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Evaluation of fungicides against leaf rust of wheat incited by *Puccinia triticina* Eriks

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Abstract
The present study entitled "Evaluation of fungicides against leaf rust of wheat incited by *Puccinia triticina* Eriks" was conducted to evaluate effect of six different fungicides (T_1)Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1% (T_2) Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 0.1%, (T_3) Tebuconazole 50% +Trifloxystrobin 25% WG @ 0.1%, (T_4) Mancozeb75%WP @ 0.25%, (T_5) Propiconazole 25% EC @ 0.1%, (T_6) Tebuconazole 25.9% w/w @ 0.1% against the leaf rust of wheat, the study's finding showed that, of the different fungicides treatments, (T_3) Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1% was the most successful, as evidenced by the significantly higher grain yield (29.11 q/ha), plant height (80.95 cm), 1000 grain weight (49.19 gm) and dry matter yield (54.11 q/ha), all these results superior over the tested fungicides and untreated control.

Keywords: Leaf rust, fungicides, wheat, yield

Introduction
Wheat (*Triticum spp*.) has been associated with human civilization since 3000-4000 BC, evolving from its ancestor Einkorn to the widely cultivated bread wheat (*T. aestivum* L.) of today. Known as the "King of Cereals," wheat is one of the most important staple crops, providing food for a majority of the world's population. Belonging to the family Poaceae and genus Triticum, it originated in the Near East and Ethiopian Highlands but is now cultivated across diverse agro-climatic regions worldwide.

Ensuring food security is a matter of prime importance for any country and is often define in terms of food production, food access and food utilization among food grains. A key cereal crop for attaining global food security is wheat. It is the second most produced crop and is grown all over the world. However, around the world, biotic and abiotic stressors mostly impact production of this crop. The most significant issue restricting wheat output, among these, is pathological illnesses, since several pathogens attack wheat plants and result in significant losses in yield and quality. This crop is known to be affected by many fungal, bacterial, viral, nematodes and mycoplasmal diseases viz., rusts i.e. black rust or stem rust (*Puccinia graminis tritici*), yellow/orange rust or stripe rust (*Puccinia striiformis*) and brown rust or leaf rust (*Puccinia triticina Ericks*.), smuts (*Ustilago nuda tritici*), bunts (*Nevossia indica*), powdery mildew (*Erysiphae graminis*), spot blotch (*Bipolaris sorokiniana*) and foliar blights (Alternaria species.), which limits its production to a considerable extent. Among these, rusts have been a major disease of various crops since times immemorial. In USA losses due to rusts was recorded to the extent of 50 per cent or more during 1918 to 1976 (Roelfs, 1978) [12].

Wheat rust pathogens are highly destructive due to their continuous evolution and ability to spread over long distances through airborne uredospores. This adaptability has led to the breakdown of crop resistance and significant losses in wheat production. To manage wheat rusts in India, triazole fungicides such as Propiconazole, Tebuconazole, and Triadimefon are commonly used for effective control. However, resistant wheat varieties remain the preferred choice among farmers due to their cost-effectiveness and minimal environmental impact. Further, growers are encouraged to adopt rust resistant cultivars (Bhardwaj *et al*., 2019) [6].

The cultivation of improved resistant cultivars has contributed significantly to increased wheat yields. However, continuous monocropping has occasionally resulted in leaf rust epidemics. Continuous efforts are always made to reduce the yield losses in wheat caused by the rusts. Although chemical control of this disease is known but it is not practical, economically feasible and environmentally friendly to use on such a large scale. Therefore, resistance to rusts in wheat is of critical importance. The utilization of resistance genes in wheat is the most effective, economic and environmentally safe approach for controlling rusts.

Materials and Methods

The study entitled "Evaluation of fungicides against leaf rust of wheat incited by *Puccinia triticina* Eriks" was undertaken at the Regional Wheat Rust Research Station, Mahabaleshwar, Dist. Satara, Maharashtra (India) during *rabi* season of the year 2024-25. Details about the materials used and the methods adopted in the present experiment are described in this chapter.

