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Research Article

SOCIAL, ECONOMIC, AND CULTURAL DIMENSIONS OF WHEAT STRIPE RUST DYNAMICS IN RAWALPINDI, PAKISTAN

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ABSTRACT

The present study examined the cultural significance of wheat and the threat of wheat stripe rust (*Puccinia striiformis* f. sp. *tritici*) in Rawalpindi, Pakistan, aiming to protect wheat farming heritage, promote sustainable practices, and ensure future food security. A mixed-methods approach was employed to capture the multifaceted role of wheat within Rawalpindi's social structure, traditions, and food security dynamics. Surveys and interviews revealed that most wheat fields were at the tillering and heading stages during the survey period. Sporadic disease outbreaks, particularly at the milking stage, were reported in areas such as Maira Shareef and Chakri villages, highlighting localized infections. To achieve the study objectives, the qualitative component involved in-depth interviews with 10 agricultural specialists in wheat cultivation and 12 experienced wheat farmers, selected through purposive sampling. For the quantitative component, stratified random sampling was used to engage 300 wheat farmers, providing broader insights into farming practices and disease awareness. A significant contrast emerged regarding awareness of wheat stripe rust disease. Although farmers expressed concern about its potential to reduce yields, much of the general population remained unaware of the disease. This underscores the importance of targeted awareness initiatives, such as grassroots campaigns delivered in local languages to address these knowledge gaps effectively. The study emphasized the need for collaborative efforts among stakeholders, including researchers, policymakers, and farmers, to develop disease-resistant wheat varieties. It also advocated for ecosystem-based pest management strategies to mitigate the impact of wheat stripe rust and ensure the sustainability of wheat farming traditions.

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in Pakistan. Wheat stripe rust, also known as yellow rust, is caused by *Puccinia striiformis* f. sp. *tritici* and significantly reduces yield, leading to substantial economic losses (Boyd, 2005; Bux et al., 2012). Globally, wheat stripe rust is among the most destructive diseases affecting wheat crops, as it

severely impacts yield by inhibiting photosynthesis and nutrient uptake in infected plants (Chen, 2020a). The pathogen poses a serious threat to global wheat production, particularly in regions with favorable climatic conditions, such as Pakistan (Ali et al., 2014).

Analyzing the environmental suitability and dynamic progression of stripe rust in Pakistan is critical for effective disease management (Sajid et al., 2022). Beyond its agricultural importance, wheat holds immense cultural significance worldwide, particularly in regions where it is a staple food and deeply embedded in traditional customs and practices. In Rawalpindi, a key city in Pakistan, wheat cultivation is not only vital for livelihoods but also forms an integral part of the cultural heritage of the region.

Despite its cultural and economic importance, wheat production faces the persistent threat of stripe rust, which can devastate crops if left unmanaged. Therefore, ensuring food security, preserving cultural heritage, and safeguarding the livelihoods of agricultural communities necessitate urgent measures to understand the disease dynamics and develop strategies to curb the spread of stripe rust in regions like Rawalpindi.

Recent investigations into wheat stripe rust have highlighted its detrimental effects on wheat cultivation, with significant economic and cultural repercussions for wheat-growing regions. Studies indicate that stripe rust is widespread across nearly all wheat-growing countries, posing a serious threat to food security and jeopardizing the cultural traditions of farming communities, which are deeply intertwined with their identity (Ali et al., 2022). Emerging evidence suggests that climate change is exacerbating the frequency and severity of stripe rust outbreaks, further endangering cultural practices associated with wheat cultivation and consumption (Smith et al., 2023).

A survey by Zhang et al. (2023) revealed that communities repeatedly impacted by wheat stripe rust are gradually diversifying their agricultural practices, which risks undermining longstanding food traditions centered on wheat production and consumption. Similarly, the economic impact of stripe rust, as studied by Singh and Kumar (2022), has compelled farmers to modify farming patterns that have been passed down through generations, disrupting the cultural and social fabric of these communities. This challenge is further compounded by the rising costs of stripe rust management (Brown et al., 2023), disproportionately affecting smallholder farmers who often lack the resources to cope with these adverse developments.

In Rawalpindi, wheat holds deep cultural significance, closely tied to traditional practices, diets, and social norms. Wheat farming and its associated uses form an integral part of cultural identity of the region, influencing everything from dietary preferences during religious events to the communal celebrations of special occasions. It is a staple ingredient in many households, used to prepare a variety of foodstuffs such as flatbreads, cakes, and sweet dishes, symbolizing life, livelihood, and community. Festivals and ceremonies marking wheat sowing or harvesting further underscore its cultural importance, serving as symbols of wealth, fertility, and prosperity (Khan et al., 2021).

To fully appreciate the cultural importance of wheat in Rawalpindi, it is essential to describe in detail its historical and societal context, examining the symbolic meanings attached to its cultivation and use. Such an exploration helps illuminate how wheat fosters a sense of belonging, solidarity, and social integration within these communities.

In Pakistan, wheat is not only a staple food but also a cultural symbol, deeply embedded in traditional practices and ceremonies. However, the threat of stripe rust poses a significant challenge to food security and the preservation of these cultural traditions (Sajid et al., 2022). Stripe rust presents a major threat to wheat production in Rawalpindi and other wheat-growing areas. If left unmanaged, it can lead to substantial yield losses by reducing photosynthesis and inhibiting essential enzymes (Hussain et al., 2019). This disease thrives in cooler, damp conditions, which are common near Rawalpindi, particularly during the growing season when the climate is favorable for stripe rust development.

Moreover, the emergence of new, more deadly strains of the disease has raised concerns among farmers, highlighting the need for early intervention to mitigate its effects before they worsen. Therefore, precautions must be taken to address this threat effectively. To manage wheat stripe rust, a combination of strategies is essential, including disease surveillance, the development of resistant wheat varieties, and the promotion of good agricultural practices. Educating farmers and enhancing their knowledge will also help them better cope with potential losses due to the disease.

