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Original Research Article

SCREENING OF SPRING WHEAT VARIETIES TOLERANT TO BROWN LEAF RUST (*PUCCINIA TRITICINA*) AND IDENTIFICATION OF ENVIRONMENTAL CONDITIONS CONDUCIVE TO DISEASE OUTBREAK.

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Abstract: *In Pakistan, wheat production faces a significant challenge due to leaf rust disease instigated by the fungus Puccinia triticina. This affliction can diminish wheat yields by as much as 10%, a notable contrast to losses caused by other rust diseases like stem and yellow rust. The impact of leaf rust varies, influenced by the wheat plant's stage of growth and its inherent resistance. As Pakistan's staple and most nutritious crop, wheat thrives across varied environmental conditions, benefiting from the nation's diverse climate and the crop's genetic adaptability. The strategic breeding of resistant wheat varieties is the most cost-effective method for managing leaf rust. Nonetheless, this strategy demands continual effort because the pathogen can evolve, potentially breaching the defenses of resistant strains. Research at the University of Agriculture in Faisalabad assessed 25 wheat genotypes, including established commercial strains, emerging lines, and traditional local varieties, for their resilience to brown rust in 2022-23. Notably, three varieties, Arooj 2022, Nishan 21, and Subhani 21remained unaffected by the disease and demonstrated superior grain yields. In contrast, over the past three years, varieties such as Pakistan-81 and Galaxy 13 consistently exhibited vulnerability. Furthermore, an analysis of environmental patterns revealed that cooler temperatures ranging from 17 to 22℃, high humidity levels exceeding 80%, and abundant rainfall contribute to a heightened risk of leaf rust proliferation.*

Keywords: Wheat, Brown Rust, Environment

Introduction

Agriculture stands as a cornerstone for nations' economic growth and societal advancement, contributing to a quarter of the global GDP and employing nearly half of the workforce. It is a lifeline for 70% of the world's populace, directly or indirectly, while propelling foreign exchange and bolstering various sectors. Wheat, a staple for most countries, accounts for 40% of global food consumption, directly or through derivative products (Anonymous, 2023). The adaptability of wheat to varied environmental conditions, its resilience to different climate patterns, and its intricate genetic makeup render it an essential and nutritious food source. The FAO has reported a balance in the worldwide wheat supply and demand (FAO, 2023). Nonetheless, with the anticipated surge in global population to 9 billion by 2025 (Chartres & Noble, 2015), the pressure to secure food availability intensifies, making the augmentation of wheat yield a critical goal due to its economic and societal significance. In the 2023-24 period, wheat cultivation spanned 9 million hectares, yielding a harvest of 28.2 million tonnes. In Pakistan, wheat farming represents 10.1% of the total agricultural activity and contributes 2.2% to the nation's GDP. With Pakistan's population expanding at a 2.4% annual rate, the demand for wheat escalates correspondingly. Projections indicate that 2025 the wheat requirement will reach 31.415 million tonnes, necessitating cultivation of over 9.050 million hectares. 2030, the demand is expected to rise to 34.25 million tonnes, even as the cultivation area remains constant (PBS, 2023). In Punjab, Sindh, NWFP, and specific areas of Balochistan, wheat is cultivated as a rabi crop during the spring. It is also grown in winter in select regions. The vast majority of Punjab's wheat cultivation, covering an area of 6,026,500, depends on irrigation, with a mere 10% contingent on rainfall. Conversely, irrigation supports nearly the entire wheat-growing area of 1,103,600 in Sindh. Despite this, Pakistan's wheat production lags behind that of more developed nations, as reported by PBS in 2023-24. Wheat crops are susceptible to various diseases like rusts—leaf, stripe, and stem—along with smut, karnal bunt, and powdery mildew, all of which diminish yields (Soliman *et al*., 2012). A significant threat to wheat is the fungus *Puccinia triticina*, the agent of leaf rust, which is airborne and capable of infecting regions far from its origin. This particular rust can lead to a reduction of up to 10% in wheat yields. While stem and yellow rusts are comparatively less harmful, the severity of leaf rust's impact on wheat crops hinges on the growth stage and the plants' resistance levels. Optimal conditions for rust infection include high humidity and temperatures ranging from 15-22°C, with the ideal temperature for spore germination being 20˚C, occurring within a brief 6–8 hour window. Early-stage leaf rust infections can slash yields by more than half. Although the visual manifestation of leaf rust may not be as dramatic as that of stripe (yellow) rust, the former's frequent occurrence means it likely contributes to more significant annual global losses. Hussain *et al*., 2006 highlighted Pakistan's deficiency in wheat varieties that are both resistant to these diseases and high-yielding. Leaf rust has had a significant economic impact, with Western Australia experiencing a 20

