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Original Research Article

IDENTIFICATION OF YELLOW RUST (*PUCCINIA STRIIFORMIS F.*) TOLERANT SPRING WHEAT GENOTYPES AND FAVOURABLE ENVIRONMENT SUPPORTING DISEASE INCIDENCE

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Abstract: *In Pakistan, the wheat crop faces a significant threat from yellow rust disease caused by Puccinia Striiform F. The impact of this disease on yield varies with the growth stage and the plant's vulnerability. Wheat's diverse growing conditions, favorable weather patterns, and genetic makeup make it a substantial financial and nutritional value crop. The most cost-effective method for managing this issue is cultivating resistant strains. However, resistance in any variety can be overcome by mutation, necessitating ongoing development of new varieties. Research at the National Agricultural Research Centre Islamabad involved screening 50 wheat genotypes, including commercial varieties, new lines, and landraces, over two years (2021-2022 and 2022-2023). Three genotypes, NR-583, NR-559, and NR-559, demonstrated tolerance and high yields. These genotypes showed resistance over the past two years, unlike Pakistan-81 and Galaxy 13, which remained consistently vulnerable. Additionally, an analysis of environmental conditions over the same period revealed that disease proliferation is exacerbated by temperatures ranging from 10 to 20°C, humidity levels over 80%, and heavy rainfall.*

Keywords: Wheat, Yellow Rust, Environment

Introduction

Agriculture is a fundamental element in the economic structure and advancement of countries. It accounts for a quarter of the Gross Domestic Product (GDP) and employs about half of the labor force. Moreover, around 70% of the population depends on agricultural activities, whether directly by participating in farming or indirectly through associated sectors. This field propels domestic economic growth and acts as a channel for generating foreign exchange, thus stimulating other industry sectors. Emphasizing its significance, it is important to note that wheat is the main food crop for most of our nation. On a global scale, wheat-related products make up 40% of the food supply chain, affecting eating patterns worldwide. This highlights the crucial function of agriculture in strengthening a nation's economy and its citizens' health (Anonymous, 2023). As per PBS's 2023 report, wheat output in Pakistan is considerably lower than that of developed countries. This gap in production is primarily due to the superior quality of seeds and the sophisticated agricultural practices utilized in these nations, leading to higher yields per hectare. The wheat crop exhibits significant variability, influenced by its wide-ranging cultivation environments, beneficial climatic conditions, and intricate genetic makeup, making it an essential and nutrient-rich food source. The Food and Agriculture Organization notes that the worldwide equilibrium between wheat supply and demand is maintained (FAO, 2024). Anticipating a surge in global population to 9 billion by 2025, as noted by Chartres and Noble in 2015, presents a formidable challenge in securing food provisions. Consequently, amplifying wheat yield is a crucial goal due to its pivotal role in economic and societal stability. The Food and Agriculture Organization's cereal supply and demand report identifies the EU-27 as the foremost wheat producer, with an extraordinary harvest of 137,443 million tons. Positioned as the runner-up is China, with a yield of 121,000 million tons, while India secures the third spot with 92,000 million tons. The United States follows with a production of 56,613 million tons, Russia with 54,000 million tons, Canada with 29,000 million tons, and Australia with 24,500 million tons. During the agricultural cycle of 2022-23, Pakistan's wheat cultivation spanned 8,834 thousand hectares, reflecting a modest reduction of 2.6% from the prior year's extent of 8,982 thousand hectares, yielding a total of 27.2 million tonnes. Wheat cultivation, representing 10.1% of the nation's aggregate crop cultivation, has a significant economic impact by contributing 2.2% to Pakistan's GDP. As the population of Pakistan continues to grow, there is an increasing need for food, especially wheat, which accounts for 9% of the nation's total food intake. This staple is more commonly consumed in agricultural areas than in cities. With a yearly growth rate of 2.4%, the demand for wheat is set to rise. By 2025, it is anticipated that Pakistan will require 31.415 million tonnes of wheat, necessitating the expansion of farmland to 9.050 million hectares. Looking ahead to 2030, the need for wheat will climb to 34.25 million tonnes, even without increasing the farmland area. Wheat farming is predominantly done in the spring as a Rabi crop in regions like Punjab, Sindh, Khyber Pakhtunkhwa, and northern Balochistan, and in some areas, during the winter season. In Punjab, 90% of the wheat is grown in irrigated fields, with the rest depending on rainfall. The province allocates 6,026,500 hectares for wheat production. Sindh, benefiting mostly from irrigation, has 1,103,600 hectares under wheat cultivation. Nonetheless, wheat fields are susceptible to various diseases, such as different types of rust, smut, karnal bunt, and powdery mildew, leading to considerable financial losses, which Soliman et al. highlighted in their 2012 study. Yellow rust poses a significant risk to wheat production, as it is a disease caused by the fungus *Puccinia striiformis* f. sp. Tritici. While stem and brown rust also cause harm, yellow rust is particularly prevalent in the Pothohar region of Pakistan. The fungus prefers cooler temperatures, ideally between 45 to 54 degrees Fahrenheit, and requires extended periods of leaf wetness to infect crops. Such conditions are common during mild, moist summers and winters, especially near coastal areas or alongside rivers and estuaries. Wheat crops can suffer yield reductions from 5% to 30% due to yellow rust, especially in varieties highly prone to the disease. The fungus produces yellow or orange pustules in striped patterns on the leaves, which impede the plant's ability to photosynthesize by depleting carbohydrates and diminishing the area of healthy green leaves. The disease can even spread to the wheat ears in extreme cases, diminishing the quantity and quality of the grain produced. Strategies often involve applying fungicides and developing resistant wheat varieties to manage this threat. However, due to the pathogen's ability to quickly adapt, continuous crop surveillance and research are essential to address new aggressive strains. The progression in genomic science and traditional genetic methods is enhancing the creation of wheat strains that are more resistant to yellow rust, thus ensuring worldwide wheat production and food stability. The presence of rust poses a significant threat to wheat yields, leading to the use of chemicals to prevent and treat the disease. However, the use of synthetic fungicides adversely affects the metabolic health of both humans and animals. Additionally, this leads to the development of wheat varieties resistant to only one type of pathogen. Researchers and field workers are finding success with strategies that mitigate the impact of stripe rust, which include evaluating the susceptibility of cultivars, the genetic resistance of varieties, the influence of climate, the disease transmission ability of microorganisms, and the process of field management (Temesgen, 2015). Certain plants produce toxic substances to pathogens; these substances can be extracted and applied to infected plants. Given the critical nature of the situation, it is imperative to annually develop disease-resistant wheat varieties, as existing varieties' resistance may eventually diminish. Therefore, it is vital to perform resilience screenings on varieties to assess their resistance to yellow rust and confirm their durability. This forward-thinking strategy is key to protecting crops against this widespread menace.