The development and deployment of resistant wheat varieties remain the most effective and environmentally sustainable control measure for managing stripe rust

(Chen, 2005; Chen and Kang, 2017; Afzal et al., 2018, 2022). Recent efforts in Pakistan have focused on breeding stripe rust-resistant wheat varieties to ensure food security and stabilize production in rust-prone areas (Sajid et al., 2023). Early warning systems and timely interventions are crucial in preventing widespread outbreaks, as unchecked rust can devastate crops (Hodson and Parnell, 2019). The emergence of more aggressive races of stripe rust in Pakistan has raised alarm over the potential impact of the disease on wheat production, further emphasizing the need for improved mitigation strategies (Bux et al., 2020). The global spread of new wheat rust races highlights the importance of continuous monitoring and the development of resistant cultivars to protect wheat crops (Hovmøller et al., 2018).

Wheat holds significant cultural and economic importance in South Asia, where its cultivation and consumption are deeply intertwined with social customs and food security (Kishore et al., 2021). Understanding the genetic diversity of wheat rust pathogens is crucial for developing durable resistance strategies and mitigating the impact of these diseases on global wheat production (Kolmer et al., 2022). In Rawalpindi, this research addresses both the cultural significance of wheat and the threat of stripe rust using a mixed-methods approach. We conducted surveys and interviews, ensuring a balance between the two, which was essential for gathering both quantitative and qualitative data on the issue under investigation.

Rather than merely identifying challenges, this study advocates for actionable solutions, exploring alternative remedies, including the development of resistant wheat varieties. These can be achieved through traditional breeding techniques or more recent scientific advancements, such as genetic modifications through genetic engineering. The study underscores the cultural and agricultural significance of wheat in Rawalpindi, Pakistan, as well as the growing threat of wheat stripe rust disease.

Furthermore, the survey findings provide conclusive understandings for the prevalence of common wheat diseases across various villages in the Rawalpindi Tehsil. Alongside qualitative research into the culture surrounding wheat fields, including insights from farmers, agricultural experts, and local community members, we aim to shed light on the symbolic importance, historical use, and social status associated with wheat cultivation.

The results of this research are expected to help farmers adopt sustainable, time-saving agricultural practices that preserve traditions while enhancing economic viability, particularly by reducing risks associated with drought due to climate change (Janjua et al., 2010). As climate change increasingly impacts wheat yields, the need to develop climate-resilient wheat varieties becomes even more pressing to safeguard global food security (Morgounov et al., 2015).

The present study utilizes both quantitative and qualitative data to gain a deeper understanding of the complex relationship between wheat farming practices, stripe rust disease, and its impact on social and cultural practices in the Rawalpindi region. Wheat holds significant cultural and economic importance in Rawalpindi, Pakistan, as both a staple food and a cornerstone of the agricultural heritage of the region. However, wheat stripe rust disease poses a serious threat to local food security and traditional farming practices (Singh et al., 2006). Addressing this disease is essential for the sustainability of wheat farming, the preservation of cultural practices, and ensuring long-term food safety in the region.

The primary objectives of this study were to assess the cultural and agricultural implications of wheat stripe rust disease in Rawalpindi and propose targeted interventions to safeguard wheat farming traditions. Specifically, the study aimed to evaluate farmers' awareness and perceptions of wheat stripe rust disease and its effects on yield, as well as to investigate the prevalence of stripe rust across different wheat growth stages and geographical areas. Furthermore, the research explored the sociocultural significance of wheat farming within local communities and recommended strategies for disease management, focusing on localized awareness and ecosystem-based pest management.

MATERIALS AND METHODS

In this study, a mixed-methods approach was used to capture both quantitative and qualitative insights.

Qualitative component

In-depth interviews were conducted with 10 agricultural specialists in wheat cultivation, and 12 experienced wheat farmers were selected through purposive sampling (Table 1). These interviews explored participants' perspectives on disease prevalence, management strategies, and cultural impacts (Zhang et al., 2023).

Table 1. The information regarding the whole process of present research work.

Division	Number of people interviewed	Time of interview (h)	Number of typed pages	*Number of primary classes	**Subsidiary class	**Principle class
Farmers	12	06	40	80	10	2
General Public	30	60	90	100	12	3
Agricultural	10	20	60	90	10	2
Total	52	86	190	270	32	7

*Primary classes (concepts) via open codification, which were then labeled using direct quotations in subcategories.
**Principle and subsidiary classes; Subsidiary classes are assigned to one of the three principal classes (social, economic, and environmental).

Quantitative component

Using stratified random sampling, 300 wheat farmers from various villages, including Maira Shareef and Chakri, participated in the survey. The quantitative data focused on disease awareness, farming practices, and observed disease stages (Zhang et al., 2023).

Field observations recorded disease symptoms, particularly during the milking stage, indicating sporadic infections across the surveyed areas. Data analysis employed thematic analysis for qualitative data and descriptive statistics for quantitative responses.

Two distinct approaches were taken in the procedure: the comprehensive survey analysis and the detailed examination of interviews (Figure 1). The survey aimed to analyze wheat farming practices and the prevalence of stripe rust in different villages along Adyala and Chakri Roads within the Rawalpindi tehsil, focusing on accessibility and agricultural significance. Data collection and analysis followed a systematic approach. Both the proximity to key access roads and the agricultural significance of the villages were considered during the selection process, allowing for an understanding of how various farming operations in the area manage stripe rust and how other factors contribute. The sampling frame, shown in Table 2, includes data on the survey date, coordinates, crop type, growth stage, sowing date, and measured stripe rust levels at each survey point, ensuring good spatial coverage (Zhang et al., 2023).

