Research Article

Evaluation of Different Triazole Fungicides for the Management of Leaf Rust of Wheat Under Agro-Ecological Zone of District Layyah

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Abstract | The present study was designed to evaluate seven different foliar fungicides such as Cholorothalonyl+metalyxl @ 2000 ml/ha; Pyraclostrobin @ 375 ml/ha; Sulphur @ 2500 g/ha; Diphenoconazole @ 375 ml/ha; Tubiconazole+trifloxystrobin @ 303 g/ha, Polyram DF @ 625 g/ha and Propiconazole @ 625 g/ha for the management of leaf rust of wheat in Research Area of Plant Pathology, Hafiz Abad Research Station, B.Z.U. Bahadar Sub-Campus, Layyah, during crop seasons 2018-2019 and 2019-2020 in Randomized Complete Block Design (RCBD) with three replications. Statistically significant ($P<0.05$) disease control was observed by Propiconazole (29.30 %) in the first crop season 2018-2019 and 28.50% in the second crop season 2019-2020, followed by Polyram DF (27.60% and 26.30%), Tubiconazole+trifloxystrobin (21.50% and 26.30%), Diphenoconazole (23.30 and 22.57), Sulphur (25.38, 24.50), Pyraclostrobin (19.57 and 18.38), Cholorothalonyl+metalyxl (18.30 and 16.30) and control (0%) during both successive seasons. The maximum number of grains per spike was recorded by Propiconazole (48.3 and 45.40) and Polyram DF (47.3 and 44.50), followed by Tubiconazole+trifloxystrobin, Diphenoconazole, Sulphur, Pyraclostrobin, Cholorothalonyl+metalyxl as compared to control. Highly Significant ($P<0.05$) 1000-grain weights were recorded by Propiconazole (42.06 g and 40.60 g) followed by Polyram DF (41.49 g and 39.13 g), Tubiconazole+trifloxystrobin (39.39 g and 37.70 g), Diphenoconazole (36.70 g and 35.17 g), Sulphur (34.15 g and 33.50 g), Pyraclostrobin (32.46 g and 31.57 g) and Cholorothalonyl+metalyxl (30.70 g and 29.38 g). All fungicides proved most effective for controlling leaf rust severity in semi-arid region of district Layyah.

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Introduction

The Asian countries Iran, Afghanistan, Pakistan and Turkey are among the world's largest producers of wheat. Pakistan cultivates it on an 8.6 Mha area, producing 26.051 million tons (GOP, 2020). The low grain production is due to an outdated farming infrastructure, older plant varieties, and insufficient fertilizer use (Ellis *et al*., 2014). Non-resistant cultivars experienced losses in yield due to leaf rust outbreaks in 2009 and 2011 (Ziyaev *et al*., 2011). The spread of disease reduced grain production. Outbreaks of leaf rust occur because susceptible cultivars are cultivated on large scales (Javaid *et al*., 2018). Fungicides protect wheat crops and reduce grain losses (Ali *et al*., 2022). In Brazil, leaf rust affected area is 2.3 Mha, in China 6 Mha, in Argentina 8.8 Mha, and in Australia it is about 5.27 Mha (Gianessi and Williams, 2011).

Leaf rust, caused by *Puccinia triticina* Ericks, is a common disease that affects wheat crops. It is identified by the presence of pustules with yellow-dark to brown uredia, which can be observed from the emergence of seedlings until the crop reaches maturity. Temperatures ranging from 15–20°C with high humidity and at least three hours of continuous wetness promote pathogen sporulation, resulting in disease epidemics (Ali *et al*., 2022, 2023). Furthermore, the fungus requires at least three hours of continuous moisture to successfully infect the host plant. It is noteworthy that leaf rust is caused by an obligate parasite thus, even in the absence of wheat; the pathogen may be able to survive solely within the volunteer plants that grow along roadsides, in fields, and along highways.