Materials

Seed

Seeds of wheat cv. Lok-1 and released wheat varieties required for the experimentation on evaluation of fungicides for management of leaf rust disease of wheat, seedling resistance test and adult plant resistance was obtained from the Wheat Rust Mycologist, Regional Wheat Rust Research Station, Mahabaleshwar, Dist. Satara, Maharashtra (India).

Fungicides

Fungicides viz., Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC, Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC, Tebuconazole 50% + Trifloxystrobin 25% WG, Mancozeb75%WP, Propiconazole 25% EC, Tebuconazole 25.9% w/w were procured from the local market.

Fertilizers

Chemical fertilizers viz., urea, single super phosphate and muriate of potash were procured from the local market.

Inoculum of Virulent Pathotypes of Leaf Rust

Inoculum of virulent pathotypes of leaf rust viz., 12-5, 77-1, 77-5, 77-9, 104-2, 77-5, 104-2, 77-8, 77-2, 12-1, 77-9, 17, 104-1, 77-1, 77, 12-5, 162A and 77A1was obtained from the Wheat Rust Mycologist, Regional Wheat Rust Research Station, Mahabaleshwar, Dist. Satara, Maharashtra (India).

Aluminium Bread Pans and Iron Marker

For growing seedlings in seedling resistance test, aluminium bread pans/trays admeasuring 35 cm x 25 cm x 9 cm were used. Moreover, iron marker device was used to make holes in a row in the soil: compost mixture filled in the aluminium bread pans.

Glassware and Miscellaneous Material

Petri plates, needles, hand sprayer, syringes, cages with gunny curtains, Marker pens and Labelling tags, Cavity dish, Trays etc. were used wherever required.

Methods

Evaluation of fungicides for management of leaf rust disease of wheat

In the said experimentation, 6 different fungicides were tested, vis-a-vis standard check fungicide mancozeb, against leaf rust of wheat, under natural epiphytotics in field.

Experimental details

Location: Regional Wheat Rust Research Station, Mahabaleshwar

- **Design:** Randomised Block Design
- **Target Disease:** Leaf Rust
- **Treatments:** Seven
- **Replications:** Three
- **Variety:** Lok-1
- **Seed rate:** 100 kg/ha
- **Fertilizers:** 120:60:40 (N, P_2O_5, K_2O kg/ha)
- **Plot size:** 3.0 m X 1.0 m
- **Spacing:** Row to row 22.5 cm

Treatment details

1. Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1%
2. Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 0.1%
3. Tebuconazole 50% +Trifloxystrobin 25% WG @ 0.1%
4. Mancozeb75%WP @ 0.25%
5. Propiconazole 25% EC @ 0.1%
6. Tebuconazole 25.9% w/w @ 0.1%
7. Untreated control

Note: First spray of the fungicides was given immediately after appearance of the first disease symptoms in the experimental plot and second spray was given 15 days after the first spray.

Observations recorded

1. Leaf rust disease intensity: Disease intensity was recorded using modified cobb's scale and per cent disease intensity (PDI) was computed using the formula:

$$PDI = \frac{\sum \text{all numerical ratings}}{\text{No. of observations recorded x Maximum score}} \times 100$$

1. **Plant height (cm):** Plant height was recorded twice, first at 50% flowering and second at harvesting of the crop
2. **Grain yield:** Grain yield was recorded in kg/plot and was converted into q/ha
3. **Dry matter yield:** Dry matter yield per plot was recorded at harvesting of the crop in kg/plot and was converted into t/ha
4. 1000- grain weight (g)

Results and Discussion

The experimental data obtained during the experimentation on "Evaluation of fungicides against leaf rust of wheat incited by *Puccinia triticina* Eriks" are presented in this chapter. The experiments were conducted at the Regional Wheat Rust Research Station, Mahabaleshwar, during *rabi* season of the year 2024-25. The results obtained in all these aspects are presented here under.