Methodology

At the Wheat Program of the National Agricultural Research Centre in Islamabad, wheat genotypes underwent evaluation at the adult stage to determine their resistance to yellow stripe rust. During the 2021-2022 and 2022-23 seasons, fifty wheat genotypes were screened for yellow stripe rust resistance. The planting was meticulously arranged with six rows spaced 25 cm apart, each plot extending 5 meters long and 1.5 m wide. Each variety was observed daily to know the impact of temperature and other environmental factors on disease development. Lines were sown early in October to find out the disease severity. All the agronomic practices were kept the same. Yield-related traits include days to flowering, days to maturity, plant height (cm), number of grains per plant, 1000-grain weight (g), and grain yield per kg/ha recorded at maturity: yellow rust reaction, symbol, and field response given in Table 1.

Table 1. Yellow stripe rust reaction, symbol, and field response

Infection type	Host response	Symptoms
1	No disease	No Visible Infection
2	Moderately Resistant-Moderately Susceptible	Small Uredia is surrounded by necrotic areas and medium credit with no necrosis but possibly some distinct chlorosis.
3	Moderately Susceptible-Susceptible	Medium uremia with some necrosis to chlorosis
4	Moderate Resistant	Small credit present surrounded by
5	Resistant	Necrotic with or without minute uremia
6	Resistant-Moderate	Symptoms between resistant and moderately resistant
7	Resistant	moderate resistant
8	Tolerant Resistant Moderately	Uredia is present but has no economic effect on plant
9	Susceptible	Medium uremia with no necrosis but possibly some distinct chlorosis
10	Tolerant Susceptible	Enormous credit is present but not enough to cause economic loss to the plant.
11	Tolerant Susceptible	Symptoms show a mixed response between susceptible and tolerant resistant

