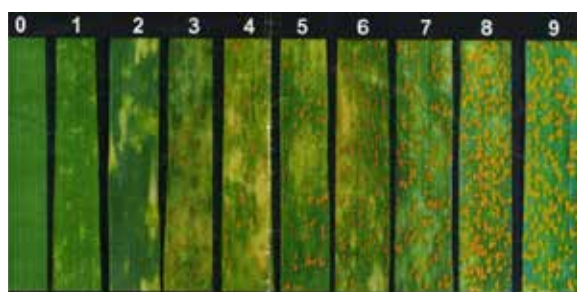
The determination of yellow rust races was performed using seedling-stage tests. In this study, a stripe rust differential set, consisting of 19 genotypes, including Avocet S, Avocet R, Yr1, Yr2, Yr3, Yr4, Yr5, Yr6, Yr7, Yr8, Yr9, Yr10, Yr15, Yr17, Yr24, Yr25, Yr27, Yr32, YrSP was used for race determination. (Table 1) (Hovmoller 2022). The genotypes in the differential set were sown in 9 cm diameter pots containing peat with seeds of each variety and the plants were grown at 15-20 °C under climate chamber (Figure 3a). For the inoculation process, yellow rust spores removed from -80 °C were firstly subjected to heat shock at 42 °C for 5 min and then applied (5 mg of spores of each isolate for each differential sets were placed in cryo tubes and spore suspension was prepared by mixing with 3M-Novec 7100 mineral oil (2 ml) (Figure 3b). The spore suspension was applied to the plants using an airbrush spray gun connected to a vacuum pump from a distance of 10 cm to 15 cm (Hovmoller et al. 2017). (Figure 3c, d). Following inoculation, the plants were kept at 9-10 °C, 98-100% humidity for 24 hours in the darkness and then the plants were transferred to a climate-controlled growth chamber with 16 hours of light and 8 hours of darkness (Figure 3e). The evaluation was carried out 14-16 days after inoculation using the 0-9 scale (Table 2) (Figure 4). Plants with a scale rating of 0-6 indicate that the pathogen is avirulent and virulent for those with scale rating of 7-9 (showing a high infection reaction) (Wan and Chen 2014) (Figure 3f, g).

Table 1. Genotypes in the yellow rust race differential set and the resistance genes

Number	Genotype	Yr-Gene	Number	Genotype	Yr-Gene
1	Morocco	-	11	Yr8/ 6* Avocet S	8
2	Avocet 'S'	-	12	Yr9/ 6* Avocet S	9
3	Avocet 'R'	A	13	Yr10/ 6* Avocet S	10
4	Yr1/ 6* Avocet S	1	14	Yr15/ 6* Avocet S	15
5	Kalyansona	2	15	Yr17/ 6* Avocet S	17
6	Vilmorin 23	3	16	Yr24/ 6* Avocet S	24
7	Hybrid 46	4	17	TP 981	25
8	Yr5/ 6* Avocet S	5	18	Yr27/ 6* Avocet S	27
9	Yr6/ 6* Avocet S	6	19	Yr32/ 6* Avocet S	32
10	Yr7/ 6* Avocet S	7	20	YrSp/ 6* Avocet S	Sp

Table 2. Disease scoring scale (0-9) of infection types (IT) for yellow (stripe) rust (McNeal et al. 1971)

Virulent/Avirulent	Scale Value	Diseases symptoms
Avirulent	0	No visible disease symptoms
	1	Minor chlorotic and necrotic flecks
	2	Chlorotic and necrotic flecks without sporulation
	3-4	Chlorotic and necrotic areas with limited sporulation
	5-6	Chlorotic and necrotic areas with moderate sporulation
Virulent	7	Abundant sporulation with moderate chlorosis
	8-9	Abundant and dense sporulation without notable chlorosis and necrosis

**Figure 3.** Cultivation of the genotypes in the race differential set in pots (a), preparation of spore suspension by mixing Novac 7100 mineral oil and yellow rust spores in Cryo tube (b), inoculation with spray gun (c, d). After inoculation, keeping the plants in a humidity cycle at 9-10 °C in the dark for 24 hours (e). Disease scoring (f, g)**Figure 4.** Disease scoring scale (0-9) of infection types (IT) for yellow (stripe) rust (McNeal et al. 1971)

RESULTS

Survey studies

According to the survey results, a total of 1,196 decare across 53 fields in Manisa province and 289 decare across 18 fields in İzmir province were surveyed (Table 3).