The management of leaf rust severity requires the cultivation of cultivars that exhibit resistance to this disease (Hussain *et al*., 2017). The reduction of primary inoculum can be achieved by removing volunteer plants during their early developmental stages (Razzaq *et al*., 2018). According to Ali *et al*. (2022), the application of triazole and strobilurin fungicide combinations within permissible range is the preferred method for leaf management. The most effective approach to managing this disease included the integrating cultural, genetic, and fungicide control methods (Atiq *et al*., 2017; Javaid *et al*., 2018).

The most common wheat cultivars in Pakistan have low yields and low resistance to different races of rust pathogens (Bundessortenamt, 2020). Fungicides with specific targets mitigate the resistance. Due to poor timing, higher vulnerability to one disease in years and with high infection pressure might result in significant yield losses despite massive fungicide use (Joshi *et al*., 2017). Thus, disease pressure, geographical and ecological considerations must all be considered in cultivar selection each year (Bundessortenamt, 2020). The economic feasibility of combining disease control thresholds with cultivar resistance has not yet been studied.

Fungicides for winter wheat crop are important part of its production technology (Jrgensen *et al*., 2008). Multi-criteria and successful inspections play vital roles in fungicide applications in the US (Wegulo *et al*., 2011). In Argentina fungicides are used to control wheat rusts on resistant cultivars even (Simón *et al*., 2011). Fungicide application is fast and easy way to manage disease which will ultimately contribute towards increase in production of wheat cultivars. Given the need to increase grain productivity, fungicides are vital as wheat production varies worldwide and world population is growing fast (Ray *et al*., 2012). The connection between fungicides and wheat varieties is that, green leaves remain effective for a long time, exhibiting absence of disease, and supply assimilates for wheat grain (Dimmock and Gooding, 2002; Lian *et al*., 2022).

Wheat varieties have varying levels of disease tolerance. It is not well understood how resistant cultivars react to fungicides. Some studies reported yield responses under strong disease pressure of rusts; however, did not report the effect of fungicides on their yields (Morgounov *et al*., 2015; Klocke *et al*., 2022). The purpose of this research was to evaluate the impact of fungicides on yields for a wheat variety SH-2 with varying degrees of resistance to leaf rust.

Materials and Methods

Present study was conducted in the Research Area of Plant Pathology, Hafiz Abad Research Station, College of Agriculture, B.Z.U., Bahadur Sub-Campus Layyah to test the seven different foliar fungicides with one control for their ability to protect wheat from leaf rust (Table 1). The trials were conducted during crop seasons 2019-2020 and 2020-2021 using a RCBD. Every year on November 24th, susceptible wheat variety SH-2 were planted. The soil was adequately prepared

Table 1: *Name of fungicides used for the management of leaf rust of wheat.*

S. No.	Treatments	Common name	Scientific name	Concentrations	Company name
1	T1	Foliogold	Cholorothalonyl+metalyxl	@2000 mL/ha	Syngenta
2	T2	Headline	Pyraclostrobin	@375mL/ha	Qol group
3	T3	Sulphur	Sulphur	@2500g/ha	Evyol group
4	T4	Score	Diphenoconazole	@375mL/ha	Syngenta
5	T5	Nativo	Tubiconazole+trifloxystrobin	@303g /ha	Bayer
6	T6	Metiram	Polyram DF	@625g /ha	Swat agro chemical
7	T7	Tilt	Propiconazole	@625mL /ha	Syngenta
8	T8	Control			

with a double disc harrow, and recommended quantity of NP (158:114 kg/ha) was applied with seed-cum-fertilizer. After the initial watering, we manually spread urea at the rate of 2.5 bags/hac. Herbicides were sprayed using a T-Jet/Flat Fan nozzle after the second watering. In total, 19 acre-inches of water were used to irrigate the field three times. Each fungicide was evaluated against leaf rust severity in separate plots before spraying. By erecting 4x3 m wire frame portions within each plot, yield data was recorded by using method proposed by Seebold *et al*. (2004). The harvesting was done after crop turned yellow. Harvested crop was wrapped and stacked in the field to protect from rain. Mini-threshers were used to accomplish the harvesting, and manual labour was used for cleaning. After sorting, the data of harvested seeds was recorded. The parameters recorded were disease control (%); number of grains per spike and 1000 grain weight (g).