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million dollar loss due to this disease. Similarly, in 1978, Pakistan saw a reduction in wheat yield by 10%, as noted by Hassan in 1979. The potential yield loss from leaf rust can be as high as 50% in extreme cases. Consequently, developing new wheat varieties that can resist leaf rust is crucial, as the disease can breach the defenses of current strains. A study was initiated to evaluate wheat genotypes for their rust resistance to address this. It aimed to identify those with genetic resilience and ascertain the climatic and weather patterns contributing to brown rust disease's prevalence.

Methodology

At the University of Agriculture in Faisalabad, a study was carried out to identify wheat varieties resistant to leaf rust. During the 2022–23 season, researchers evaluated 25 wheat genotypes for their resilience against brown leaf rust. The experimental design maintained a consistent row spacing of 30 cm, extending each plot 5 meters long. The Morocco variety was utilized as a natural inoculum to promote disease presence and spread. Environmental conditions, such as temperature and humidity, were meticulously documented to determine their influence on the prevalence of brown leaf rust. The wheat was planted in early October to assess the intensity of the disease. Uniform agronomic practices were applied across all genotypes. Data on yield-contributing factors were collected at the time of harvest, including the number of days to flowering, days to maturity, plant height in centimeters, grain count per plant, 1000-grain weight (g), and the total grain yield per plant. Leaf rust reaction, symbol, and field response are given in Table 1.

Table 1: Leaf rust reaction, symbol, and field response

Infection type	Host response	Symptoms
1	No disease	No Visible Infection
2	Moderately Resistant Moderately Susceptible	Necrotic areas and medium credit surround small Uredia 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	Large credit is present but not enough to cause economic loss to the plant
11	Tolerant Susceptible	Symptoms show mix response between susceptible and tolerant resistant

Results & Discussion

Genotypic resistance is the most appropriate and eco-friendly strategy to mitigate the damage caused by leaf rust. The crop's response is classified into eight distinct groups to assess the disease's severity. Observations from screenings of wheat varieties for resistance to leaf rust have shown diverse outcomes. Out of 25 varieties tested, only three were identified as tolerant varieties. In contrast, cultivars such as Galaxy-13 and Pakistan-81 remained entirely vulnerable throughout the period. Other varieties exhibited variable levels of resistance. The temperature plays a crucial role in the disease's progression and the spore production rate (Kolmer JA, 2005). Several climatic factors influence leaf rust's progression, such as temperature, humidity, wind speed, and precipitation. These elements are crucial as they significantly determine where urediospores will settle and the intensity of the disease. A direct relationship exists between the increase in humidity, precipitation, wind speed, and the escalation of the disease. Conversely, temperature stands in inverse relation, meaning that as temperature rises, the likelihood and severity of leaf rust tend to decrease (Collard & Mackill, 2008). Before the onset of March, the prevailing conditions of low temperatures, humidity, and wind speed were unsuitable for disease propagation. However, with the arrival of March's first week, the environment became more hospitable for the infection, proliferation, and dissemination of urediospores, owing to the continued presence of cooler temperatures, elevated humidity levels, and wind velocity. These factors collectively created an optimal setting for the rapid spread of the spores (Hussain *et al*., 1980). On March 4, brown rust spores were detected in Morocco, followed by observations in Sahar-06. To identify the climatic conditions conducive to the infection of urediospores, a comparative analysis was conducted using data on average temperatures and humidity levels from mid-January to mid-April (Brian, 2006). After the artificial introduction of urediospores, varieties such as Arooj 2022, Nishan 21, and Subhani 21 demonstrated resistance to leaf rust. The data presented in Table 3 also indicated that these resistant varieties yielded robust harvests. Conversely, varieties Pakistan-81 and Galaxy 13 were consistently susceptible to brown rust, adversely affecting their grain yield per plant. In Pakistan, planting rust-resistant crops commences in early October to mitigate leaf rust. This timing is crucial as it allows plants to advance to the dough and maturity stages sooner when