Out of the 71 fields surveyed, 45 were found to be disease-free, while 26 were infected, and a total of 26 stripe rust

samples were collected throughout the survey. Spore multiplication was successfully carried out for 20 of the collected samples. Six stripe rust samples from Manisa did not recover and could not be multiplied. The virulence patterns of the twenty successfully multiplied samples are presented in Table 4.

Race analysis

Six different virulence patterns were identified among the 20 isolates. Of these, three isolates originated from İzmir and three from Manisa provinces. All isolates from both provinces were avirulent on *Yr1*, *Yr5*, *Yr10*, *Yr15*, *Yr24*, and *YrSP*, indicating that these resistance genes remain effective in these regions. Conversely, all isolates were virulent on *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr17*, *Yr25*, and *Yr27*. The number and percentage of virulent and avirulent isolates on the wheat genotypes included in the differential set are presented in Table 5. Isolates (TRYRT1, TRYRT2 and TRYRÖ) detected in Torbalı and Ödemiş districts were determined to be the most prevalent race in İzmir province. This race was found to be virulent on 9 resistance genes (*Yr2*, *Yr4*, *Yr6*, *Yr7*, *Yr8*, *Yr17*, *Yr25*, *Yr27*, *Yr32*) and avirulent on 8 resistance genes (*Yr1*, *Yr3*, *Yr5*, *Yr9*, *Yr10*, *Yr15*, *Yr24*, *YrSp*). Unlike the Torbalı and Ödemiş isolates, Tire isolate was found to be virulent on the *Yr3*. The isolate which was detected in Kiraz was found to be virulent on the *Yr2*, *Yr3*, *Yr4*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr17*, *Yr25*, *Yr27* and *Yr32*. The difference between races identified in the province of İzmir has emerged in genotypes containing the *Yr3* and *Yr9*. All isolates identified in the province of İzmir were found to be avirulent on *Yr1*, *Yr5*, *Yr10*, *Yr15*, *Yr24* and *YrSp*; and virulent on *Yr2*, *Yr4*, *Yr6*, *Yr7*, *Yr8*, *Yr17*, *Yr25*, *Yr27*, and *Yr32*. Additionally, the resistance gene *Yr4* was ineffective against all isolates in İzmir. It has been determined that the isolates with the highest virulence in the province of İzmir were TRYRK1 and TRYRK2, and that these isolates were virulent on 11 resistance genes.

Table 3. In the districts belonging to the provinces of İzmir and Manisa, the area examined in 2021, cultivated area, investigation area, the number of fields, the number of samples taken

Province	District	Cultivated Area	Investigation Area	Number of fields examined	Number of samples taken
Manisa	Ahmetli	12617	36	2	2
	Akhisar	140720	255	7	4
	Alaşehir	49160	52	3	1
	Demirci	92000	118	5	3
	Gördes	71573	74	4	0
	Köprübaşı	24652	62	3	0
	Kırkağaç	11440	28	2	0
	Saruhanlı	54446	82	3	1
	Salihli	113331	115	5	1
	Sarıgöl	33384	38	2	0
	Selendi	155640	165	8	5
	Soma	7863	55	2	0
	Turgutlu	19020	56	3	2
	Yunusemre	18759	22	2	0
	Şehzadeler	28240	38	2	1
	TOTAL		1196	53	20
İzmir	Ödemiş	17480	32	2	1
	Torbalı	14379	33	2	2
	Tire	29200	25	1	1
	Menderes	58676	62	3	0
	Kiraz	23212	22	2	2
	Dikili	23180	45	3	0
	Bergama	38800	42	3	0
	Aliağa	19387	28	2	0
	TOTAL	224314	289	18	6