1. Evaluation of fungicides for management of leaf rust disease in wheat

Undeniably, growing resistance varieties is the best method to control any biotic and abiotic stresses in plants; however, the role of fungicides in disease control cannot be overlooked. Hence in the present discourse, attempts were made to screen various fungicides in field conditions against leaf rust disease of wheat.

a) Before spray

The data in regard to leaf rust intensity before application of fungicidal spray, presented in table 1, indicated that no significant differences among all the treatments in terms of leaf rust disease intensity.

b) Second fungicidal spray

The data presented in table 1clearly indicated significant differences among all the treatments in terms of leaf rust disease intensity over untreated check. The treatment (T_3) of application of Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1% recorded significantly lowest per cent disease intensity of 7.67 per cent at the first fungicidal spray application, which gave 88.06 per cent disease control. This treatment was found significantly superior over rest of the treatments in controlling the disease intensity. It was followed by treatment (T_1) Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @0.1% which recorded 11.00 per cent disease intensity, which gave 82.81 per cent disease control. The treatment (T_6) of Tebuconazole 25.9% w/w @0.1% was found to be at par with the treatment (T_5) of Propiconazole 25% EC @0.1%. Maximum leaf rust intensity of 64.00 per cent was observed in untreated control.

Viljanen-Rollinson *et al.* (2002) [14] reported that Azoxystrobin was highly effective in reducing the rust diseases of wheat when applied as early eradicant. Similarly, Bagga (2007) [2] and Bal (2014) [3] also reported that Azoxystrobin followed by Difenoconazole significantly reduced the leaf and yellow rust severity resulting in increased grain yield. Results of the present investigation are in general agreement with those of Singh *et al.* (2016) [13] who evaluated fungicides and bioagents for managing stripe rust (*Puccinia striiformis* f. sp. *tritici*) and optimizing spray timing during two *rabi* seasons (2014-15 and 2015-16). The strobilurin fungicide azoxystrobin 25SC (Amistar @ 0.1%) was most effective in reducing disease severity to 1.22% and achieving 98.67% disease control, leading to 77.33% and 44.14% increases in grain yield and thousand grain weight, respectively. Difenoconazole 25EC (Score @ 0.1%) followed with 92.89% disease control. Least effective were penconazole and mancozeb. Best spray timing was at flag leaf emergence or when 20% of leaves showed rust infection. Furthermore, Barro *et al.* (2017) [4] studied two fungicide combinations and application frequencies for controlling wheat leaf rust in TBIO Pioneiro 2010. Both combinations (azoxystrobin + tebuconazole and trifloxystrobin + prothioconazole) achieved over 85% disease control. Fungicide-treated plots showed significantly better yield components than untreated ones.

Basandrai *et al.* (2020) [5] evaluated eleven fungicides over two years at RWRC, Malan, for managing yellow rust in wheat. Tebuconazole 25% EC @ 0.1% showed the highest efficacy, reducing disease severity to 1.84% with 99.64% control. Other effective fungicides included Nativo 75WG, Amistar SC, Propiconazole, and Amistar Top 325 SC. All showed significant disease reduction, yield improvement, and better economic returns. Bajoriya *et al.* (2023) assessed four modern fungicides against wheat stem rust on two susceptible varieties. Tebuconazole 50% EC showed the highest curative effect, reducing disease incidence by 45.62% at 7 days and 74.92% at 14 days post-application. It also reduced disease severity to 1.67%, significantly better than the untreated check. Propiconazole 25% EC was the next most effective, with no significant difference from Tebuconazole. Results of the present investigation are in general agreement with these researchers.