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Result & Discussion

Genotypic resistance is the most appropriate and environmentally friendly way, which is economical in controlling losses caused by yellow rust. Experiments were conducted to determine the resistance of different varieties against yellow rust and find the best varieties in Pakistan that can perform better against yellow rust. The response shown by the entire crop is divided into eight categories to observe the disease's effect critically. Screening of wheat varieties in 2021-2022 and 2022–23 showed different results against yellow rust. Out of 50 genotypes, three genotypes, NR-583, NR-559, and NR-559, were resistant, showing the same response in two years. Two varieties, Galaxy-13 and Pakistan-81, were susceptible throughout this period. At the same time, other varieties showed a mixed response. Temperature plays a vital role in disease development and sporulation (Kolmer JA, 2005). The development of yellow rust depends upon temperature, humidity, wind speed, and rainfall of the field area, as the incidence and severity of disease in urediniospores are very much concerned by these environmental factors. The temperature negatively correlates with the disease, while humidity, rainfall, and wind speed positively correlate with disease development (Collard &). Before March, despite low temperatures, humidity and wind speed were not favorable for disease development. During the first week of March, environmental conditions were favorable for disease development as the temperature was low and humidity and wind speed were high, causing urediniospores to infect, multiply, and spread at a higher rate (Hussain et al., 1980). Therefore, by comparing two years of data with the average temperature and humidity from mid-January to mid-April, we can find the environmental conditions that favor the infection of urediniospores (Brian, 2006). The pustules of stripe rust, which contain yellow to orange-yellow uridiospores, usually form narrow stripes on the leaves. Pustules also can be found on leaf sheaths, necks, and glumes. Primary infections are caused by wind-borne urdediospores that may have traveled long distances. The disease may develop rapidly when free moisture (rain or dew) occurs and the temperature ranges between 10-20℃. At temperatures above 25℃, the production of urdiospores is reduced or ceases, and black teliospores are often produced. Only three common varieties showed resistance after comparing the data of three years. Varieties named NR-583, NR-559, and NR-582 were resistant to yellow rust after infection of urediniospores. The tolerant varieties also indicated high yield in Table 3. Pakistan-81 and Galaxy 13 were only susceptible throughout this period, and due to susceptibility to yellow rust, grain yield per plant was also affected. Varieties were cultivated in early October to screen against yellow rust in Pakistan. Due to this, plants reach their dough and maturity stage early when urediospores infect different varieties. That is why losses caused by uredidospore infection were reduced. The flowering stage is most vulnerable, causing a high yield loss when urediospores cause infection (Duplessis). However, environmental factors also play an essential role in disease development. It is concluded that temperature, humidity, and rainfall increase the chances of yellow rust infection after comparing two years of data (Schnurbusch, 2019). The temperature negatively correlates with yellow rust, while humidity and rainfall positively correlate with yellow rust. Spores need a low temperature between 18 and 25ºC humidity. Above 80% and rainfall in the range of 10 mm favor disease a lot (Huerta-Espino *et al*., 2011). Urediospores require six to eight hours of moisture for infection (Dawn, 2008). Wind speed is also needed for spreading urediospores to long distances as they can travel and infect on the continental level. The tolerant varieties can be used in the hybridization program. To protect wheat from yellow rust, it should be cultivated from 15 Oct-30 Oct as infection of urediospores in Pakistan usually occurs in mid-February to March, and at this stage, the plant would have a dough or maturity stage. At this stage, the effect of yellow rust on grain yield is minimized (Dubcovsky & Dvorak, 2007). After the flowering stage, the plant concentrates on its grains; its primary purpose is grain, not fodder. So, chemical application after infection of yellow rust is foolish because humans consume grains, and are hazardous to their lives. Therefore, no chemical fertilizer should be applied after infection of yellow rust after the flowering stage. The primary purpose of urediospores is to turn yellow, which ultimately dies the entire leaves, a good sign for plant grain.