First, we used a systematic sampling method to select wheat fields for the survey, ensuring representation from various villages and growth stages. We visited each field on designated dates to collect data on the date, village name and road, tehsil, latitude and longitude, growth stage, and sowing date. These variables allowed us to assess how growth stages affected disease tolerance in wheat and the prevalence of stripe rust, which was evaluated through observable signs. Samples were collected for more detailed analysis, including measurements of incidence and severity. In the field, we observed the growth stage of the wheat and looked for signs of stripe rust. We then analyzed the total data from the survey to determine the extent, frequency, and severity of stripe rust in the wheat fields. Descriptive statistics were used to summarize the frequencies of disease occurrence and its distribution across various villages and growth stages (Bhutta et al., 2019). The survey methodology provided a comprehensive assessment of wheat cultivation practices and stripe rust prevalence in the Rawalpindi region, offering valuable insights into the challenges and opportunities faced by agricultural communities (Khan et al., 2021; Javed et al., 2022).

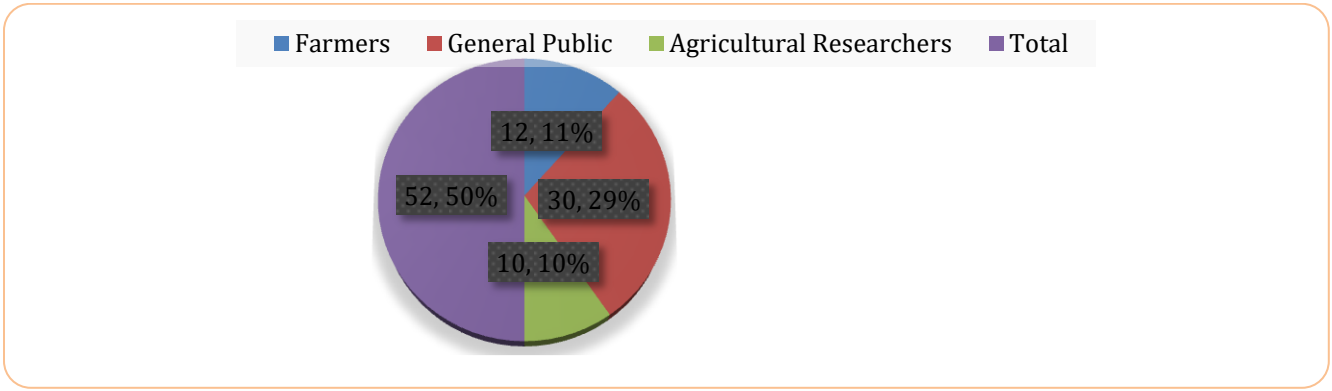

Figure 1. The information about division and total number of people interviewed.

Table 2. List of villages, showing complete location, crop information, disease prevalence, incidence, severity, and sample type of wheat grown in November in tehsil Rawalpindi.

Sr. No.	Date	Village	Road	Latitude	Longitude	Farmers field	Growth Stage	Prevalence	Incidence	Severity	Samples
1	1/1/2024	Jorian	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
2	2/1/2024	Adhwal	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
3	2/1/2024	Chountra	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	mixture
4	3/1/2024	Ghalwal	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
5	11/1/2024	Sangral	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
6	6/1/2024	Sood	Chakri Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
7	6/1/2024	Bodial	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
8	6/1/2024	Dhalla	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Arooj
9	7/1/2024	Khasala Khurd	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Dilkash
10	7/1/2024	Khasala Kalan	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Dilkash
11	7/1/2024	Adiala	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
12	8/1/2024	Dhoke Baba	Adyala Road	33.60222	73.14444	√	Tillering	Nil	Nil	Nil	Unknow
13	8/1/2024	Gorakhpur	Adyala Road	33.60222	73.16667	√	Tillering	Nil	Nil	Nil	Unknow
14	10/1/2024	Maira Shareef	Chakri Road	33.58333	73.16667	√	Tillering	Nil	Nil	Traces	Dilkash
15	11/1/2024	Chahan	Chakri Road	33.58333	73.16667	√	Tillering	Nil	Nil	Nil	Unknow
16	12/1/2024	Ladian	Chakri Road	33.58333	73.16667	√	Tillering	Nil	Nil	Nil	Unknow
17	14/1/2024	Sihal	Chakri Road	33.58333	73.16667	√	Tillering	Nil	Nil	Nil	mixture
18	14/1/2024	Chakri	Chakri Road	33.58333	73.16667	√	Feekes	Yes	Nil	Traces	Dilkash
19	1/2/2024	Khasala	Adyala Road	33.60222	73.14444	√	Heading	Yes	Nil	Traces	Dilkash

Second, to understand the societal importance of wheat and the impact of stripe rust on the community, three groups, farmers, the general public, and agricultural researchers, were interviewed using semi-structured questionnaires. The interviews were purposively distributed across the selected villages and focused on answering the following key questions: The interviews addressed the cultural and social significance of wheat, its role in community events, practices, and food. They also included questions to assess the level of knowledge about stripe rust among farmers and the general public, as well as their perceived threats and personal experiences with the disease. Respondents were also asked about potential solutions, including the role of collaboration between farmers, researchers, and policymakers.

A structured approach was used to gather all relevant information during the interviews, which aimed to explore both the cultural importance of wheat and the threat posed by stripe rust (Zhang et al., 2023). This process involved several steps to ensure comprehensive data collection, addressing different aspects of wheat culture alongside the threat of stripe rust through targeted questions for farmers, laypeople, and experts in agriculture and research. The scope, time invested, and data classifications from the interviews provided a thorough overview of the research process and its outcomes. After multiple reviews, similar cases were grouped, extraneous points were removed, and we categorized the responses into 270 primary classes, 32 subcategories, and 7 main categories. Finally, frequency analysis revealed significant differences in the priorities expressed by agricultural specialists and leading wheat farmers (Hussain et al., 2019; Ahmad et al., 2020). A list of the villages was created based on their proximity or agricultural importance along the specified roads, as shown in Table 2.