Table 4. Virulence pattern of İzmir and Manisa isolates

ID	Isolate	Province/district	Virulence pattern	Number of virulences
1	TRYRT1	İzmir-Torbalı	M, AvS, AvR, -, 2, -, 4, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	9
2	TRYRT2	İzmir-Torbalı	M, AvS, AvR, -, 2, -, 4, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	9
3	TRYRÖ	İzmir-Ödemiş	M, AvS, AvR, -, 2, -, 4, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	9
4	TRYRTi	İzmir-Tire	M, AvS, AvR, -, 2, 3, 4, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	10
5	TRYRK1	İzmir-Kiraz	M, AvS, AvR, -, 2, 3, 4, -, 6, 7, 8, 9, -, 17, -, 25, 27, 32, -	11
6	TRYRK2	İzmir-Kiraz	M, Avs, AvR, -, 2, 3, 4, -, 6, 7, 8, 9, -, 17, -, 25, 27, 32, -	11
7	TRYRS1	Manisa-Selendi	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
8	TRYRS2	Manisa-Selendi	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
9	TRYRS3	Manisa-Selendi	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
10	TRYRS4	Manisa-Selendi	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
11	TRYRS5	Manisa-Selendi	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
12	TRYRD1	Manisa-Demirci	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
13	TRYRD2	Manisa-Demirci	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
14	TRYRTu1	Manisa-Turgutlu	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
15	TRYRTu2	Manisa-Turgutlu	M, AvS, AvR, -, 2, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	8
16	TRYRA1	Manisa-Akhisar	M, AvS, AvR, -, 2, 3, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	9
17	TRYRA2	Manisa-Akhisar	M, AvS, AvR, -, 2, 3, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	9
18	TRYRA3	Manisa-Akhisar	M, AvS, AvR, -, 2, 3, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	9
19	TRYRA4	Manisa-Akhisar	M, AvS, AvR, -, 2, 3, -, -, 6, 7, 8, -, -, 17, -, 25, 27, 32, -	9
20	TRYRŞe	Manisa-Şehzadeler	M, AvS, AvR, -, 2, -, -, 6, 7, 8, 9, -, -, 17, -, 25, 27, -, -	8

Table 5. The number of virulent and avirulent yellow rust isolates on resistance genes and their rates

Yr- Genes	Number of isolates						Total rate (%)
	İzmir (6 izolates)			Manisa (14 izolates)			
	Virulent	Avirulent	Rate (%)	Virulent	Avirulent	Rate (%)	
Morocco	6	0	100	14	0	100	100
Avocet S	6	0	100	14	0	100	100
Avocet R	6	0	100	14	0	100	100
Yr1	0	6	0	0	14	0	0
Yr2	6	0	100	14	0	100	100
Yr3	3	3	50	4	10	28	35
Yr4	6	0	100	0	14	0	30
Yr5	0	6	0	0	14	0	0
Yr6	6	0	100	14	0	100	100
Yr7	6	0	100	14	0	100	100
Yr8	6	0	100	14	0	100	100
Yr9	2	4	33	1	13	7	15
Yr10	0	6	0	0	14	0	0
Yr15	0	6	0	0	14	0	0
Yr17	6	0	100	14	0	100	100
Yr24	0	6	0	0	14	0	0
Yr25	6	0	100	14	0	100	100
Yr27	6	0	100	14	0	100	100
Yr32	6	0	100	13	1	92.8	95
YrSp	0	6	0	0	14	0	0

In Manisa province, the most common race was detected in isolates from Selendi, Demirci and Turgutlu districts. This race was found to be avirulent on 9 resistance genes (*Yr1*, *Yr3*, *Yr4*, *Yr5*, *Yr9*, *Yr10*, *Yr15*, *Yr24* and *YrSp*) and virulent on 8 resistance genes (*Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr17*, *Yr25*, *Yr27* and *Yr32*) (Table 2). The difference between the 3 yellow rust races detected in Manisa province was found on *Yr3*, *Yr9* and *Yr32*. All yellow rust races identified in Manisa were virulent on *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr17*, *Yr25* and *Yr27* resistance genes and avirulent on *Yr1*, *Yr4*, *Yr5*, *Yr10*, *Yr15*, *Yr24* and *YrSp* resistance genes. It has been determined that the Akhisar isolates (TRYRA1, TRYRA2, TRYRA3 and TRYRA4) have the highest virulence in Manisa province.

It was determined that seven (35%) of all isolates were virulent on *Yr3*. Half of the isolates collected from Izmir province were virulent on *Yr3* while the other half were avirulent (Table 5). In Manisa province, only 4 (28%) of the isolates were virulent on *Yr3* (Table 5).

