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Wheat leaf rust disease caused by Puccinia triticina Eriks

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Abstract

One of the biggest obstacles to increasing wheat production and yield is diseases. Diseases not only reduce the amount of product but also negatively affect product quality. Rust diseases in wheat are among the most important biotic stress factors limiting wheat production in our country. In epidemic years, early infections on cereals susceptible varieties can cause yield losses of up to 80-90% and can cause varieties to be completely removed from production. In our country, yield losses caused by different types of rust on wheat plants have been recorded between 12-80%. Product losses vary depending on the sensitivity of varieties, environmental conditions, and the races of the factors, as well as from year to year and from region to region. Leaf rust (Lr) (Puccinia triticina Eriks.) is seen almost everywhere wheat is grown, but the damage it causes is not as noticeable as the damage caused by black and yellow rust. However, these two rust agents are not effective every year and cause serious epidemics every 7-8 years. Leaf rust, on the other hand, occurs almost every year and causes a certain amount of yield loss. The most important method for creating broad-spectrum disease resistance in cereals is the combined use of biotechnology and traditional breeding methods.

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Introduction

The grain group is very important in terms of agricultural production as well as agriculture and food industry. When industry is involved, it is important in both of labor force, value-added product, economy and environmental safety. Both in other countries in the world and in Türkiye wheat is more important than other agricultural products as it is the raw material of the most basic nutrients in human nutrition. As it is known that, wheat has strategic importance as a basic food source in the world. It is especially the most suitable and cheapest grain for bread making. In addition flour, which has more economic value, is obtained from wheat and the remaining part is used as animal nutrition (Anonymous a., 2024). When we look at wheat cultivation areas around the world the top 5 countries are India, Russia, China, EU and USA. Cereals have the largest cultivation area and production among the cultivated plants in the world. Türkiye's wheat cultivation area constitutes 3.5% of the world's wheat cultivation area, and this area also corresponds to 33% of the total cultivated agricultural area in Türkiye (Anonymous b., 2024) (Table 1).

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Table 1. Türkiye Wheat Production by Regions in 2022.

Region Names	Cultuvated area (hectar)	Production	Yield
Marmara Region	850.000	3.800.000	4.47
Aegean Region	650.000	1.650.000	2.54
Central Anatolia Region	2.200.000	5.250.000	2.39
Mediterranean region	600.000	1.600.000	2.67
Eastern Anatolia Region	650.000	1.500.000	2.31
Southeastern Anatolia Region	1.100.000	2.200.000	2.00
Black Sea region	610.000	1.500.000	2.46
Total	6.660.000	17.500.000	2.63

Among the organisms that cause diseases in cereals, pathogenic fungi are one of the most important diseases that can be found in almost every region in our country. Among these, rust diseases stand out with their serious yield losses. Since rust become the most widespread and important diseases of wheat, they started to be studied more. Wheat rust resistance gene resources have been used by breeders for many years and therefore new breeds that can break the effects of the resistance genes of host plants can emerge. Genetic resistance is the cheapest and most effective method for controlling rust diseases although protective fungicides are recommended against this diseases, it is not economical in practice. Therefore, in addition to cultural measures, using resistant varieties or lines is the most effective control method (Anonymous c., 2024).

Resistance to pathogens in host plants;

Race-specific (vertical) resistance: A host plant while it is resistant to some physiological races of the pathogen, it is sensitive to other races of the pathogen. Race-specific resistance breaks down quickly. However, this type of resistance provided by a few large genes which is not a very desired type of resistance, as it is easily broken by high pathogen populations in environment and the emergence of new races. Therefore, in order to control newly developing virulent pathogen races, breeders are constantly creating new varieties with new resistance genes or gene combinations must be developed.

Non-race specific (horizontal) resistance: It shows resistance against all races of the host pathogen. Many moderately effective genes or their interactions play a role in this type of resistance.

In wheat production areas, rust (Puccinia spp.) diseases are very important and can cause big yield and quality losses at fields. The climate factor is also critical for rust diseases. It is known that the occurrence of this diseases and the magnitude of the damage also depend on the virulence pattern of the disease population and the host genotype (Singh et al., 2004a).

Taxonomy of Puccinia spp. is; Kingdom: Fungi, Phylum: Basidiomycota, Class: Urediniomycetes, Team: Uredinales, Family: Pucciniaceae, Genus: Puccinia

Puccinia spp. urediospores, which play an important role in spread of rust diseases, are mostly formed in spring and summer. They carried out by wind and cause new infections in other plants. In temperate zones, the rust spores spend winter as urediospores in autumn on crops and wild grasses. Summer spores, which are formed in spring and spread around by wind and cause new infections in optimum humidity and temperature (10-18°C) conditions (Lipps, 2006). Urediospores are single-celled. The fungus enters the host plant through stomata by being transmitted to the host plant by external factors such as wind. Urediospores which are on the leaf surface absorb water and swell when they come into contact with rain or dew, developing germination tubes. This germination occurs 4-8 hours later at 20 °C under 100% humidity, and the spores can maintain their viability for 1-3 days without germination (Bolton et al., 2008).

