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Research Article

ASSESSING LEAF RUST RESISTANCE IN PAKISTANI WHEAT LANDRACES AND ITS IMPACT ON GRAIN YIELD

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ABSTRACT

Leaf rust, caused by the fungus *Puccinia triticina*, is the most widespread rust disease in wheat, involving two hosts: common wheat as the primary host and specific plants like *Thalictrum speciosissimum* or *Isopyrum fumaroides* as alternate hosts. The present study investigated the crucial interplay between leaf rust resistance and grain yield in 10 Pakistani wheat landraces. By employing comprehensive assessments, including field trials and molecular analyses, the research sheds light on the resistance mechanisms within these landraces. Moreover, it examines the direct correlation between leaf rust resistance levels and the resultant grain yield, unraveling critical insights into the potential enhancement of wheat cultivars amidst the escalating challenges posed by this devastating disease. The findings hold promise for optimizing agricultural strategies, ensuring sustainable wheat production, and safeguarding global food security. The study focused on 10 bread wheat landraces, examining traits crucial for high-yielding varieties. Traits such as days to heading, days to maturity, grain filling period, flag leaf area, peduncle length, spike length, grains per spike, as well as measurements like 10-grain width, 10-grain length, and 100-grain weight were recorded. The analysis of variance (ANOVA) for these ten genotypes highlighted significant differences ($P<0.05$ and $P \leq 0.01$) across all traits.

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INTRODUCTION

Rusts, which are caused by the fungus (*Puccinia* spp), are damaging diseases affecting wheat and hold economic significance in agriculture (Boyd, 2005). These diseases manifest as reddish-brown pustules and dots present on the leaves and glumes of wheat plants (Singh, 2000). The optimal conditions for rust disease development involve warm days, mild nights, moisture, and humidity. Leaf rust, caused by the fungus *Puccinia triticina*, is the most widespread rust disease in wheat (Bolton, 2008; Marasas, 2004; Vikas et al., 2014). It involves two hosts: common wheat as the primary host and specific plants like *Thalictrum speciosissimum* or *Isopyrum fumaroides* as alternate hosts. While mainly affecting leaf blades, it can also infect sheaths and glumes in highly susceptible varieties, potentially leading to significant yield losses of over 30% if early infection occurs (Ahmad et al., 2010).

Moreover, *P. triticina* has been reported in other wheat varieties like durum, wild emmer, domesticated emmer wheat, and triticale (Singh, 2017). The decrease in crop yield due to leaf rust can vary from 5% to 20%, escalating to around 50% during outbreaks (Knott, 1989; Eversmeyer and Kramer, 2000).

In contrast to rust diseases like stripe rust and stem rust, leaf rust thrives in a milder temperature range (10–25°C). Yet, with the effects of global warming, leaf rust has significantly widened its affected areas and accelerated its appearance throughout the year (Helfer, 2014). Wheat landraces are seen as genotypes that possess strong resistance to both biotic and abiotic stresses, ensuring consistent high yields within cost-effective farming systems (Zeven, 1998). They are referred to as farmers' or folk varieties, highlighting the significant role farmers play in their development and upkeep. Landraces exhibit genetic diversity and various traits due to natural and human-driven selections (Bechere et al., 1996), thriving in diverse agro-ecologies (Mondini et al., 2010), and adapting to different local farming systems (Myers, 1994; Teklu and Hammer, 2008).

Wheat landraces are valued biological resources due to their genetic variability and possession of genes absent in modern cultivars. Consequently, selecting landraces with new HMW-GS alleles has become part of certain breeding strategies to enhance their effectiveness. Therefore, the objective of the present study was to highlight the damaging impact of rust diseases caused by *Puccinia* spp. on wheat crops and their economic significance in agriculture. Furthermore, it aimed to emphasize the importance of wheat landraces as genetic resources with strong resistance traits and their role in breeding strategies to improve crop effectiveness.

MATERIALS AND METHODS

Procurement of wheat germplasm

A set of 10 wheat landraces including a rust susceptible control "Morocco" was collected from Wheat Wide Crosses and Cytogenetic laboratory (WWC), Islamabad. Wheat landraces are mentioned in Table 1.

Table 1. Names of wheat landraces of *Triticum aestivum* L.assessed for morphological variations and leaf rust resistance

Sr. No.	Plant identification number	Name of landrace	Region of collection
1	40951	Type No.11	Punjab, Pakistan
2	181087	8639	Sindh, Pakistan
3	182079	S-3	Sindh, Pakistan
4	182084	S-10	Sindh, Pakistan
5	182087	S-12	Sindh, Pakistan
6	182088	S-13	Sindh, Pakistan
7	270016	756	KPK, Pakistan
8	270022	779	Azad Kashmir, Pakistan
9	270023	821	Azad Kashmir, Pakistan
10		Morocco	

Site of experiment

The research study was undertaken at Wheat Research Institute (WRI) Sakrand, District Nawabshah, Sindh.