It was observed that 6 (30%) of all isolates were virulent on *Yr4*. Although the *Yr4* resistance gene all isolates in Izmir province, it was effective still provided resistance in

Manisa province (Table 4). When the virulence of yellow rust isolates on *Yr9* was evaluated; it was observed that three isolates (15%) were virulent on *Yr9*. TRYRK1 and TRYRK2 isolates in İzmir province and only TRYRŞe isolate in Manisa province were virulent on *Yr9*. Thirteen of isolates were virulent on *Yr32*. This resistance gene was ineffective against all isolates of İzmir province and against all isolates except one isolate (TRYRŞe) in Manisa province (Table 5).

DISCUSSION

Race analyses were conducted on 20 isolates 6 from İzmir and 14 from Manisa provinces for which spore propagation was successful, and six different virulence patterns were identified. Of these, three patterns were detected in İzmir and three in Manisa provinces. Of the six virulence patterns identified, three were observed in İzmir and three in Manisa provinces. Overall, all isolates were virulent on *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr17*, *Yr25*, and *Yr27* and avirulent on *Yr1*, *Yr5*, *Yr10*, *Yr15*, *Yr24*, and *YrSP*. The resistance genes *Yr3*, *Yr4*, *Yr9*, and *Yr32* exhibited variable reactions against the yellow rust isolates. Previous studies have indicated that these genes generally maintain their resistance. El Amil et al. (2020)

determined that yellow rust races were avirulent *Yr1*, *Yr4*, *Yr5*, *Yr10*, *Yr15* and with these resistance genes showing effective resistance against the races. In a similar study, Brar et al (2016) determined that the yellow rust isolates were avirulent on *Yr4*. Shahin (2017) reported that *Yr2+*, *Yr5*, *Yr10*, *Yr15* and *YrND* resistance genes were effective against to isolates while *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr17*, *Yr27* and *Yr32* were ineffective. In a similar study, it was determined that yellow rust races were virulent to *YrA*, *Yr6*, *Yr7*, *Yr17*, *Yr28* and *Yr31* and avirulent to *Yr1*, *Yr5*, *Yr10*, *Yr15*, *Yr24/26*, *YrSp* and *YrTye* and *Hybrid 46* (Brar and Kutcher 2016).

The resistance genes *Yr5*, *Yr10* and *Yr15* were found to be effective against all *Pst* populations in Türkiye (Mert et al. 2012, 2016). Similar outcomes were obtained in this investigation. Çat (2021) collected 28 isolates, 15 from the Mediterranean region and 13 from the Aegean region. He found that majority of the isolates were virulent at various frequencies on *Yr1* (50%), *Yr6* (100%), *Yr7* (78%), *Yr8* (50%), *Yr9* (84%), *Yr10* (25%), *Yr17* (38%), *Yr24* (22%), *Yr27* (31%), *Yr32* (22%), *Yr43* (47%), *Yr44* (6%), *YrSp* (41%), *YrTr1* (6%) and avirulent on *Yr5* and *Yr15*.

Ölmez (2023) carried out survey in Southeastern Anatolia and Mediterranean Regions and he collected 25 yellow rust isolates as a result of a survey study. As a result of the study, he was determined that yellow rust races were avirulent on *Yr1*, *Yr5*, *Yr10*, *Yr15* and *Yr24* and virulent on *Yr2*, *Yr3*, *Yr4*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr17*, *Yr25*, *Yr27*, *Yr32* and *YrSp*. In our study, it was determined that yellow rust isolates were avirulent on *Yr5*, *Yr10*, *Yr15* and *Yr24* resistance genes, but all yellow rust races except one race were virulent on *Yr32* resistance gene. Ölmez (2023) reported that yellow rust races were avirulent on *Yr5*, *Yr10*, *Yr15* and *Yr24*. The results obtained in this thesis were in parallel with the previous studies. However, Çat (2021) determined that yellow rust isolates were virulent to *Yr1*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr10*, *Yr17*, *Yr24*, *Yr27*, *Yr32*, *Yr43* and *YrSp*. Although this study was conducted in a similar region to our study, it was determined that *Yr10*, *Yr24* and *YrSp* resistance genes lost their effectiveness against some yellow rust races contrary to our study. It was found that most of the resistance genes have lost their resistance in studies conducted both in Türkiye and abroad. Among the resistance genes *Yr5*, *Yr10*, *Yr15* and *Yr24* which are known to be resistant to yellow rust races, it was observed that except *Yr15*, the other genes did not provide resistance against yellow rust races in our country. However, in this study, it was determined that the resistance genes *Yr5*, *Yr10*, *Yr15*, and *Yr24* still maintain their effectiveness in İzmir and Manisa provinces. Although this result suggests that the presence of an alternate host, especially in İzmir province,