There are 3 rust diseases on wheat. Yellow (stripe) rust (*Puccinia striiformis* f.sp. *tritici*), stem rust (*Puccinia graminis* f. sp. *tritici)* and leaf rust (*Puccinia triticina* Eriks.). Since pesticide treatment is often economical in the fight against this diseases, the use of resistant varieties are important when climate conditions are optimum for disease development, rainfall and temperature is effective (Bayram et al., 2007). Yellow rust is an epidemic disease and causes more crop losses

in coastal areas and mid-elevation mountainous regions with cool and rainy climates. The disease, which spreads unnoticed for a few years, can suddenly turn into an epidemic causing significant losses.

Stem rust is seen towards the end of the season and causes significant crop losses in humid conditions and high temperatures. It is known that it causes 50-80% yield losses in many countries (Singh et al., 2004b). Leaf rust disease occurs more regularly each year compared to the other two rust diseases seen in wheat (Chester, 1946; Samborski, 1985; Aykut Tonk and Yüce, 2007). The damage caused by leaf rust on wheat depends on the wheat's growth period at the time of disease infection in relation to the development phase of the rust. Serious losses occur before or during flowering and especially when the flag leaf is infected. Especially in last 30 years, the widespread use of rust-resistant winter wheat varieties have been effective in reducing losses caused by leaf rust. There are many races of leaf rust fungus and varieties are not resistant to all races. New races occur every few years and previously resistant varieties become susceptible. The resistance period of varieties resistant to leaf rust generally remain between 2-4 years (Lipps, 2006). Leaf rust causes approximately 50% yield losses in wheat worldwide. Although it does not cause large and sudden product losses. Yellow and black rust can cause more damage and yield losses. Because the disease is seen more or less every year and can cause significant crop losses over many years. In our country, leaf rust disease is mostly seen in the Aegean and Mediterranean coastal areas, and it also occurs in inland regions as the weather gets warmer. The countries and regions where leaf rust is most common are the USA, Canada, Western Europe, Eastern Russia, Siberia, China, South America, North Africa, India, Japan, Australia and Scandinavia (Altay, 1978; Liu and Kolmer, 1997).

Leaf rust (*Puccinia triticina* Eriks.) Disease Symptoms

Usually on leaf; under optimum conditions, infection can also occur in glumes and awns. Symptoms can also be seen on the leaf sheath and stem. Yield loss occurs in decrease in the number of grains per ear, a decrease in grain size, a decrease in 1000 grain and hectoliter weight and a decrease in protein content (Aktaş, 2001). This disease generally limits the photosynthesis area with the pustules that it forms on the leaves (Khan et al., 1997). On the upper surface of the leaf, initially small, round to oval yellow spots appear on infected tissues. In late stages of the disease, these spots turn into orange coloured pustules and these pustules are surrounded by a yellow halo. These pustules form many spores that can be easily spread around. At late stages of the disease black spores can also form, also orange and black spores may appear together on the same leaf. Sometimes uredospore beds may occur as large beds in the middle and small beds at the edges. This look makes leaf rust identification easier (Singh et al., 2004a).

Main hosts of *Puccinia* spp.:
Wheat species: *Triticum aestivum* L., *T. tingidum, T. dicoccon*, T. *dicoccoides, Aegilops speltoides* and triticale.
Intermediate hosts: *Thalictrum flavum glaucum, Isopyrum fumaroides*.

Method of Determination of Wheat Leaf Rust Breeds (classical racial discrimination)

The wheat varieties which are available today are not mostly resistant to leaf rust. New races appear every few years and by the time resistant varieties become susceptible. Nowadays number of resistance genes are increased significantly. Leaf rust detected and mapped on wheat more than ever during the last 10 years (Bolat et al., 1999). The durability period of leaf rust resistant variety generally varies between 2-4 years. There are many races of leaf rust and the available varieties are not resistant to all races. By reforming of new races, winter spores (teliospores), which are necessary for the fungus to survive in unsuitable conditions, initiate the sexual period on intermediate hosts and enable the formation of new physiological races (Khan et al., 1997). The reasons for using different sets and genotypes in determining physiological races are explained by McIntosh et al. (1995) explained as follows;

- Although the virulence of the rust factor depends on a number of conditions, great changes can be seen depending on the different areas and years in which wheat is grown.
- Rusts can spread over long distances with the wind and getting effective in different areas. This situation increases race diversity in areas where the rust factor may be effective, and in order to define this diversity, the number of genotypes in the differential sets must be increased or expanded by adding new genotypes to these sets over time.