Experimentation

Wheat landraces were cultivated to observe the agro-morphological diversity of different traits. The landraces were planted in four rows, each row being 20 m long, with a distance of 30 cm between rows. Genotypes were planted with three replications following the randomized complete block design (RCBD).

Cultural practices

All cultural practices, such as irrigation, moulding, weeding, and fertilization, were applied according to standard recommendations.

The wheat landraces were evaluated for resistance to leaf rust. Details and the procedures applied during data recording were as follows:

Disease inoculation

Various methods were used for inoculation, including transplanting rusted leaves, brass rubbing, scattering with rust inoculums, and sprinkling with talcum powder (Stubbs et al., 1985). The site was sprayed weekly during the booting stage to apply pressure. The experimental field was watered shortly afterward to maintain soil moisture, as moisture favors rust infection and development.

Observation of disease

Disease response was observed until physiological maturity using a modified Cobb's scale as described by Peterson et al. (1948). The final disease rating was recorded at the time of 80-100% disease severity.

Data analysis of leaf rust resistance response in wheat landrace

Disease data recording in the field

For field data, i.e. Infection types (IT) and disease severity were noted in the field at three stages;

First data of leaf rust severity and disease response was recorded at Zadoks growth (Booting) stage 45. Second data of leaf rust severity and disease response was recorded at Zadoks growth (Heading) stage 50. Third data of leaf rust severity and disease response was recorded at Zadoks growth (Flowering) stage 60.

Data analysis

Relative resistance index (RRI) (Table 2) was used to observe the severity of brown rust. Mean comparison was measured using Microsoft excel 2013.

Table 2. Reaction types shown by rust disease and their description.

Sr. No.	Reaction type	Description
01	Immune	No observable infection
02	Resistant	Noticeable chlorosis or necrosis, no uredia
03	Moderately Resistant	Uredia (slight) surrounded by either chlorotic or necrotic areas
04	Moderately Susceptible	Uredia (average size) no necrotic margins
05	Susceptible	Uredia (large) with no necrosis and little or no chlorosis

McNeal et al. (1971) rating scale for Host response and infection type.

Comparative performance

Comparative performance of wheat landraces based on response to brown rust and grains yield was measured.

Disease data recording in the field

Field data, specifically infection types (IT) and disease severity were noted at three stages:

The first set of data regarding leaf rust severity and disease response was recorded at Zadoks growth stage 45 (Booting). The second set of data regarding leaf rust severity and disease response was recorded at Zadoks growth stage 50 (Heading). The third set of data regarding leaf rust severity and disease response was recorded at Zadoks growth stage 60 (Flowering).

Comparative performance

Comparative performance of wheat landraces based on response to brown rust and grains yield was measured.

RESULTS AND DISCUSSION

Leaf rust resistance in wheat landraces

The primary record of brown rust severity and disease reaction was noted at the Zadoks growth (Booting) stage 45. Rust data were recorded up to the functional maturity of the wheat. The results obtained regarding leaf rust severity and disease response of 10 wheat genotypes grown under field conditions at the Wheat Research Institute Sakrand are briefly mentioned in Table 3.

According to the obtained data, 4 cultivars (V-1, V-2, V-3, and V-5) showed moderately susceptible (MS) responses, three (V-7, V-8, and V-9) showed moderately resistant (MR) responses, two (V-6 and Morocco) were moderately susceptible to susceptible (MSS), and two cultivars (V-4 and V-6) presented a highly resistant (HR) response to brown rust at the booting stage.

Disease assessment of wheat landraces at heading (stage 50)

The data of two cultivars (V-5 and Morocco) showed susceptible (S) responses, one (V-9) showed moderate resistance (MR), four (V-2, V-3, V-7, and V-8) showed moderate susceptibility (MS), one (V-1) exhibited moderate susceptibility to susceptibility (MSS), and two cultivars (V-4 and V-6) showed resistance (R) responses to leaf rust at the heading stage of 50 (Table 4).

Disease assessment of wheat landraces at flowering (stage 60)

Two cultivars (V-1 and V-3) showed moderate susceptibility to susceptible MSS; four (V-4, V-7, V-8, and V-9) showed moderate resistance MR; two (V-5, V-2, and Morocco) were susceptible S; and one (V-6) showed resistance R response to leaf rust at the flowering stage 60 (Table 5).

Table 3. Leaf rust response of wheat landraces at Zadoks growth (Booting) stage 45.

