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Synergistic potential of compatible fungicides in the suppression of powdery mildew

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Abstract
Powdery mildew, caused by *Blumeria graminis* f. sp. *tritici* (Bgt) is a persistent foliar disease of wheat in cool and temperate regions, where its biotrophic nature and rapid polycyclic growth lead to notable yield loss. The pathogen reproduces asexually through abundant conidia and sexually *via* chasmothecia, aiding efficient spread and survival. Although host resistance and cultural practices help reduce disease, fungicides remain the most dependable option in areas with recurring epidemics. This study evaluated the compatibility and field performance of seven fungicidal treatments-Azoxystrobin + Cyproconazole, Azoxystrobin + Difenoconazole, Tebuconazole + Trifloxystrobin, Propiconazole, Tebuconazole, Mancozeb and Bayleton-against wheat powdery mildew. All treatments significantly lowered disease severity and improved yield components over the untreated control. Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC showed the best performance, recording the highest thousand-grain weight, followed by Azoxystrobin + Cyproconazole. Overall, triazole-strobilurin combinations proved more effective than single fungicides, supporting their role in integrated disease management.

Keywords: *Blumeria graminis* f. sp. *tritici*, wheat powdery mildew, fungicidal compatibility, triazole-strobilurin mixtures, azoxystrobin, difenoconazole, integrated disease management, disease severity, yield improvement

Introduction

Powdery mildew fungi are obligate biotrophic ascomycetes belonging to the family *Erysiphaceae*, the sole family within the order *Erysiphales* (Agrios, 2005; Glawe, 2008) [1, 12]. Within this group, *Blumeria graminis* is the species complex that infects grasses, and the forma specialis *tritici* is responsible for powdery mildew of wheat (Dean *et al.*, 2012) [7]. This pathogen is one of the most common and easily recognizable foliar diseases of wheat in cool and temperate production regions. It produces the characteristic white, powdery colonies on aerial plant parts, most notably on leaf surfaces but also on leaf sheaths, stems and spikes (Glawe, 2008) [12]. Although the pathogen does not typically cause rapid tissue necrosis, its prolonged colonization of the leaf surface and extraction of nutrients through specialized feeding structures can substantially reduce photosynthetic area, leading to stunting, poor grain filling and measurable yield losses, particularly in susceptible cultivars grown under conducive conditions (Griffey *et al.*, 1993) [13].

Once the initial infection is established, the fungus produces superficial mycelium that spreads over the leaf surface and develops secondary hyphae. From these hyphae, erect conidiophores arise and produce chains of conidia, which are easily detached and dispersed by air currents to new infection sites (Glawe, 2008) [12]. Under favourable environmental conditionscmoderate temperatures, high relative humidity without free water, and dense crop canopies-this rapid, polycyclic asexual reproduction leads to the familiar powdery appearance of infected leaves and drives the build-up of epidemics over relatively short time periods (Agrios, 2005) [1]. Later in the season, especially under stress or towards crop maturity, the pathogen may also form sexual fruiting bodies (chasmothecia) which contribute to survival between seasons and facilitate genetic recombination, enhancing the evolutionary potential of the wheat powdery mildew population (Müller & McDonald, 2020) [20].

Fig 1: Typical powdery mildew symptoms observed on leaves of wheat

The powdery mildew pathogen *Blumeria graminis* f. sp. *tritici* (Bgt), which infects wheat, exhibits both asexual and sexual phases in its life cycle. The asexual cycle begins when wind-borne conidia settle on a susceptible wheat leaf surface. After deposition, each conidium germinates and produces a short primary germ tube, which then differentiates into a specialized infection structure known as the appressorium (Bushnell *et al.*, 1984) [5]. This appressorium plays a crucial role in host penetration, helping the fungus breach the cuticle and epidermal cell wall while leaving the plant plasma membrane intact. The high turgor pressure generated within the appressorium, combined with the secretion of lytic enzymes, enables the formation of a penetration peg that invades the epidermal cell and develops into a haustorium-the main feeding organ of the pathogen (Hückelhoven & Panstruga, 2011; Spanu, 2012) [14, 26]. Upon successful establishment, the primary hyphae expand over the leaf surface and give rise to secondary hyphae, from which conidiophores emerge vertically. These produce chains of conidia, and repeated cycles of asexual reproduction leads to the rapid spread of white, powdery colonies characteristic of the disease (Glawe, 2008) [12].