Although it seems possible to work with all defined genotypes although each of which has separate resistance genes, the need for a climate chamber/greenhouse, labor and other costs increases for race identification studies to be carried out with a large number of isolates. Identification of leaf rust races is carried out by seedling tests. Leaf rust 'Thatcher Monogenic Lines' consisting of 20 different genotypes are used as a breed differential set. Each of these lines carries different leaf rust resistance genes. In racial analysis, it is necessary to ensure that the spores are pure. To obtain pure spores, it is very important to start working with single pustule isolation. A differential set is used for each isolate that is sure to be pure. Thatcher Monogenic Lines are in groups of 4 and pure spore suspensions are inoculated to the leaves of 20 different Lr lines. The genotypes in the race-differentiating set are grown in pots and when the second leaf begins to appear, the isolates are The inoculation process will be carried out. Following inoculation the plants are kept in the dark at 18°C and 95% relative humidity for 24 hours and then transferred to climate chamber conditions at 15-20°C. Approximately 14 days after inoculation, scorings can ben done. The scale determines resistant and susceptible genotypes by using 0-4 scale (Stakman et al., 1962) based on infection types. According to this scale, 0, ;, 1, 2 and their combinations are resistant (R), 3-4 and their combinations are considered susceptible (S) genotypes (Table 2).

Table 2. Seedling test scale to determine wheat leaf rust races (Stakman et al., 1962).

Scale		Infection type
0	**Resistant**	There are no macroscopic signs of uredia or infection.
;	**Resistant**	There are no uredia, but necrotic chlorotic spots of different sizes belonging to hypersensitive reaction are seen.
1	**Resistant**	There are small uredia surrounded by necrotic areas.
2	**Resistant**	Small uredia surrounded by necrotic and chlorotic areas are mostly seen.
3	**Susceptible**	Medium-sized uredia with chlorosis, rarely necrosis are seen.
4	**Susceptible**	Large uredia without chlorosis or necrosis are seen.

Breed naming is done according to the North American standard breed naming system using 'Thatcher Isogenic Lines' (Long and Kolmer, 1989), (Table 3). In race diagnoses, each code is determined according to the infection types given by the 20 Lr line, and these codes are brought together to create codes and breeds are determined.

Table 3. *Puccinia* classification of different North American hosts for P. triticina spp. listed in groups of 4 (Long and Kolmer, 1989).

Thatcher Isogenic Lr Genes That Give Infection Types				
Wheat set 1	1	2a	2c	3a
Wheat set 2	9	16	24	26
Wheat set 3	3ka	11	17	30
Wheat set 4	b	10	14a	18
Wheat set 5	3bg	14b	20	28
***Pt* code**				
B	R	R	R	R
C	R	R	R	S
D	R	R	S	R
F	R	R	S	S
G	R	S	R	R
H	R	S	R	S
J	R	S	S	R
K	R	S	S	S
L	S	R	R	R
M	S	R	R	S
N	S	R	S	R
P	S	R	S	S
Q	S	S	R	R
R	S	S	R	S
S	S	S	S	R
T	S	S	S	S

Scoring of adult plant disease observations under field conditions, Modified It is made according to the infection severity range (0-100%) according to the Cobb Scale (Roelfs et al., 1992).

Table 4. Wheat rust disease field adult plant scale (Roelfs et al., 1992).

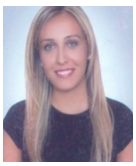
Reaction	Explanation
R	Resistant; necrotic spots with hollow or small pustules.
MR	Intermediate resistant; small pustules surrounded by necrotic areas.
MS	Intermediate sensitive; medium-sized pustules, no necrotic areas.
S	Sensitive; large pustules, necrotic spots, no chlorosis.

R: Resistant; MR: Moderately resistant; MS: Moderately susceptible; S: Susceptible

Conclusion

Wheat rust disease spread to all regions of our country where wheat is produced.The damage caused by rust disease in wheat varies according to climate changes, can sometimes cause epidemics and cause big damage. Yield loss according to susceptibility of varieties, environmental conditions and the races of the pathogens, as well as from year to year from region to region. The disease can spread rapidly over long distances with wind and human factors and the capacity to create new races races in the biological process of the disease multiplies the potential threat to wheat production on a global level. Factors such as the host's reaction to the disease and the phenological stage of the plant when the disease is first seen can affect the possible yield losses to varying degrees. In wheat, leaf rust disease caused by *P. triticina* is commonly seen in the coastal areas of Turkey. In epidemic years, yield losses caused by the disease are considerable. The most economical and environmentally friendly method to minimize yield losses caused by leaf rust disease is to use disease-resistant varieties. Leaf rust significantly affects grain quality and as well as yield. It reduces photosynthesis and increases respiration and evaporation. Thus, it significantly affects the development of the plant. In breeding studies to develop varieties resistant to leaf rust disease in wheat, classical breeding methods were used to crossbreed varieties with different resistance genes and to combine the resistance genes in a single variety. In recent years, DNA studies have become more important. With the development of molecular markers, marker-supported selection studies have accelerated and thus, studies on yield, quality, and resistance to diseases and pests in cereals have increased and successful results have been obtained. Using molecular biotechnology methods in combination with classical breeding methods in the development of varieties resistant to leaf rust disease saves time, labor and cost.

Biodata of Author



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