Table 1: Evaluation of fungicides for management of leaf rust disease in wheat

Tr. No.	Treatment details	Before 1st spray	Leaf Rust (ACI) 15 days after 1st spray	Per cent disease reduction
1	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1%	0.67 (3.83)	11.00 (19.32)	82.81
2	Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 0.1%	1.00 (5.74)	19.00 (25.84)	70.31
3	Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%	1.33 (5.42)	7.67 (16.02)	88.06
4	Mancozeb 75% WP @ 0.25%	1.00 (5.74)	24.00 (29.32)	62.5
5	Propiconazole 25% EC @ 0.1%	1.00 (5.74)	16.67 (24.09)	73.95
6	Tebuconazole 25.9% w/w @ 0.1%	1.00 (5.74)	14.33 (22.23)	77.61
7	Untreated Control	0.67 (3.83)	64.00 (53.15)	--
	SE±	NS	0.89	--
	CD at 5%	NS	2.73	--

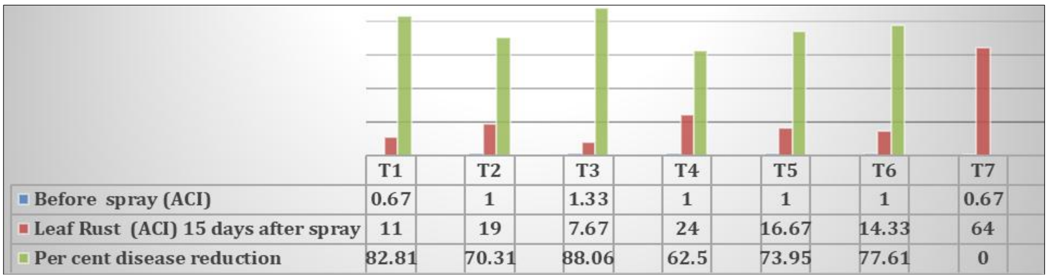

Fig 1: Evaluation of fungicides for leaf rust disease management and Average Coefficient of Infection (ACI) value before spray and after second spray

2. Effect of fungicides on plant height

It is evident from the Table 2 that the treatment T_3 (Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%) recorded the highest plant height of 80.95 cm, representing a 16.02% increase over the untreated control (69.77 cm). This was followed non-significantly by the treatment T_1

(Azoxystrobin 18.2% + Cyproconazole 7.3% SC @ 0.1%), yielding a plant height of 78.47 cm (12.46%). Thus, these two treatments were found to be significantly superior over rest of the treatments in enhancing plant height. Treatment T_6 (Tebuconazole 25.9% w/w @ 0.1%) registered a plant height of 76.80 cm (10.08%), followed closely by treatments T_2 (Azoxystrobin 18.2% + Difenoconazole 11.4% SC @ 0.1%), T_5 (Propiconazole 25% EC @ 0.1%), and T_4 (Mancozeb 75% WP @ 0.25%), yielding 75.73 cm (8.54%), 75.64 cm (8.41%), and 75.35 cm (8.00%), respectively. All these treatments were at par with each other, indicating comparable efficacy in supporting wheat crop growth.

The present findings are in agreement with those reported by Alemu *et al.* (2023) [1] and Gemechu *et al.* (2024) [8] who observed that fungicide applications had a notable influence on plant height. The study showed that reduced rust infection, due to effective fungicidal control, was associated with an increase in plant height. This is likely because managing rust diseases promotes healthier vegetative growth, thereby positively impacting overall plant development.

Table 2: Effect of fungicides on plant height of wheat crop

Tr. No.	Treatment	Plant height (cm)	Per cent increase over control
1	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1%	78.47	12.46
2	Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 0.1%	75.73	8.54
3	Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%	80.95	16.02
4	Mancozeb 75% WP @ 0.25%	75.35	8.00
5	Propiconazole 25% EC @ 0.1%	75.64	8.41
6	Tebuconazole 25.9% w/w @ 0.1%	76.80	10.08
7	Untreated Control	69.77	--
	SE±	1.12	
	CD at 5%	3.44	