The sexual stage involves the fusion of two compatible mating types, forming chasmothecia containing asci and ascospores which act as long-term survival structures (Müller & McDonald, 2020) [20]. In wheat-growing regions such as the Tarai belt of Uttarakhand, chasmothecia may function as important overwintering and oversummering reservoirs of primary inoculum. Although the exact role of ascospores in early-season infections is not fully understood, their infection process is considered similar to that of conidia (Spanu, 2012) [26]. In some powdery mildew species, the sexual stage is epidemiologically significant, whereas in others it is rarely observed under field conditions (Glawe, 2008) [12].

Currently, management of wheat powdery mildew relies on two major strategies: deployment of resistant varieties and application of fungicides. Wheat breeding programs have developed several resistant or moderately resistant genotypes; however, rapid evolution of new virulent races of Bgt often limits the durability of resistance (Wyand & Brown, 2003; Cowger & Brown, 2019) [28, 6]. Alternative management options, such as inorganic compounds, organic amendments, biological agents and nanoparticle-based formulations, have been explored as safer supplements to fungicides (Kumar *et al.*, 2021) [16]. Nevertheless, in many wheat-growing areas, chemical fungicides remain the most reliable tool for disease suppression, which increases the risk of fungicide resistance development in pathogen populations (McGrath, 2001) [19].

Materials and Methods

Experimental Site and Field Preparation

The field experiment was conducted under natural epiphytotic conditions at Norman E. Borlaug, Crop Research Centre, Wheat pathology Block, G.B.P.U&T, Pantnagar to evaluate the compatibility and efficacy of different fungicides against wheat powdery mildew. The land was prepared by ploughing, harrowing and levelling to obtain a fine tilth. Recommended fertilizer doses, irrigation scheduling, and weed management practices were followed uniformly across all plots to ensure optimum crop growth.

Experimental Design and Layout

The trial was arranged in a Randomized Block Design (RBD) with three replications. Each plot measured 5 × 1 m, with 0.5 m spacing between plots and 1.5 m between replications, which also served as irrigation channels. A known susceptible wheat cultivar (PBW 343) was used to ensure uniform disease development. Seeds were hand sown in shallow furrows, covered lightly with soil and managed following standard agronomic practices.

Fungicidal Treatments

Eight treatments were evaluated, including seven fungicides and one untreated control. The fungicides and their corresponding doses were given in table 1.

Application of Fungicides

Two foliar sprays of the respective fungicides were applied at 10-day intervals, beginning at the initial appearance of powdery mildew symptoms. Sprays were delivered uniformly using a hand-operated knapsack sprayer fitted with a hollow-cone nozzle to ensure adequate leaf coverage.

Disease Assessment

Powdery mildew severity was recorded using the Saari & Prescott (0-9) scale. Observations were taken before spraying and 10 days after each application. Percent Disease Intensity (PDI) was computed using McKinney's formula:

$$\text{PDI} = \frac{\sum \text{Disease ratings}}{\text{Number of plants} \times \text{Maximum rating}} \times 100$$

Harvesting and Yield Estimation

At maturity, each plot was harvested and threshed separately. Plot yields were recorded in kilograms and converted to quintals per hectare based on plot size. Percent yield increase over the untreated control was calculated as:

$$\text{Yield Increase (\%)} = \frac{\text{Yield in treated plot} - \text{Yield in control}}{\text{Yield in control}} \times 100$$

Statistical Analysis

All recorded data were subjected to statistical analysis using standard procedures appropriate for RBD. Treatment means were compared using relevant statistical tests to determine significance among fungicidal treatments.