Statistical analysis

The collected data were analyzed statistically by applying the analysis of variance technique at a 5% probability level (Steel *et al*., 1997).

Results and Discussion

Effect of fungicides on disease control (%) of leaf rust

The application of all treatments exhibited a significant (P < 0.05) reduction in the leaf rust severity during both crop seasons, 2019-2020. However, Propiconazole proved the most effective in controlling leaf rust severity, with 29.30 % reduction in disease in the first crop season 2018-2019, whereas there was a 28.50% reduction in the second crop season 2019-2020. Similarly, Polyram DF controlled the disease severity by 27.60% in the first crop season and 26.30% in the second growing season. The fungicide such as Tubiconazole+trifloxystrobin, significantly reduced the disease severity by 21.50% in the first crop season and 26.30% in the second crop season followed by Diphenoconazole, Sulphur, Pyraclostrobin and Cholorothalonyl+metalyxl over control (Table 2).

Table 2: *Evaluation of different fungicides to control leaf rust severity during crop seasons 2018-2019 and 2019-2020.*

Treatments	Disease control (%)	
	2018-2019	2019-2020
Propiconazole	29.30a	28.50a
Polyram DF	27.60b	26.30b
Tubiconazole+trifloxystrobin	21.50e	20.19e
Diphenoconazole	23.30d	22.57d
Sulphur	25.38c	24.50c
Pyraclostrobin	19.57f	18.38f
Cholorothalonyl+metalyxl	18.30g	16.30g
Control	0.00h	0.00h

Efficacy of different fungicides on number of grain/ spike against leaf rust

Significant (P<0.05) variations were observed in the number of grains per spike with the foliar applications of different fungicides during both rating seasons, i.e., 2019-2020. It was observed that by application of Propiconazole maximum number of grains per spike were recorded at 48.3 and 45.40 in the first and second crop seasons, respectively, over control. Similarly, the maximum number of grains per spike was recorded by Polyram DF 47.3 and 44.50 during 2018-2019 and 2019-2020, respectively, as compared to Tubiconazole + Trifloxystrobin, Diphenoconazole, Sulphur, Pyraclostrobin and Cholorothalonyl+metalyxl over control (Table 3).

Efficacy of different fungicides on 1000-grain weight against leaf rust

The present study indicated that applying all treatments significantly (P<0.05) affected the 1000-grain weight against leaf rust severity. Among all fungicides, Tilt gave the most effective results in increasing the 1000-grain weight of wheat. With the application of Propiconazole maximum 1000-grain weight (42.06 g) was recorded in the first crop season 2018-2019 and second crop season 2019-2020 (40.60 g). Similarly, with the application of polyram DF 41.49 g 1000-grain weight was observed in the first crop season and 39.13 g in second growing season, respectively. Tubiconazole+trifloxystrobin recorded significant (P<0.05) result in 1000-grain weight (39.39 g) in first crop season and 37.70 g in second crop season compared to Diphenoconazole, Sulphur, Pyraclostrobin, Cholorothalonyl+metalyxl over control (Table 4).

Table 3: *Efficacy of different fungicides on no. of grain/spike against leaf rust during crop season 2018-2019-2019-2020.*

Treatments	No of grain/spike	
	2018-2019	**2019-2020**
Propiconazole	48.3a	45.40a
Polyram DF	47.3b	44.50b
Tubiconazole+trifloxystrobin	46.4c	43.60c
Diphenoconazole	45.8d	42.80d
Sulphur	45.2e	42.20e
Pyraclostrobin	44.4f	40.93f
Cholorothalonyl+metalyxl	43.5g	37.90g
Control	35.4h	37.30h

Table 4: *Efficacy of different fungicides on 1000-grain weight against leaf rust during crop season 2018-2019-2019-2020.*