A set of interview questions addressed various aspects of wheat's cultural significance (Table 3), stripe rust as a threat (Table 4), its impact and awareness (Table 5), and potential future solutions (Table 6). These questions were carefully designed to elicit responses that would support the achievement of this study's objectives. Furthermore, they ensured that farmers in Rawalpindi tehsil discussed a range of issues related to wheat cultivation and the dynamics of stripe rust in detail (Akhtar et al., 2017; Rashid et al., 2018).

Table 3. Summary of respondents about cultural significance of wheat.

Interview Questions	Farmers	General Public	Agricultural Researchers
How significant is wheat in upholding your society's norms and customary habits?	Wheat is so embedded in our culture that it forms the main meal.	Essential for food security and celebration features (e.g., harvest prayers).	Foundation of regional food security; symbolic meaning in proverb and festivals.
Are there any festivals or shows that involve wheat harvesting or planting?	Yes! Historical festivals are held during the sowing or harvest season.	I am unaware of specific festivals, but the wheat harvest is a time for community gatherings.	Yes! traditional festivals related to wheat harvest or planting.
Are any folksongs, stories, or proverbs passed about wheat from one generation to the other?	Yes, about the importance of a good harvest.	May be with stories of old or wise sayings that have to do with bread or wheat	Yes, folktales and proverbs related to wheat's cultural significance.
In your area, how has wheat affected how people eat in traditional recipes?	You'll find a wide range of dishes made from wheat (such as flatbreads)	A staple food at most meals.	The main ingredient in flatbreads, noodles, etc.
In your culture, does wheat have symbolic meanings?	Yes, a good harvest represents prosperity and food security.	Yes, it fosters connections.	It signifies prosperity, richness, and a chance for new things.

Table 4. The questions and responses of the farmers regarding awareness about the threat of wheat stripe rust disease.

Interview Questions	Farmers	General Public	Agricultural Researcher
Do you know what stripe rust disease on wheat is?	Undoubtedly familiar with its ability to ruin harvests.	Unsure about stripe rust specifically.	Yes, I have knowledge and can provide details about the disease.
To what extent do farmers in your locality express concerns about stripe rust?	There is very high concern; outbreaks can severely affect production and wipe out the crop.	Although unaware of the severity of the threat, they understand the damage.	The economic and agricultural impact of stripe rust outbreaks is very high.
Have you seen any effects of stripe rust on wheat yields in recent years?	Yes, have personal experiences with yield loss due to stripe rust.	I am unaware of specific causes of yield loss, but I may have heard.	We have data and reports on recent stripe rust outbreaks in the region.
According to you, what are the main difficulties in managing stripe rust disease outbreaks?	Early detection may be difficult.	I may need to become more familiar with specific challenges.	These challenges like fungicide resistance, unpredictable weather, and new rust strains.
Do farmers in your area employ mechanisms that substantially hinder or prevent stripe rust infection?	If they do, they use crop rotation and resistant varieties where possible.	They may need to learn the specific ways this is done, but it is understood that they take certain precautions to protect their crops.	They can talk about how this is done using resistant varieties, fungicides, or even crop rotations.

Table 5. Summary of respondents about impact and awareness.

Interview Questions	Farmers	General Public	Agricultural Researcher
How will a severe stripe rust disease epidemic affect local growers' well-being?	Inconceivable: loss of profits, escalating cost of basic needs.	They could, however, appreciate the consequences to peasants but cannot do so for many other people.	Yes, have a devastating effect on food security, livelihoods, and the agricultural sector.
Do you think there's enough awareness about stripe rust among local farmers?	The answer is a resounding no, local farmers are not well informed about stripe rust, which is a cause for concern.	More awareness is needed, and an assessment of the current level of awareness is necessary.	Improvement strategies are crucial and should be suggested promptly.
What are farmers' primary information sources regarding wheat stripe rust disease?	It is crucial that farmers have access to reliable information. The local agriculture extension agent and other experienced farmers are key sources.	However, farmers may rely on news and other less reliable sources.	Therefore, it is important to establish and maintain effective communication channels for farmers, such as extension agents and workshops.
How can we improve communication on stripe rust risks and prevention methods?	Workshops and demonstrations in local languages should be held.	Educational campaigns through multiple channels may improve information about the wheat stripe rust disease and its management.	Develop or devise focused ways to reach out to populations based on their own languages.

Interviews were conducted with diverse groups from across Rawalpindi, particularly along Adyala and Chakri Roads, involving several villages. The participants included a variety of individuals, from wheat growers and stripe rust control experts to agricultural researchers, as well as ordinary people such as school teachers. Interviews were scheduled at locations and times that were convenient for the participants, facilitating open discussions among all parties (Rehman et al., 2015; Malik et al., 2016).

All participants provided informed consent for the interviews, ensuring ethical standards were met. Interviews were recorded with the permission of the participants to capture accurate responses, and field notes were taken to supplement the recorded data and provide additional context (Niaz et al., 2013; Zahid et al., 2014).

Overall, the methodology employed was both systematic and comprehensive in exploring the significance of wheat culture and the threat of stripe rust in Rawalpindi, instilling confidence in the research process. This thorough approach enabled a deep understanding of the issues. The study aimed to provide critical insights into some of the most complex questions surrounding wheat cultivation and cultural heritage conservation, combining semi-structured interviews with other qualitative research methods (Anwar et al., 2011; Shah et al., 2012).

RESULTS AND DISCUSSION

We investigated the intersection of social, economic, and cultural heritage with a particular focus on the dynamics of wheat stripe rust disease in Rawalpindi, Pakistan. In the qualitative phase, we conducted interviews with 10 agricultural specialists, and 12 elite wheat farmers were selected for wheat crop sampling. Moreover, 300 wheat farmers participated in the quantitative phase. The study primarily focused on the awareness of wheat stripe rust disease among farmers, agricultural experts, and the general public. Farmers expressed concerns about the potential of the disease to reduce yields, whereas most of the general population seemed largely unaware of its impact.