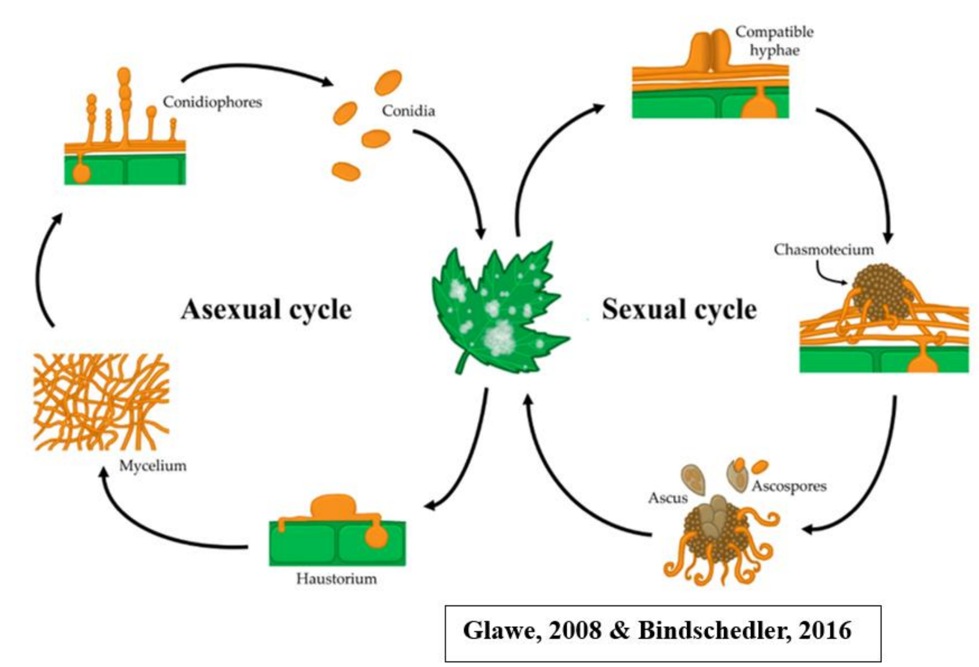

Fig 2: Typical life cycle of powdery mildew fungi

Fungicides, the Main Anti-Powdery Mildew Tools

The application of foliar fungicides has traditionally been the only means of chemical control for powdery mildew. Their application is based on scouting fields for symptoms and assessing disease severity from tiller elongation through flowering stages of growth. Fungicides can be applied based on the level of disease in the field, the known susceptibility of the variety, and the market price of the grain. Seed-applied systemic fungicides are no available that control early season development of the disease. These are especially effective for winter wheat. Foliar fungicides are effective but should only be applied if the cultivar is susceptible and an economic return is likely (Leath and Bowen, 1989) [17]. Triadimenol seed treatment prevented excess tillering caused by powdery mildew infection early in the season and contributed to a higher grainy especially when high temperatures during grain filling reduced the amount of disease later in the season (Frank and Ayers, 1986; Leath and Bowen, 1989 and Everts and Leath, 1992) [11, 17, 10]. Fungicide insensitivity is a concern where fungicides are used intensively such as in Western Europe.

Fungicidal management

Foliar fungicides are effective but these should only be applied if the cultivar is susceptible and an economic return is assured, that is, in seed production plots. Avoid applying fungicides too early so that these may be effective during the grain filling period.

Basandrai *et al.*, (2013) [3] reported that 1-2 foliar sprays of fungicide Propiconazole, Hexaconazole and Triadimefon @ 0.1% and Mancozeb 75WP @ 0.25% resulted in significantly less severity of powdery mildew and resulted in significantly more yield as compared with no spray (check). Several fungicides, such as Benlate (0.1 percent), Karathane (0.1 percent) and others, can be applied as foliar sprays to combat PM. Fungicides such as Morpholines (e.g., Fenpropidin), Triazoles (e.g., Tebuconazole, Propiconazole, Hexaconazole, and Cyprconazole), and Strobilurin (e.g., Tebuconazole, Propiconazole, Hexaconazole and Cyprconazole) and Strobilurins are effective in managing wheat powdery mildew.