Table 3. Two years response of tested verities Against Wheat Yellow Stripe Rust

No.	Varieties	2021–22	2022–23
1	NR-583	10R	5R
2	NARC Super 21	5R	5R
3	Dilkash-20	5R	10R
4	Blue Silver	0	10R-MR
5	Inqilab	5MRMS	20MS
6	Lu-26	20MSS	60S
7	Kohi Noor	30MSS	60S
8	Maxi Pak-65	10MRMS	60S
9	NR-559	5MRMS	5R-MR
10	A2-180026	10MSS	60S
11	Bahawalpur-97	60MSS	80S
12	W.L-711	40S	60S
13	B.W.P-2000	5S	20MSS
14	Bakhar-2002	20MRMS	10MR

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15	A.S-2002	20MSS	60S
16	NR-582	5MR	20MSS
17	Uqab-2000	10MRMS	30S
18	Durum-97	0	5R
19	Punjnad-01	10MRMS	80S
20	Derawar-97	10MSS	40S
21	Sehar-06	20MRMS	80S
22	Shafaq-06	20MSS	30S
23	Chakwal-50	5MRMS	30S
24	Lasani-08	5R	20MS
25	Mairaj-08	10MRMS	80S
26	NR-566	20TR	5MR
27	Faisalabad-08	10MSS	60S
28	AAS-11	5S-TR	10RMR
29	AARI-2011	20S	10RMR
30	I.D-01	0	70S
31	Punjab-11	5MRMS	5R
32	Millat-11	40S	20MSS
33	Ufaq-02	10MRMS	60S
34	NARC-11	0	TR
35	Galaxy-13	30MSS	40MS
36	Pir-Sabaq	0	60MSS
37	Zincol 2016	TR	10MSS
38	Borlaug-16	0	40S-TR
39	Ujala-15	0	TR
40	Gold-16	5MRMS	60S-5R
41	Johar-16	5MRMS	60S-5R
42	13B-2809	0	50S
43	A1-180003	0	TR
44	A1-180004	0	TS
45	A1-180015	10MRMS	80S
46	A2-180025	20TR	5MR
47	A2-180027	5MSS	30S
48	A4-180059	10MRMS	60S
49	Pakistan-81	40S	50S
50	Galaxy 2013	40S	70S

Table 2: Mean values of wheat genotypes of yield and yield-related traits 2021-22 and 2022-23

2021-22						
Genotypes	**DOF m±S.E**	**DOM m±S.E**	**PH (cm) m±S.E**	**NOG P^{-1}**	**1000 GW (g) m±S.E**	**GYP^{-1} (kg/ha m±S.E**
NR-583	100±0.84	156.6±0.85	98.4±0.88	67.3±0.54	42.5±0.58	5192±0.89
NR-559	95.6±0.58	151.3±0.76	101.7±0.6	64.3±0.87	39.3±0.87	4713±0.58
NR-582	98.3±0.78	154.6±0.79	89.1±0.57	63.3±0.87	35.3±0.78	4427±0.35
NR-566	99.6±0.42	159.3±0.73	96.4±0.54	58.3±0.53	34.8±0.74	4173±0.56
Arooj-2022 (Check	105.6±0.5	161.6±0.71	94.2±0.54	53.3±0.87	32.5±0.86	3192±0.56
2022-23						
Genotypes	**DOF m±S.E**	**DOM m±S.E**	**PH (cm) m±S.E**	**NOG P^{-1}**	**1000 GW (g) m±S.E**	**GYP^{-1} (kg/ha m±S.E**
NR-583	90±0.79	146.6±0.85	91.4±0.88	57.3±0.54	38.5±0.58	3696±0.89
NR-559	83.6±0.88	145.3±0.76	88.7±0.62	54.3±0.87	35.3±0.87	3596±0.58
NR-582	86.3±0.78	144.6±0.79	88.1±0.57	53.3±0.87	35.0±0.78	3501±0.35
NR-566	95.6±0.42	145.3±0.73	95.4±0.54	50.3±0.53	30.8±0.74	3456±0.56
Arooj-2022 (Check	94.6±0.63	149.6±0.71	95.2±0.54	43.3±0.87	25.5±0.86	3192±0.56

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Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.
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Conflict of interest

The authors declared the absence of a conflict of interest.

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