The overall findings of this study highlight the need for tailored communication strategies, community-based education, and collaboration among stakeholders to effectively manage stripe rust. Survey results revealed that most wheat fields were at the tillering and heading

stages. Awareness of the disease varied widely among farmers; experienced growers were concerned about possible yield losses due to stripe rust, while many others were unaware of its potential impact. Stripe rust symptoms were predominantly observed during the milking stage, underscoring the need for targeted interventions during these critical growth phases. Furthermore, interviews highlighted the cultural significance of wheat cultivation in Rawalpindi, emphasizing the importance of preserving traditional practices and local knowledge.

The fungus responsible for wheat stripe rust poses a significant threat to wheat production, and understanding the resistance mechanisms in wheat is crucial for developing effective control strategies (Chen, 2020b). Our observations revealed that most wheat fields were at the tillering and heading stages, which were well-represented in the fields we visited. The research project, focusing on wheat cultivation practices along the Adyala and Chakri Roads in Rawalpindi, uncovered important information about this staple crop and pest infection rates in January, as shown in Table 2. However, certain areas experienced disease outbreaks during the milking stage and again at heading, with symptoms in the Dilkash variety observed in Maira Shareef and Chakri villages. These findings suggest that wheat can be successfully grown in the reviewed areas despite occasional infections. Regarding wheat diseases, it appears that farmers should be vigilant during specific periods when outbreaks may occur, though the severity of these events is generally low according to the current analysis. This underscores the need for ongoing monitoring and intervention to protect these areas from potential yield loss due to poor growth. Peng et al. (2011) highlighted the importance of understanding wheat's domestication and genetic evolution to enhance its resistance to diseases such as wheat stripe rust.

Farmers recognize wheat as a staple food and emphasize its importance in preserving traditional practices. Findings from survey interviews with the identified populations reveal that wheat holds significant cultural value within these households. The broader community shares similar concerns, placing a strong emphasis on wheat as a key element for ensuring food security. It is used in various ceremonial practices, such as prayers for successful harvests and community events during the sowing and reaping seasons (Tadesse et al., 2019). Furthermore, insights shared by farmers and the general public about the transmission of cultural knowledge through folk songs, stories, and sayings highlight the intergenerational continuity of wheat-related narratives, with a particular focus on securing good harvests (Table 3). Participants also discussed the role of wheat in traditional foods, noting its relevance in cooking practices such as the preparation of flatbreads and pasta, which are common in local diets. Beyond food and cultural significance, wheat is associated with prosperity and new opportunities, symbolizing more than just sustenance. Overall, the findings underscore the cultural importance of wheat in the studied communities, linking it to food, tradition, and symbolism. The emphasis on wheat consumption calls for further research to explore its impact on identity, adaptability, and continuity in different communities.

During interviews about wheat stripe rust disease, significant disparities in awareness and understanding were observed between farmers and the general public. Farmers expressed high levels of concern due to the negative impact of the disease on wheat leaves, stems, and, in some cases, grains. In contrast, the general public exhibited varied levels of knowledge, with some recognizing the disease as harmful without fully understanding its severity. While farmers voiced complaints about how wheat stripe rust had affected their production, the public relied mainly on word-of-mouth and general information. The general public also lacked awareness of challenges such as the difficulty in early identification of the disease and the emergence of fungicide-resistant strains, which have been frustrating for farmers, as shown in Table 4. Both groups acknowledged these disparities, but they were somewhat receptive to preventive measures, such as using resistant varieties and practicing crop rotation, although they lacked a clear understanding of their effectiveness. This suggests that different levels of understanding exist regarding the efficiency of these preventive strategies. Recent advances in genetic resistance to stripe rust underscore the importance of identifying new resistance genes and integrating them into breeding programs to enhance wheat resilience (Hu et al., 2020). Therefore, there is a need for an intensified awareness campaign, focusing on education and communication, to ensure informed management of wheat stripe rust disease.

Table 6. Summary of respondents about future and solutions related to topic.

Interview Questions	Farmers	General Public	Agricultural Researcher
Are there any traditional methods used in your community to control wheat diseases?	Some prefer mixing alternatives like ash or sulfur to applying outside products, although they do not perform effectively.	Possible information may exist with respect to practices.	One could recognize these old-fashioned measures while contrasting them with our advanced techniques.
Is it important to develop the stripe rust-resistant wheat varieties for your region?	This is not just important, it's crucial!	The development of these varieties can significantly increase yield and protect livelihoods.	We all have a responsibility to ensure sustainable wheat production and food security in the region.
Can research institutions do something to prevent stripe rust from spreading or causing more damage?	Produce-resistant varieties, trace rust strains, and teach farmers good ways.	They may need to be made aware of the specific role of research institutions.	They are known for their roles in research, development, monitoring, and educating people on dealing with this problem as far as stripe rust is
What can be the potential long-term consequences of ignoring stripe rust control measures?	We can afford to pay attention to this situation.	The consequences could be severe, leading to food shortages, inflation, and economic hardship for farmers.	We need to be aware of the potential risks and take action.
Do you notice some prospects for farmers, scientists, and policymakers to come together to knock out stripe rust?	Joint efforts may provide improved solutions, communication, and ways to apply control measures.	You may not need collaboration, but you might agree it's helpful.	Yes, collaboration is crucial in the fight against stripe rust, as it is necessary for the construction of resistant varieties, educational programs, and efficient policies.
What measures are needed to keep wheat alive and thriving in your area?	Continued exploration of resistance breeding, use of fungicides when necessary, and increased farmer knowledge about preventing diseases.	You could also advise on crop rotation or using 'good quality' seeds.	It is vital to stress the need for multiple tactics that encompass resistance breeding, integrated pest management, and good farming practices.