Systemic fungicides

1. Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC

Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC is a systemic fungicide with broad spectrum efficacy against important diseases. It's used to treat powdery mildew and rust in wheat, powdery mildew and anthracnose in chilies, as well as early and late blight in tomatoes, blast and sheath blight in paddy, blight and downy mildew in maize. Difenoconazole also has systemic activity against powdery mildew. The combination of Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC gives better results in controlling powdery mildew of wheat.

2. Azoxystrobin 18.2% w/w + Cyproconazole 7.3% WG

In wheat, a new combination fungicide Azoxystrobin 18.2% + Cyproconazole 7.3% WAV (Ampect Xtra 280 SC) was investigated for powdery mildew and rust infections and found to be good in controlling powdery mildew of wheat.

3. (Nativo) Tebuconazole 50% + Trifloxystrobin 25% WG

Nativo is a new combination fungicide containing Tebuconazole and Trifloxystrobin. Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) is a systemic broad-spectrum fungicide with both preventive and curative effects that not only control the disease but also improve crop quality and yield. Nativo protects the flag leaf of wheat from powdery mildew and yellow rust and contributes to improving the yield and quality of grains. Nativo's timely treatment has remarkable efficacy in controlling mango powdery mildew and anthracnose infections, resulting in a high and high-quality mango yield.

4. Propiconazole

In wheat crop, one spray of Propiconazaole (Tilt 25EC @ 0.1%) on powdery mildew appearance is highly effective.

Boiko and Pokova, 1993 suggested alternate application of Tilt (Propiconazole) and Bayleton (Tridemorph) reduce the chances of the development of mildew-resistant populations *Blumeria graminis* f.sp. *tritici* in wheat. In Finland, a study demonstrated that under good growing conditions the control of *B. graminis and Septoria nodorum* Berk with a foliar application of Tilt (Propiconazole) often delayed leaf senescence, prolonged grain filling and resulted in an increase in kernel weight and yield in wheat.

5. Tebuconazole

Dunn and Gaynor (2020) [8] concluded that the fungicide treatments provided a significant reduction in the severity of symptoms, with the split application of Tebuconazole and both the single and split applications of Tebuconazole + Prothioconazole providing the most effective control of the powdery mildew disease of wheat. Vikas *et al.*, 2020 [27] conducted a field experiment and concluded that the highest powdery mildew control was recorded in Difenoconazole (85.96%) followed by Trifloxystrobin + Tebuconazole (83.60%), Tebuconazole (82.07%), Hexaconazole (78.99%), Propiconazole (77.20%) and Dinocap (71.97%) in cereal crops.

The use of Azoxystrobin 120 + Tebuconazole 240 SC fungicide is found to be safe for powdery mildew of chili crop and none of the symptoms like chlorosis, necrosis, scorching, epinasty and hyponasty symptoms were recorded even at the highest dosage of treatment *viz*., 3320 ml/ha and up to 10 days of after I, II and III spraying (Sivakumar *et al.*, 2020) [25]. Elad *et al.,* 2021 [9] reported that Tebuconazole 25 EC and Sitara (Hexaconazole 5 EC), were highly effective and resulted in more than 91% control of powdery mildew of cucurbits disease with more than 144.5 to 155.4% increase in crop yield.

6. Bayleton

In powdery mildew of wheat three sprays of Bayleton 25% WP (0.05%) at stem elongation, flag leaf and flowering stages resulted in 69.54% controlled over the unsprayed check followed by Tilt 25 EC (67.82%), Punch (62.47%) and Topas (55.75%) and were effective in increasing yield from 15.8 to 31.8% over control (Singh and Ramesh, 2000) [24]. Six triazole fungicides namely propiconazole (Tilt 25EC), Triadimefon (Bayleton 25EC), Difenoconazole (score 25EC), mono and di-potassium salts of phosphorous acid (Topaz), Fenarimol (Rubigan 12.5EC) applied @ 0.1%, Hexaconazole (Contaf 5EC) @ 0.2% along with Mancozeb (Indofil M 45) @ 0.25% were evaluated as foliar sprays for the management of powdery mildew (PM) caused by *Blumeria graminis* f sp. *tritici,* leaf rust (LR) caused by *Puccinia triticina* and yellow rust (YR) caused by *Puccinia striiformis* of wheat using variety Sonalika and he concluded that Triadimefon (Bayleton 25EC) is effective in controlling powdery mildew of wheat Basandrai *et al.*, 2021 [2]. Mahmood, 2008 [18] found that Score (Difenoconazole) and Bayleton (Triadimefon) were very effective in reducing the disease severity (93%) of powdery mildew of peas (*Erysiphe polygoni*) compared to other fungicides.