may lead to variation in virulence, it was notable that the resistance genes *Yr5* and *Yr15* remained effective against the races in both İzmir and Manisa provinces. Ragab et al. (2020) determined that *Yr5*, *Yr10*, *Yr15* and *YrSp* were found to be effective against the dominant yellow rust races in Egypt. Sufyan et al. (2021), reported that 8 yellow rust races were avirulent on *Yr5*, *Yr10*, *Yr15*, *Yr24*, *Yr24*, *Yr32*, *Yr32*, *YrSp* and *YrTye* and virulent on *Yr1*, *Yr8*, *Yr9* and *Yr27*. Gulyaeva et al. (2022) determined that all yellow rust races were avirulent on *Yr5*, *Yr10*, *Yr15* and *Yr24* resistance genes.

In this study, no virulent race was detected on *YrSp*. In many studies conducted abroad, it has been reported that *YrSp* resistance gene provides resistance against yellow rust races and yellow rust races are avirulent on this gene (Ali et al. 2014, Abu Aly et al. 2014, Al-Maaroof et al. 2015, Brar and Kutcher 2016, Wan et al. 2017, Wamalva et al. 2019, Ragab et al. 2020, Gangwar et al. 2021, Sufyan et al. 2021). Our results showed similar outcomes and it was observed that *YrSp* maintained its resistance against yellow rust races. However, Çat (2021) stated in his study that *YrSp* lost its effective against some yellow rust races. Similarly, Ölmez (2023) reported that 28% of yellow rust isolates were virulent on *YrSp*. Regional origin and genetic diversity of the isolates may play a role in the observed differences.

In conclusion; as a result of this study, six virulence patterns were identified. Our study showed that all isolates were virulent on *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr17*, *Yr25*, and *Yr27* but, avirulent on *Yr1*, *Yr5*, *Yr10*, *Yr15*, *Yr24*, and *YrSp* genes.

Monitoring of yellow rust disease with survey studies, determination of the yellow races distributions in the region studies, to carry out studies for the identification of resistance genes in wheat genotypes should be carried. Evaluation of the findings obtained from these studies in breeding programmes is of great importance in the against the disease.

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Author's Contributions

Authors declare that each author's contribution is equal.

Statement of Conflict of Interest

The authors have declared no conflict of interest.

ÖZET

Puccinia striiformis f. sp. *tritici* (Pst)'nin neden olduğu sarı pas, Türkiye'de buğday üretiminde verim kaybının başlıca nedenlerinden biridir. Bu hastalığın İzmir ve Manisa illerindeki yaygınlığını belirlemek ve mevcut pas ırklarını tanımlamak amacıyla 2021 yılı Mart–Mayıs ayları arasında arazi sürveyleri yürütülmüştür. İncelenen toplam 71 buğday tarlasının 45'inde hastalık belirtisine rastlanmazken, 26 tarlada sarı pas enfeksiyonu tespit edilmiştir. Hastalıkla bulaşık yapraklardan elde edilen 20 Pst izolatu spor çoğaltma işlemlerinin ardından karakterizasyon çalışmalarına tabi tutulmuştur. Irk analizi çalışmaları fide dönemi testleri ile gerçekleştirilmiş ve 19 adet Yr tek genini içeren ırk ayırıcı set kullanılmıştır. Elde edilen bulgulara göre tüm izolatların Yr2, Yr6, Yr7, Yr8, Yr17, Yr25 ve Yr27 genlerine karşı virulent; Yr1, Yr5, Yr10, Yr15, Yr24 ve YrSp genlerine karşı avirulent oldukları belirlenmiştir.

Anahtar Kelimeler: buğday, sarı pas, *Puccinia striiformis* f.sp. *tritici*, ırk, ırk analizi

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