Genotype	Replication No. 1	Replication No.2	Replication No.3	S.E
V-1	MS 20	MS 20	MS 20	0.0
V-2	MSS 30	MS 20	MS 20	5.773
V-3	MS 20	MS 20	MS 20	0.0
V-4	HR 5	HR 5	HR 5	0.0
V-5	MS 20	MS 20	MS 20	0.0
V-6	HR 5	HR 5	HR 5	0.0
V-7	HR 5	MR 10	MR 15	2.886
V-8	HR 5	MR 15	MR 10	2.886
V-9	MR 10	MR 10	MR 10	0.0
Morocco	MSS 30	MSS 30	MSS 30	0.0

Table 4. Leaf rust response of wheat landraces at Zadoks growth (heading) stage 50.

Genotype	Replication No. 1	Replication No.2	Replication No. 3	S.E
V-1	MS 20	MS 20	MSS 30	3.333
V-2	MSS 30	MS 20	MS 20	3.333
V-3	MR 10	MS 20	MS 20	3.333
V-4	R 10	R 10	R 10	0.0
V-5	S 40	S 40	S 40	0.0
V-6	R 10	R 10	R 10	4.409
V-7	HR 5	MR 10	MS 20	4.409
V-8	HR 5	MR 10	MS 20	4.409
V-9	MR 10	MR 10	MR 10	0.0
Morocco	S 40	S 40	S 40	0.0

Table 5. Leaf rust response of wheat landraces at Zadoks growth (flowering) stage 60.

Genotype	Replication No. 1	Replication No.2	Replication No.3	S.E
V-1	MSS 30	MS 30	MSS 30	0.0
V-2	MSS 30	MSS 30	S 40	4.409
V-3	MR 15	MSS 30	MSS 30	4.409
V-4	MR 10	MR 10	MR 10	0.0
V-5	S 50	S 50	S 50	0.0
V-6	MR 10	R 5	R 5	3.333
V-7	HR 5	R 10	MR 15	2.886
V-8	HR 5	MR 15	MR 10	2.886
V-9	MR 10	MR 10	MR 10	0.0
Morocco	S 70	S 65	S 65	1.666

An experiment was conducted to assess the resistance of Pakistani wheat landraces against Brown rust at the Wheat Research Institute in Sakrand, Nawabshah. The study also delved into the performance of these landraces in response to leaf rust, grain yield, and their morphological diversity. The morphological characteristics play a pivotal role in the investigation, assessment, and preservation of durum wheat landraces (Zarkti et al., 2012). This study focused on 10 bread wheat landraces, examining traits crucial for high-yielding varieties (Inamullah et al., 2006). Traits such as days to heading, days to maturity, grain filling period, flag leaf area, peduncle length, spike length, grains per spike, as well as measurements like 10-grain width, 10-grain length, and 100-grain weight were recorded. The analysis of variance (ANOVA) for these 10 genotypes highlighted significant differences ($P<0.05$ and $P \leq 0.01$) across all traits.

Leaf rust (*Puccinia triticina* f.sp. *tritici*) causes substantial damage to wheat production globally (Hussain et al., 2011). Evaluating existing genotypes for resistance remains an effective strategy to control brown rust in wheat (Singh et al., 2000; Martinez et al., 2001). Field data revealed varying levels of resistance among landraces, with some being resistant, moderately susceptible to susceptible, or highly susceptible to brown rust. Approximately 60% of Pakistani wheat landraces exhibited resistance to brown rust, attributed to possessing rust-resistant genes that confer prolonged effectiveness against leaf rust, even when the pathogen undergoes modifications (Kolmer, 2003).

The findings suggest that landraces displaying resistant responses against disease severity could be considered as durable rust resistance lines against *Puccinia triticina* Erik's, warranting their inclusion in breeding programs. Similar studies by Sohail et al. (2013) and Javed et al. (2011) also support these outcomes regarding wheat's resistance to leaf rust in Pakistan. The study emphasizes that susceptible genotypes may suffer higher yield losses compared to resistant ones. Yield losses tend to decrease as genotypes shift from susceptible to resistant reactions. This insight could prove beneficial in future screenings to identify resistant sources in wheat germplasm against leaf rust, contributing to their utilization in breeding programs (Becheree et al., 1996). The comparative performance of wheat landraces based on their response to leaf rust, grains per spike, and 100-grain weight was also observed in this study. Highly susceptible landraces exhibited fewer grains per spike and lower 100-grain weight, while resistant landraces showed higher numbers of grains per spike and heavier 100-grain weight. The study indicates that as leaf rust disease escalates, yield losses in terms of grains per spike and 100-grain weight also increase. These results align with studies conducted by Kassem et al. (2011).

Ultimately, this research underscores the potential for projecting and enhancing plant yield by considering yield parameters and introducing high-yielding wheat genotypes in cultivation to enrich wheat production.

AUTHORS' CONTRIBUTIONS

SS collected the data and wrote and paper; MSS and ARJ reviewed the manuscript; GSC provided technical support.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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