Evaluation of Fungicide Compatibility and their efficacy in controlling Powdery Mildew

The efficacy of various fungicidal formulations against wheat powdery mildew was rigorously evaluated under field conditions during the Rabi season to determine their comparative performance and compatibility in disease suppression.

Percent Disease Intensity (PDI)

A field experiment laid out in a Randomized Block Design (RBD) with independent replications was conducted to assess the performance of seven fungicidal treatments-Azoxystrobin 18.2% + Cyproconazole 7.3% (0.1%), Azoxystrobin 18.2% + Difenoconazole 11.4% (0.1%), Tebuconazole 50% + Trifloxystrobin 25% (0.06%), Propiconazole 25 EC (0.1%), Tebuconazole 250 EC (0.1%), Mancozeb (0.25%), and Bayleton 25 WP (0.05%)-applied as foliar sprays, along with an untreated control. The recorded data (Table 2) clearly demonstrated a pronounced reduction in Percent Disease Intensity (PDI) across all fungicidal treatment's relative to the control.

Prior to the application of fungicides, PDI ranged from 2.53% to 15.20%, with the minimum observed in the Azoxystrobin + Difenoconazole treatment and the maximum in the untreated control. Following the first spray, a substantial decline in disease severity was observed across treatments. The lowest PDI (18.83%) was again recorded in T_2 (Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC), followed closely by T_1 (Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC) at 20.56%, and by Propiconazole 25 EC and Bayleton 25 WP, which recorded 22.53% and 22.56%, respectively. Higher PDI values were noted in T_3 (Tebuconazole + Trifloxystrobin), T_5 (Tebuconazole 250 EC), and T_6 (Mancozeb), although all performed substantially better than the control, which exhibited the highest PDI of 45.20%.

A similar trend persisted after the second fungicide application. Treatment T_2 consistently maintained superiority with the lowest PDI (35.60%), followed by T_1 (37.60%), T_7 Bayleton (39.10%), and T_4 Propiconazole (39.40%). Treatments T_3, T_5, and T_6 exhibited PDI values of 43.10%, 42.53%, and 43.10%, respectively, *yet all* were significantly more effective than the control (72.43%).

The analysis of pooled (mean) PDI revealed that T_2 registered the minimum disease intensity (18.98%), significantly outperforming all other treatments. This was followed by T_1 (20.35%), T_4 Propiconazole (22.36%), Bayleton (22.25%), T_3 (23.67%), T_5 (24.38%), and T_6 Mancozeb (25.47%). The untreated control recorded the maximum mean PDI (44.27%), indicating severe disease pressure in the absence of fungicidal intervention. Mancozeb was found to be the least effective among the tested fungicides, although still markedly superior to the control.

The percent disease control over check further substantiated these observations. The highest reduction was achieved by Azoxystrobin + Difenoconazole (57.12%), followed by Azoxystrobin + Cyproconazole (54.03%). Other treatments provided moderate yet significant control within the range of 42.46-49.78%, demonstrating the overall effectiveness of the evaluated fungicides in comparison to the untreated control.