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infected by urediospores, thereby reducing the potential losses caused by such infections. During the flowering stage, plants are most vulnerable to urediniospore infection, which can lead to considerable reductions in yield (Duplessis *et al*., 2021).

Environmental factors play a pivotal role in the emergence of diseases. A comprehensive analysis of data spanning three years has revealed that variables such as temperature, humidity, and precipitation significantly increase the risk of leaf rust infection. These findings underscore the importance of considering climatic conditions when assessing disease risk in plant populations (Schnurbusch, 2019). Leaf rust is more likely to occur when there is ample rainfall and humidity, yet it is inversely affected by temperature. The optimal conditions for the proliferation of spores are found within a more relaxed climate range of 18–25°C, coupled with elevated humidity levels. Conversely, a high temperature exceeding 80% combined with significant rainfall, measuring at least 10 mm, markedly promotes the incidence of this disease (Huerta-Espino *et al*., 2011) in Fig1. Pesticides are commonly employed to combat rust, which diminishes the grain yield of wheat crops. However, the chemical composition of synthetic fungicides can adversely affect the health and metabolic processes of both animals and humans. Moreover, these chemicals contribute to developing disease resistance in monoculture wheat varieties. Researchers and agricultural professionals are discovering that a combination of approaches is effective to counteract the damage inflicted by leaf rust. These include leveraging the susceptibility of cultivars, exploiting the genetic resistance of varieties, understanding the interplay with climate, assessing the disease transmission capabilities of microorganisms, and refining field management practices. These strategies collectively contribute to reducing the impact of leaf rust on wheat crops (Temesgen, 2015). Certain plants contain poisonous compounds called pathogens, which are extracted from the plant and applied to diseased plants.

Urediospores require a wetness duration of six to eight hours to initiate infection, as noted (Dawn, 2008). These spores can traverse continents, making wind speed critical for their widespread dissemination. Varieties that exhibit tolerance can be incorporated into hybridization programs. To safeguard wheat against leaf rust, it is advisable to cultivate it between October 15 and October 30. Typically, infections by urediospores occur in Pakistan from mid-February to mid-March, coinciding with the dough or maturity stage of the plant. Dubcovsky and Dvorak (2007) suggest that the influence of leaf rust on grain yield is negligible. After the flowering phase, the plant dedicates its resources to grain production, which is its primary purpose, rather than serving as fodder, as noted by Ahmad et al. (2010). Consequently, applying chemicals to combat leaf rust infections is ill-advised, considering the potentially fatal consequences for humans consuming the treated cereals. Since urediospores primarily cause the leaves to yellow and die, which benefits the plant's grain production, it is advisable to refrain from applying chemicals, water, or fertilizer during a leaf rust infection post-flowering.