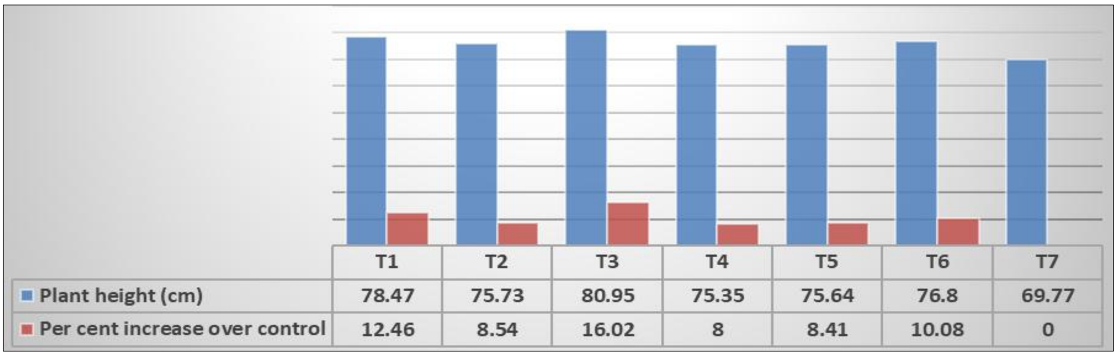

Fig 2: Effect of fungicides on plant height (cm) and per cent increase in plant height (cm) of wheat crop over control

3. Effect of fungicides on yield

The data of wheat grain yield presented in table 3 substantiated that, the treatment (T_3) of Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1% recorded highest grain yield of wheat to the tune of 29.11 q/ha, which showed 72.35 per cent increase in wheat grain yield over the untreated check. It was found significantly superior over rest of the treatments. It was followed by treatment (T_1) Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @0.1% which recorded wheat grain yield of 26.67 q/ha. This showed 72.35 per cent increase in wheat

grain yield over the untreated check. The treatment (T_6) of Tebuconazole 25.9% w/w @ 0.1% was found to be at par with the treatment (T_5) of Propiconazole 25% EC @ 0.1%. Minimum grain yield of 16.89 q ha^{-1} was observed in untreated control.

Results of the present investigation are in general agreement with those of Chaudhry *et al.* (1994) [7] who found that Baytan (triadimenol) was the most effective and economical, followed by Folicur (tebuconazole) and Spotless (diniconazole). These results highlighted the strong potential of systemic fungicides in managing leaf rust.

Comparable outcomes were observed in the studies by Macharia *et al*. (2013) [11] and Kebede *et al*. (2025) [10], who all noted that fungicidal applications had a marked positive effect on wheat grain yield. The highest yield was recorded in plots treated with Nativo 300 SC (trifloxystrobin 100 g/L + tebuconazole 200 g/L) at 1.0 L/ha, which significantly outperformed the untreated control.

Table 3: Effect of fungicides on yield

Tr. No.	Treatment	Yield (q/ha)	Per cent increase in yield over control
1	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1%	26.67	57.90
2	Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 0.1%	21.02	24.45
3	Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%	29.11	72.35
4	Mancozeb 75% WP @ 0.25%	20.22	19.72
5	Propiconazole 25% EC @ 0.1%	23.22	37.48
6	Tebuconazole 25.9% w/w @ 0.1%	24.33	44.05
7	Untreated Control	16.89	--
	SE±	0.69	
	CD at 5%	2.12	

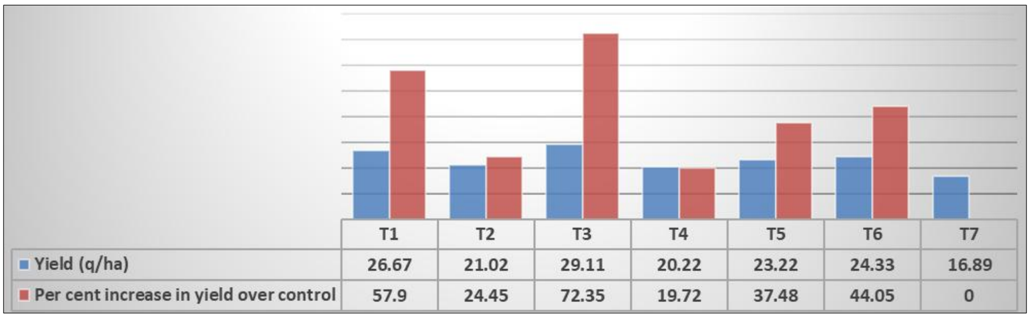

Fig 3: Effect of Fungicides on yield (q/ha) and per cent increase in yield of wheat crop over control