The results align with earlier scientific findings emphasizing the need for novel fungicides with reduced toxicity and enhanced biological efficacy. Robin *et al.* (2022) [23] highlighted the importance of developing next-generation fungicides with improved pathogen-target specificity and lower ecological footprints. In this context, strobilurins such as Azoxystrobin-characterized by a unique mode of action, high antifungal potency, and low toxicity to non-target organisms-represent an important advancement in chemical disease management and resistance mitigation. Parween *et al.* (2016) [21] also reported superior efficacy of Azoxystrobin 18.2% + Cyproconazole 7.3% across multiple dose levels in suppressing wheat powdery mildew. Jagtap *et al*. (2018) [15] further corroborated the superior performance of triazole-based fungicides (e.g., difenoconazole, hexaconazole, tebuconazole, myclobutanil) owing to their sterol biosynthesis-inhibiting properties, which effectively disrupt fungal cell membrane integrity.

Table 1: Treatments of fungicides with their doses tested in field

S. No.	Treatments	Doses (%)
T_1	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC	0.10%
T_2	Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC	0.10%
T_3	Tebuconazole 50% + Trifloxystrobin 25% WG	0.06%
T_4	Propiconazole 25EC	0.10%
T_5	Tebuconazole 250EC	0.10%
T_6	Mancozeb	0.25%
T_7	Bayleton 25WP	0.05%
T_8	Control	

Table 2: Evaluation of different fungicides against powdery mildew of wheat in field condition

S. No.	Treatment	Dose (%)	Percent Disease Intensity (PDI)							
			Before Spray	First Spray	Second Spray	Mean	Percent disease increase over control	Yield (Q/ha)	Percent yield increase over control	1000 Grain weight
T_1	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC	0.10%	2.9	20.56	37.6	20.35	54.03	47.4	52.26	40.75
T_2	Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC	0.10%	2.53	18.83	35.6	18.98	57.12	49.55	59.17	43.26
T_3	Tebuconazole 50% + Trifloxystrobin 25% WG	0.06%	5.23	24.06	41.73	23.67	46.53	42.81	37.57	36.75
T_4	Propiconazole 25EC	0.10%	5.16	22.53	39.4	22.36	49.49	45.81	47.34	38.25
T_5	Tebuconazole 250EC	0.10%	6.13	24.5	42.53	24.38	44.92	42.78	37.42	35.00
T_6	Mancozeb	0.25%	7.4	25.93	43.1	25.47	42.46	41.86	34.46	32.25
T_7	Bayleton 25WP	0.05%	5.1	22.56	39.1	22.25	49.78	45.81	47.34	38.75
T_8	Control		15.2	45.2	72.43	44.27	0	31.13	0	30.24
	SE(m)		0.31	1.98	0.46	3.29		1.18		0.05
	$C.D_{(0.05)}$		0.96	6.011	1.39	10.08		0.38		1.68

Thousand - grain weight

The thousand-grain weight recorded in the present study ranged from 30.24 to 43.26 g, with all fungicidal treatments producing significantly higher grain weight compared to the untreated control (30.24 g). The highest thousand-grain weight (43.26 g) was obtained in treatment T_2 (Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC @ 0.10%), indicating its pronounced effect on improving grain filling. Treatment T_1 (Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC @ 0.10%) also recorded a comparatively high grain weight of 40.75 g, while Bayleton 25 WP and Propiconazole 25 EC resulted in 38.75 g and 38.25 g, respectively, and were statistically at par with each other. The remaining treatments-Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.06%, Tebuconazole 250 EC @ 0.10%, and Mancozeb @ 0.25%-yielded grain weights of 36.75 g, 35.00 g, and 32.25 g, respectively. Despite variability among treatments, all fungicide applications significantly enhanced the thousand-grain weight relative to the check, suggesting their positive influence on reducing disease impact and improving grain development.