Table 2: Screening of wheat genotypes against brown leaf rust

No.	Varieties	2022–23
1	Arooj 2022	5R
2	Nishan-21	10R
3	Subhani-21	5R
4	MH-21	TR
5	Sadiq-21	5MR
6	Nawab-21	10MRMS
7	Rahber-21	5MSS
8	Dilkash-20	TR
9	Akbar-19	20MRMS
10	Bakhar Star-19	TR
11	Ghazi-19	10MRMS
12	Barani 91	5MR
13	PB 85	TR
14	FD 85	5MSS
15	Koh-e-nor-83	5MSS
16	FD-83	5MR
17	NASEER 2000	0
18	Shahkar 2011	5MSS
19	PB-96	0
20	Uqab 2000	TR
21	AS-2002	15MSS
22	Sahar 06	80S
23	Morocco	100S
24	Pakistan-81	100S
25	Galaxy 2013	10S

Table 3: Mean values of wheat genotypes of yield and yield-related traits

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**
Arooj 2022	90±0.79	146.6±0.85	91.4±0.88	57.3±0.54	38.5±0.58	3696±0.89
Nishan-21	83.6±0.88	145.3±0.76	88.7±0.62	54.3±0.87	35.3±0.87	3596±0.58
Subhani-21	86.3±0.78	144.6±0.79	88.1±0.57	53.3±0.87	35.0±0.78	3501±0.35
MH-21	95.6±0.42	145.3±0.73	95.4±0.54	50.3±0.53	30.8±0.74	3456±0.56
Sadiq-21	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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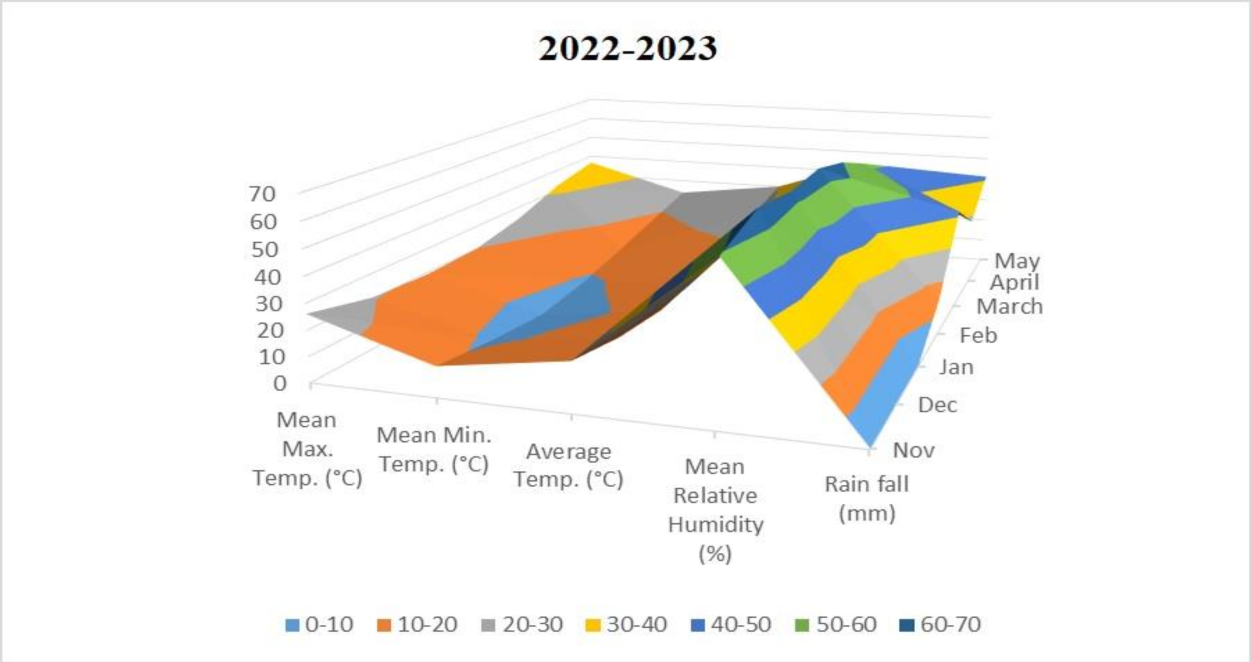

Fig 1. Meteorological data was recorded at Faisalabad during the wheat crop season 2022-23.

Declarations

Data Availability statement

All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned.

Consent for publication

Approved

Funding

Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

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