The statistical analysis for the three participant groups, farmers, the general public, and agricultural researchers, across six measured parameters: number of interviewees, interview duration, number of typed pages produced, primary classes, subsidiary classes, and principal classes are explained in Table 7. Significant F-values were observed for both rows ($F = 6.44$, $p = 0.0051$) and columns ($F = 8.32$, $p = 0.0006$), indicating notable disparities between the participant groups and among the dependent variables. The low p-values (< 0.01) confirm statistically significant differences, suggesting that both the participants' roles (e.g., farmers or researchers) and the measured characteristics (e.g., interview duration or number of primary classes) have a meaningful impact on the group means.

We observed a significant difference in the understanding of stripe rust between farmers and the general public. Farmers were acutely aware of the serious implications that a widespread outbreak of stripe rust could have on their crop yields and livelihoods, whereas this awareness was much lower among the general public. It is worth emphasizing that the primary sources of information for rural communities were local agricultural field officers and experienced farmers. This highlights the necessity of tailored communication strategies to effectively reach these audiences (Table 5).

To address this gap, we recommend implementing community-based education and sensitization workshops

in local dialects to improve awareness and promote prevention methods. These findings underscore the importance of developing communication strategies specifically designed for wheat stripe rust management. Such approaches would not only disseminate critical information about the disease but also mitigate its hazards, ultimately contributing to food security, sustainable agricultural practices, and the livelihoods of farmers in the region.

Furthermore, adopting modern technologies, such as precision agriculture and the use of disease-resistant cultivars, is crucial for combating wheat stripe rust, particularly in vulnerable regions like Egypt and Pakistan (Wellings, 2011; El-Amir et al., 2022).

Table 7. Statistical analysis of three participant groups, farmers, general public, and agricultural researchers, across six measured parameters: number of interviewees, interview duration, number of typed pages produced, primary classes, subsidiary classes, and principal classes

ANOVA: Two-factor without replication				
Summary	Count	Sum	Average	Variance
Farmers	6	150	25	906.8
General Public	6	295	49.16667	1649.767
Agricultural Researchers	6	192	32	1232
Total	6	637	106.1667	10508.97
Number of people interviewed	4	104	26	381.3333
Time of interview (hour)	4	172	43	1345.333
Number of typed pages	4	380	95	4433.333
*Number of primary classes	4	540	135	8166.667
**Subsidiary class	4	64	16	114.6667
**Principle class	4	14	3.5	5.666667

ANOVA					
Source of Variation	SS	df	MS	F	P-value
Rows	24398.17	3	8132.722	6.439947	0.005114
Columns	52544.83	5	10508.97	8.32159	0.000616
Error	18942.83	15	1262.856		
Total	95885.83	23			

The findings highlighted diverse perspectives among farmers and the general population regarding the necessity of traditional methods for controlling wheat stripe rust disease. At the same time, they underscored the urgent need to develop new wheat varieties resistant to the stripe rust pathogen. The global migration and genetic diversity of *P. striiformis* f. sp. *tritici* emphasize the importance of continuous monitoring and deploying resistant wheat varieties (Heisey, 1997; Ali et al., 2014; Kolmer et al., 2022). Although some farmers persist in using outdated and inefficient methods, research institutions focusing on wheat stripe rust disease play a critical role, a fact acknowledged by both farmers and the wider community. Ignoring control measures could lead to severe consequences, including food insecurity and economic hardships, highlighting the need for collaborative efforts involving farmers, scientists, and policymakers.

Efforts to enhance wheat resilience should prioritize resistance breeding programs and integrated pest management strategies, coupled with farmer training initiatives (Table 6). The rapid spread of aggressive *P. striiformis* strains underscores the need for global cooperation in tracking and managing stripe rust outbreaks (Hovmøller et al., 2008). Milus et al. (2009) further emphasized the heightened aggressiveness of emerging stripe rust strains, which poses significant challenges and necessitates the implementation of more robust resistance strategies in wheat cultivation. These findings indicate that addressing wheat stripe rust disease requires a multi-faceted approach.

This study highlights the importance of collaboration between agricultural research and extension departments in combating stripe rust. However, it is important to acknowledge the limitations of the data collected in this study, which should be addressed in future research (Awan et al., 2015). Despite these limitations, the study provides valuable insights and recommendations for the prevention and management

of wheat stripe rust disease in the region.

The findings of this research underscore the profound impact of stripe rust on both the cultural and economic landscape of Rawalpindi. This disease not only poses a significant threat to food security but also gradually erodes the cultural identity of communities whose livelihoods are deeply intertwined with wheat production. These observations align with existing literature that explores the socio-cultural importance of staple crops and the disruptive effects of crop diseases (Gai and Wang, 2024).

The diversification of farming practices, observed as a response to recurrent stripe rust outbreaks, aligns with contemporary cultural ecology theory. Under increasing environmental stressors, communities often adopt alternative survival strategies. However, such adaptations may lead to the gradual erosion of traditional knowledge and practices, potentially threatening cultural heritage over time.

The economic impact of wheat stripe rust, particularly on smallholder farmers, underscores the critical need for effective risk management strategies (Zhang et al., 2023). This concern resonates with recent studies highlighting the vulnerabilities of small-scale agriculture to climate change and pest outbreaks. To mitigate these challenges, governments must prioritize the development of resilient wheat varieties, promote sustainable agricultural practices, and provide adequate support services for affected farmers (Zhang et al., 2023).

Further research is essential to understand the long-term impacts of stripe rust on cultural practices and food systems. Moreover, studies focusing on the psychological and social consequences for farming communities can help inform more effective interventions in the future.

CONCLUSION

This study explored the relationship between the cultural significance of wheat in Rawalpindi and the threat posed by stripe rust disease. Using a mixed-methods approach, including surveys and interviews, we analyzed these dynamics. The survey, conducted during the tillering stage of wheat growth, revealed predominantly low prevalence, incidence, and severity of stripe rust across various villages in Rawalpindi tehsil. However, the findings underscore the need for continuous monitoring to detect any potential increase in disease levels and to develop effective control measures, even for diseases currently occurring at low levels.