The improvement in thousand-grain weight across all fungicidal treatments aligns with earlier reports highlighting the role of effective powdery mildew control in enhancing grain filling and overall productivity. Several researchers have documented that timely management of *Blumeria graminis* f. sp. *tritici* improves photosynthetic efficiency and prolongs the effective grain-filling period, ultimately increasing test weight. The superior performance of Azoxystrobin + Difenoconazole in the present study corroborates the findings of previous studies, where strobilurin-triazole combinations were shown to provide broad-spectrum protection and promote physiological benefits such as delayed senescence and enhanced carbohydrate accumulation. Similarly, the comparable performance of Propiconazole and Bayleton has been reported by earlier workers, who emphasized the consistent efficacy of triazoles in minimizing disease intensity and stabilizing grain weight under field conditions. The moderate grain weight observed under treatments like Tebuconazole, Trifloxystrobin combinations and Mancozeb further supports the notion that while these fungicides suppress disease to varying degrees, their physiological benefits may differ depending on their mode of action and persistence. Overall, the present results reinforce the conclusion that effective chemical management of powdery mildew significantly contributes to improvement in thousand-grain weight, consistent with previously published research on fungicidal impacts on wheat yield components.

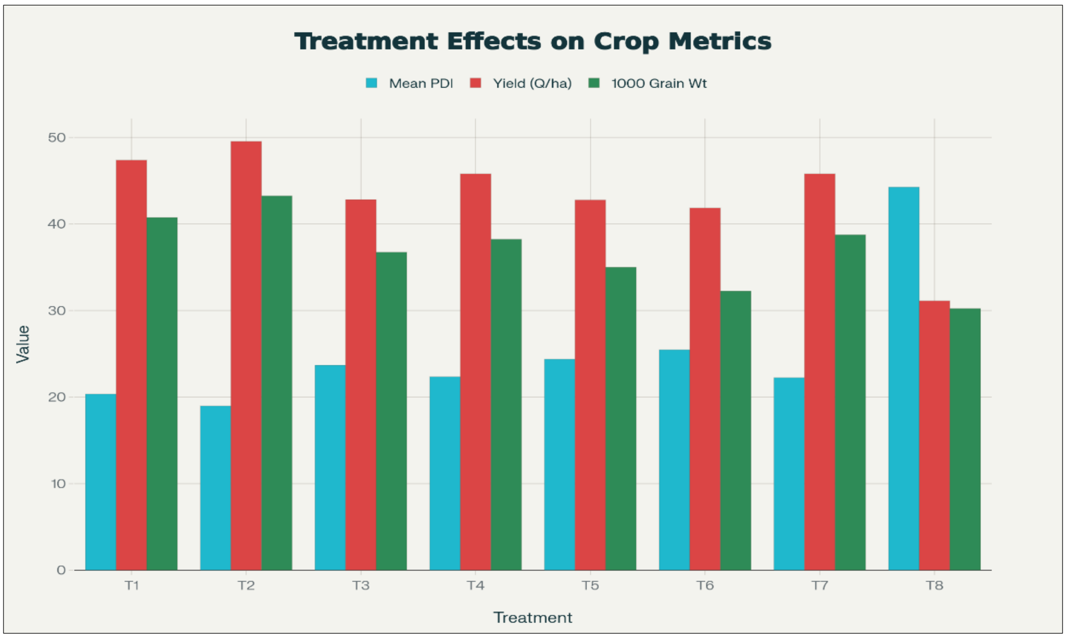

Fig 3: Effect of different fungicidal treatments on mean PDI, yield and 1000 grain weight in wheat