4. Effect of fungicides on dry matter yield

It is evident from the data presented in Table 4 that the treatment T_3 (Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%) achieved the highest dry matter yield of wheat, recording 54.11 q/ha, which was 36.02% increase over the untreated control (39.78 q/ha). This treatment was, however, at par with T_1 (Azoxystrobin 18.2% + Cyproconazole 7.3% SC @ 0.1%), yielding 50.22 q/ha (26.24%), indicating a comparable level of efficacy between these treatments. Thus, these two treatments were found to be significantly superior over rest of the treatments in improving dry matter yield of wheat. Treatments T_2 (46.11 q/ha, 15.91%), T_5 (47.33 q/ha, 18.98%), T_6 (48.11 q/ha, 20.94%), and T_4 (44.44 q/ha, 11.71%) also performed reasonably well, in comparison to untreated check, with dry matter yields being statistically at par with each other. In general, the results demonstrated that these fungicidal treatments effectively enhanced the dry matter yield of the wheat crop compared to the untreated control.

Table 4: Effect of fungicides on dry matter yield

Tr. No.	Treatment	Dry matter yield (q/ha)	Per cent increase over control
1	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1%	50.22	26.24
2	Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 0.1%	46.11	15.91
3	Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%	54.11	36.02
4	Mancozeb 75% WP @ 0.25%	44.44	11.71
5	Propiconazole 25% EC @ 0.1%	47.33	18.98
6	Tebuconazole 25.9% w/w @ 0.1%	48.11	20.94
7	Untreated Control	39.78	--
	SE$\pm$	0.79	--
	CD at 5%	2.43	--

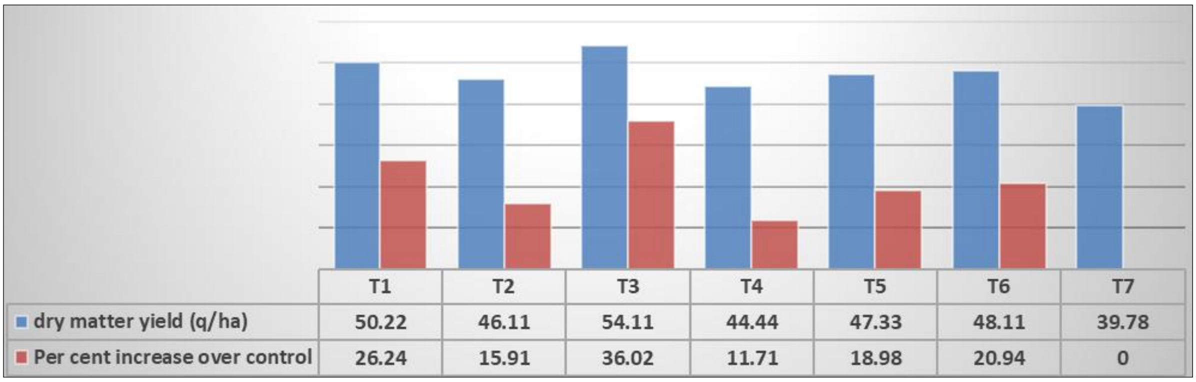

Fig 4: Effect of fungicides on dry matter yield (q/hq) and per cent increase of dry matter yield over control

5. Effect of fungicides on 1000 grain weight

The results presented in Table 5 clearly revealed the significant effect of different treatments on the 1000-grain weight of the wheat crop. The highest 1000-grain weight was observed with T_3 (Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%), recording 49.19 g, representing a 34.00% increase over the untreated control (36.71 g). This was found to be statistically significant and superior over the rest of the treatments.