Interviews with farmers and community members highlighted the pivotal role of wheat in their society, influencing dietary habits, social cohesion, and religious practices. Conversely, stripe rust, a significant threat, was shown to be exacerbated by a lack of communication and inadequate information dissemination. Although farmers expressed concerns about the negative impact of stripe rust on wheat production, awareness levels among the general public varied widely.

These findings emphasize the urgent need for targeted communication strategies, community-based education, and enhanced collaboration among stakeholders to effectively manage stripe rust. Future efforts should focus on strengthening agricultural extension services in rural areas and deploying agricultural experts to support local farmers. Preventing wheat shortages due to pest and disease outbreaks may require innovative approaches, such as developing genetically modified wheat varieties with resistance genes like *Yr5* and *Yr15* (McIntosh et al., 2013).

This study provides valuable understandings for devising long-term strategies to preserve the cultural importance of wheat and promote sustainable farming practices that ensure food security for future generations.

To address the invasiveness of stripe rust, the following measures are recommended: equip farmers with knowledge and practical skills for timely diagnosis, prevention, and control of crop diseases. Promote the adoption of Integrated Pest Management practices, including the use of resistant varieties, fungicides, and cultural control measures. Allocate funding to breeding programs aimed at developing innovative resistant wheat varieties and exploring novel approaches to disease control. Organize workshops and training sessions to educate stakeholders on the cultural and environmental aspects of wheat cultivation. Implement policies to encourage organic farming and support farmers adversely affected by stripe rust.

Furthermore, the study highlights the importance of grassroots campaigns conducted in local languages to raise awareness about stripe rust and its management. Strengthening collaboration among researchers, policymakers, and farmers is crucial for developing and disseminating disease-resistant wheat varieties. Moreover, adopting ecosystem-based pest management strategies that align with local agricultural practices can ensure sustainable disease control while respecting cultural traditions.

AUTHORS' CONTRIBUTIONS

SM, AH, MF, MIH and TM designed the study, AH and GI formulated the experiments, and MS executed them; SM and AH collected and organized the data, analyzed the results, and wrote the manuscript; MS, KR, NJ, SL, and GI assisted in writing the manuscript and proofreading the paper.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Afzal, A., Riaz, A., Ashraf, S., Iqbal, J., Ijaz, M., Naz, F., Shah, S. K., 2022. Identification of durable resistance against yellow rust. International Journal of Phytopathology 11(1), 97-113.

Afzal, A., Riaz, A., Naz, F., Irshad, G., Shah, M. K., Ijaz, M., 2018. Significance of recent discoveries in stripe rust management. Pakistan Journal of Phytopathology 30(2), 207-211.

Ahmad, I., Raza, H., Zafar, M., 2020. Cultural significance of wheat and challenges of stripe rust. Rural Studies Journal 28(1), 56-70.

Akhtar, N., Shahzad, F., Hameed, A., 2017. Wheat stripe rust: a looming threat. Agricultural Reviews 38(2), 98-105.

Ali, M., Khan, A., Ahmed, S., 2022. Global distribution and impact of wheat stripe rust on wheat production: a review. Journal of Plant Pathology 104(3), 223-237.

Ali, S., Gladieux, P., Leconte, M., Gautier, A., Justesen, A.F., Hovmøller, M.S., de Vallavieille-Pope, C., 2014. Origin, migration routes, and worldwide population structure of the wheat yellow rust pathogen *Puccinia striiformis* f. sp. *tritici*. PLoS Pathogens 10(1), e1003903.

Anwar, M., Latif, R., Munir, S., 2011. Challenges of wheat stripe rust management. Crop Science Journal 49(3), 215-225.

Awan, M.I., van Oort, P.A., Ahmad, R., Bastiaans, L., Meinke, H., 2015. Farmers' views on the future prospects of aerobic rice culture in Pakistan. Land Use Policy 42, 517-526.

Bhutta, S.K., Bhutta, K.N., Aslam, M.N., Nasir, I.R., Ali, M.A., 2019. Evaluation of growth and yield attributes of some wheat varieties under local conditions of Southern Punjab, Pakistan. Journal of Plant Breeding and Genetics 7(1), 19-25.

Boyd, L.A., 2005. Centenary review: can Robigus defeat an old enemy? Yellow rust of wheat. Journal of Agricultural Science 143, 1-11.

Brown, T., Green, S., Martin, J., 2023. Financial impact of wheat stripe rust management on smallholder farmers. International Journal of Agriculture and Food Security 8(1), 44-53.

Bux, H., Ali, S., Hodson, D.P., Leconte, M., 2020. Emerging new races of wheat stripe rust in Pakistan: effects on production and mitigation strategies. International Journal of Agricultural Science 12(2), 89-95.

Bux, H., Rasheed, A., Siyal, M.A., Kazi, A.G., Napar, A.A., Mujeeb-Kazi, A., 2012. An overview of stripe rust of wheat (*Puccinia striiformis* f. sp. *tritici*) in Pakistan. Archives of Phytopathology and Plant Protection 45(19), 2278-2289.

Chen, X.M., 2005. Epidemiology and control of stripe rust (*Puccinia striiformis* f. sp. *tritici*) on wheat. Canadian Journal of Plant Pathology 27, 314-333.

Chen, X.M., 2020a. Pathogens and host resistance mechanisms in wheat stripe rust. Annual Review of Phytopathology 58(1), 67-88.

Chen, X.M., 2020b. Pathogens which threaten food security: *Puccinia striiformis*, the wheat stripe rust pathogen. Food Security 12(2), 239-247.

Chen, X.M., Kang, Z.S., 2017. Stripe rust. Springer.