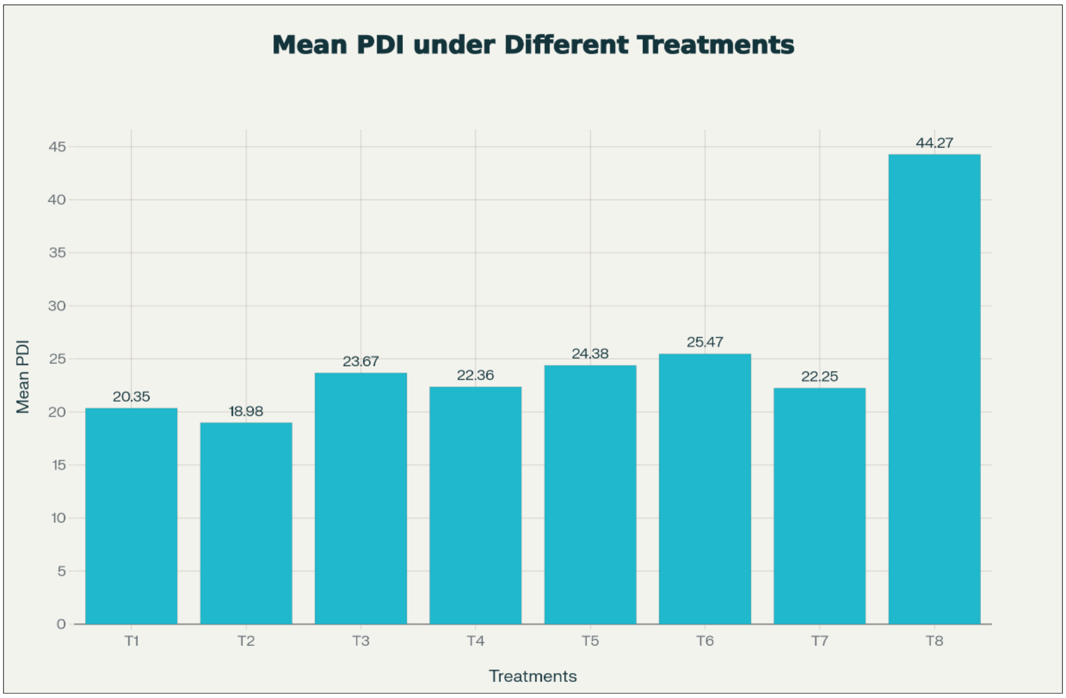

Fig 4: Mean PDI across fungicidal treatments T_1-T_8 in wheat

Conclusion

The efficacy of different fungicides was evaluated against powdery mildew of wheat under field conditions. The field experiment was conducted to screen different fungicides *viz*., Azoxystrobin 18.2%+ Cyproconazole 7.3% (0.1%), Azoxystrobin 18.2% + Difenoconazole 11.4% (0.1%), Tebuconazole 50% + Trifloxystrobin 25% (0.06%), Propiconazole (0.1%), Tebuconazole (0.1%), Mancozeb (0.25%), and Bayleton (0.05%) as a foliar spray along with control. The data on the Percent Disease Intensity (PDI), plot yield and thousand grain weight in different treatments were observed. Data analysis revealed that the lowest percent disease intensity (18.98) and maximum percent disease increase over check (57.12%) was observed in Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC @ 0.10%, which is superior to all the fungicides in controlling powdery mildew of wheat.

Among all the eight treatments the maximum yield and percent yield increase over check was recorded in Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC @ 0.10% i.e. 49.55q/ha and 59.17% respectively. However, other treatments such as Propiconazole 25EC and Bayleton 25WP produces similar percent yield increase over check i.e. 47.34% and both are significantly at par with each other. The thousand grain weight in the study was recorded in the range of 30.24-43.26 gm, all the treatments produced significantly higher 1000 grain weight as compared to check. Maximum 1000 grain weight (43.26 gm) was observed in T_2 (Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC @ 0.10%). Hence, Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC @ 0.10% was found to be superior in controlling powdery mildew disease of wheat with better yield and in future it may be included in the management practice of powdery mildew of wheat.

Furthermore, integrating this fungicide within an IPM framework not only ensures effective disease suppression but also promotes balanced and sustainable crop protection practices. By coupling the use of Azoxystrobin + Difenoconazole with preventive measures such as the adoption of resistant cultivars, adjustment of sowing dates to avoid peak disease-favourable conditions, and maintaining optimal plant spacing for better aeration, the overall disease pressure can be significantly minimized even before chemical intervention becomes necessary. Regular field scouting and disease forecasting models should also be employed to determine the precise need and timing for fungicidal applications, thereby reducing unnecessary sprays and preventing over-reliance on a single chemical group. Additionally, the rotation of fungicides with different modes of action, along with integrating biocontrol agents where feasible, can further strengthen the resilience of the management program and delay the development of fungicide resistance. In this context, the demonstrated efficacy of Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC @ 0.10% makes it a valuable chemical tool within a broader IPM strategy aimed at safeguarding wheat production while maintaining environmental and economic sustainability.

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