The second-best treatment was T_1 (Azoxystrobin 18.2% w/w + Cyproconazole 7.3% SC @ 0.1%), yielding a grain weight of 46.77 g (27.40%), followed closely by T_6 (Tebuconazole 25.9% w/w @ 0.1%), with 45.38 g (23.62%). Other treatments such as T_5 (Propiconazole 25% EC @ 0.1%), T_2 (Azoxystrobin 18.2% + Difenoconazole 11.4% SC @ 0.1%), and T_4 (Mancozeb 75% WP @ 0.25%) gave grain weights of 44.57 g (21.41%), 43.65 g (18.90%), and 42.27 g (15.15%), respectively.

The result of the present investigation are in conformity with those of Kalappanavar *et al*. (2010) [9] who reported that all treatments improved both grain yield and 1000-grain weight compared to the untreated control. Among the fungicides, propiconazole was the most effective, followed by triadimefon and hexaconazole. The treated plots with propiconazole, triadimefon, and hexaconazole showed significantly higher yield and grain weight, indicating the substantial impact of leaf rust on yield.

Table 5: Effect of fungicides on 1000 grain weight

Tr. No.	Treatment	1000 grain weight (g)	Per cent gain over control
1	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.1%	46.77	27.40
2	Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC @ 0.1%	43.65	18.90
3	Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1%	49.19	34.00
4	Mancozeb 75% WP @ 0.25%	42.27	15.15
5	Propiconazole 25% EC @ 0.1%	44.57	21.41
6	Tebuconazole 25.9% w/w @ 0.1%	45.38	23.62
7	Untreated Control	36.71	--
	SE±	1.11	
	CD at 5%	3.41	

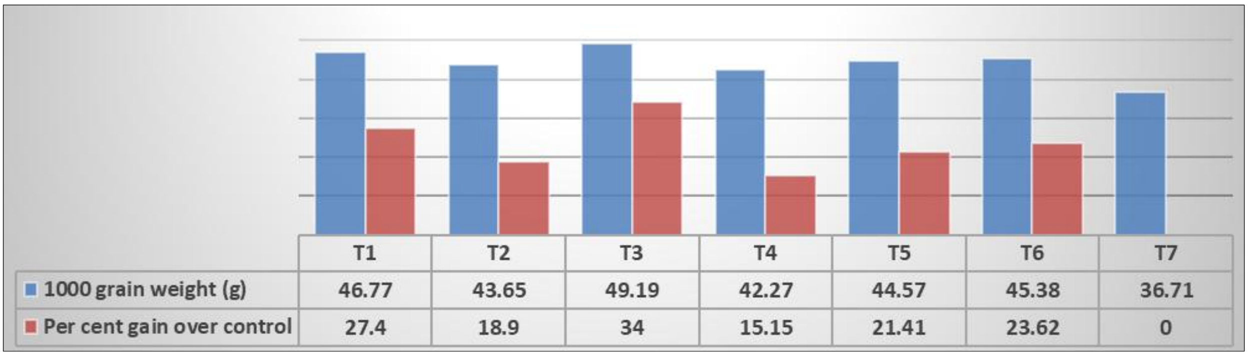

Fig 5: Effect of fungicides on 1000 grain weight (g) and per cent gain in 1000 grain weight over control

Conclusion

A field experiment was conducted during the 2024-25 *rabi* season to assess the effectiveness of different fungicides in controlling leaf rust of wheat and their impact on crop performance. The results revealed significant variations among the treatments with respect to disease intensity, grain yield, plant height, dry matter yield, and 1000-grain weight when compared to the untreated control. Among all the treatment, (T_3) Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.1% was the most effective, as evidenced by the significantly higher grain yield (29.11 q/ha), plant height (80.95 cm), 1000 grain weight (49.19 gm) and dry matter yield (54.11 q/ha).

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