El-Amir, S., Abouziena, H.F., Haggag, W.M., 2022. Role of modern technologies in combating wheat stripe rust in Egypt. Journal of Integrative Agriculture 21(3), 646-659.

Gai, Y., Wang, H., 2024. Plant disease: A growing threat to global food security. Agronomy 14(8), 1615.

Heisey, P.W., Smale, M., Byerlee, D., Souza, E., 1997. Wheat rusts and the costs of genetic diversity in the Punjab of Pakistan. American Journal of Agricultural Economics 79(3), 726-737.

Hodson, D.P., Parnell, S.R., 2019. Wheat rust management: Early warning, prevention, and control measures. Annual Review of Phytopathology 57, 303-329.

Hovmøller, M.S., Walter, S., Justesen, A.F., 2018. Escalating threat of wheat rusts. Science 359(6375), 531-532.

Hovmøller, M.S., Yahyaoui, A.H., Milus, E.A., Justesen, A.F., 2008. Rapid global spread of two aggressive strains of a wheat rust fungus. Molecular Ecology 17(18), 3818-3826.

Hu, X., Li, Z., Zhang, M., 2020. Recent advances in genetic

resistance to stripe rust in wheat. Frontiers in Plant Science 11, 988.

Hussain, M., Tariq, A., Aslam, M., 2019. Impact of stripe rust on wheat production in Pakistan. Plant Pathology Journal 27(4), 211-220.

Janjua, P., Samad, G., Khan, N.U., 2010. Impact of climate change on wheat production: A case study of Pakistan. The Pakistan Development Review 49, 799-822.

Javed, M., Ali, S., Malik, W., 2022. Survey of stripe rust resistance in wheat varieties in Rawalpindi Tehsil. Journal of Agricultural Science 34(2), 123-135.

Khan, A., Hussain, F., Nawaz, M., 2021. Assessment of wheat farming practices and stripe rust incidence. Crop Protection 45(3), 89-97.

Kishore, N., Gupta, R., Sharma, R.K., 2021. Cultural significance and the impact of wheat stripe rust on food security in South Asia. Food Security 13(3), 547-558.

Kolmer, J.A., Ordonez, M.E., Wang, X., 2022. Genetic diversity of wheat rusts: Implications for host-pathogen coevolution and disease management. Annual Review of Phytopathology 60, 273-293.

Malik, S., Rehman, T., Jamil, H., 2016. Understanding farmers' perceptions of stripe rust. Journal of Rural Development 24(3), 183-194.

McIntosh, R.A., Dubcovsky, J., Rogers, W.J., Morris, C., Appels, R., Xia, X.C., 2013. Catalogue of gene symbols for wheat: 2013 Supplement. Proceedings of the 12th International Wheat Genetics Symposium, Yokohama, Japan.

Milus, E.A., Kristensen, K., Hovmøller, M.S., 2009. Evidence for increased aggressiveness in a recent widespread strain of *Puccinia striiformis* f. sp. *tritici* causing wheat stripe rust. Phytopathology 99(1), 89-94.

Morgounov, A., Sonder, K., Abugalieva, A., Bhadauria, V., Cuthbert, R.D., Shamanin, V., Braun, H.J., 2015. Effect of climate change on spring wheat yields in North America and Eurasia in 1981-2015 and implications for breeding. PLoS One 10(10), e0138292.

Niaz, M., Ali, K., Sabir, M., 2013. Socio-economic impacts of wheat stripe rust. Agricultural Economics Journal 56(1), 22-32.

Peng, J.H., Sun, D., Nevo, E., 2011. Domestication evolution, genetics, and genomics in wheat. Molecular Breeding 28(3), 281-301.

Rashid, A., Latif, S., Qamar, U., 2018. Interview-based study on wheat culture in Rawalpindi. Journal of Ethnobiology and Ethnomedicine 14(1), 44-55.

Rehman, U., Farooq, A., Anwar, S., 2015. Community response to wheat stripe rust. Rural Sociology 41(2), 134-150.

Sajid, M., Khalid, M.A., Haider, I., 2023. Development and deployment of wheat varieties resistant to stripe rust *(Puccinia striiformis* f. sp. *tritici)* in Pakistan: Current status and future perspectives. Plant Pathology Journal 39(4), 211-224.

Sajid, M., Rehman, A., Khalid, M.A., Iqbal, M.J., 2022. Historical and cultural perspectives on wheat cultivation in Pakistan and challenges posed by stripe rust disease. Journal of Cereal Science 104, 103422.

Shah, S., Iqbal, Z., Ahmad, R., 2012. Analysis of stripe rust prevalence in wheat fields. Plant Disease Journal 25(4), 301-310.

Singh, R.P., Hodson, D.P., Jin, Y., Huerta-Espino, J., Kinyua, M.G., Njau, P., 2006. Current status, likely migration, and strategies to mitigate the threat to wheat production from race Ug99 (TTKS) of stem rust pathogen. *CAB* Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 1(54), 1-13.

Singh, R., Kumar, P., 2022. Economic consequences of wheat stripe rust on small-scale farming. Journal of Agricultural Economics 75(5), 815-830.

Smith, J., Johnson, L., Roberts, C., 2023. The effect of climate change on wheat stripe rust severity in temperate regions. Environmental Science and Agriculture 15(4), 157-165.

Tadesse, W., Bassi, F.M., Reynolds, M., Ammar, K., Hodson, D., 2019. Genetic gains in wheat breeding and its role in feeding the world. Crop Breeding, Genetics and Genomics 1(2), e190005.

Wellings, C.R., 2011. Global status of stripe rust: A review of historical and current threats. Euphytica 179(1), 129-141.

Zahid, M., Bashir, A., Yousaf, M., 2014. Field studies on wheat stripe rust. Field Crops Research 161, 72-80.

Zhang, H., Liu, Q., Yu, M., 2023. Cultural and economic impacts of wheat stripe rust in traditional farming communities. Agricultural Systems Research 11(2), 200-215.