Treatments	1000-grain weight	
	2018-2019	**2019-2020**
Propiconazole	42.06a	40.60a
Polyram DF	41.94a	39.13b
Tubiconazole+trifloxystrobin	39.39b	37.70c
Diphenoconazole	36.70c	35.17d
Sulphur	34.15d	33.50e
Pyraclostrobin	32.46e	31.57f
Cholorothalonyl+metalyxl	30.70f	29.38g
Control	29.00g	27.50h

Fungicides are utilized to increase grain yield; however, the chemical reactions of these substances vary. It is the fact that the effectiveness of most sprays depends on their composition, the cost of their by-products, and the degree of grain yield. Farmers are ready to apply fungicides to control rusts if the cost of these compounds remains low with some additional benefits (increase in grain) (Ali *et al*., 2022).

In the past 15 years, leaf rust has become a chronic threat to the wheat crop in Central Asia, with four recorded outbreaks and severe output losses (Ziyaev *et al*., 2011; Sharma *et al*., 2013). In addition, most yield losses in past studies were based on estimations. Grain production losses which are attributable to leaf rust in Central Asia, are further hampered by lack of knowledge of well-conducted studies. This study provides evidence-based estimates of the losses to Middle Eastern grain output caused by leaf rust. In certain rust-prone places where conditions are favourable for the establishment of leaf rust, epidemics occur annually (Ali *et al*., 2017). These results suggested that the sowing of non-resistant cultivars is influenced by leaf rust because of the low yield of grain due to multiple seasons (Ali *et al*., 2019).

Farmers can manage it by using fungicides on wheat varieties that have low resistance to leaf rust (Ziyaev *et al*., 2011) and those are mostly cultivated in huge areas of middle Asia. By treating their fields with fungicides to prevent leaf rust, wheat farmers have increased their yields by roughly 42%, allowing them to not only successfully combat the disease but also improve the quality of their grain. In addition, the spraying of fungicides enhances the quality of straw, which is widely utilized as animal feed in middle Asia and emerging nations. In Asia, where leaf rust is the persistent problem, the only solution to increase wheat yield is planting resistant varieties against leaf rust. Current research indicates that resistant varieties of leaf rust are prevalent and widespread in middle Asian nations (Sharma *et al*., 2013).

The application of fungicides proved the most efficient for reducing the severity of leaf rust in the fields. Ram *et al*. (2022) observed that Propiconazole fungicide was effective in suppressing rust in wheat crops, which concurred with these findings. The effectiveness, rates, and timing of fungicide treatments were crucial for wheat rust control. In the United States, five fungicides were effective against barley and wheat rust diseases: propiconazole, azoxystrobin, propiconazole + trifloxystrobin, strobilurin, and azoxystrobin + propiconazole. However, the use of fungicides significantly increased the price of wheat production, which was a burden for many farmers, particularly in developing countries. The usage of fungicides caused health issues for users, negatively impacted the environment, and led to the selection of fungicide-resistant disease strains (Ali *et al*., 2018). Growing cultivars with an acceptable amount of fungicides are the best way to prevent these challenges and control rust.

Conclusions and Recommendations

It was concluded that, under optimum conditions, leaf rust could significantly decrease grain production in susceptible varieties. Growers in the agroecological zone of district Layyah can boost grain output and protect against the risk of disease epidemics by using a variety of triazole fungicides such as sulpher, metiram, and propiconazole to prevent the inoculum of disease on susceptible genotypes.

Novelty Statement

In Pakistan, no research has been carried out on the positive effects of triazole fungicides on *Puccinia recondita* infections and yield attributes simultaneously, which represents the main novelty of this study.

Author's Contribution

Yasir Ali: Conceived the research idea.
Muhammad Shahbaz and Hafiz Muhammad Aatif: Conducted research.
Salman Ahmad and Muhammad Zeeshan Majeed: Writing of the manuscript.
Saqib Saeed and Mohsin Iqbal: Proof-read the manuscript.
Mozam Ejaz and Javaria Khalid: Analyzed the research data.

Conflict of interest
The authors have declared no conflict of interest.

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