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RESEARCH PAPER

Efficacy of Bioagents and Fungicides Against *Pyricularia setariae* Causing Blast of Foxtail Millet Under *In Vitro* and Field Conditions

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ABSTRACT

Foxtail millet (*Setaria italica*) is a climate-resilient minor cereal valued for its nutritional profile and adaptability to rainfed systems, yet its productivity is severely hindered by blast disease caused by *Pyricularia setariae* and *P. grisea*. This study evaluated the efficacy of selected fungicides and bioagents against *Pyricularia* spp. through *in vitro* and field trials at Mahatma Phule Krishi Vidyapeeth during the *Kharif* 2024–2025 season. *In vitro* assays revealed that *Trichoderma harzianum* achieved complete mycelial inhibition (100%), while *Pseudomonas fluorescens* showed moderate inhibition (63.51%). Among fungicides, Tebuconazole 50% + Trifloxystrobin 25% WG, Tricyclazole 75% WP, and Carbendazim 12% + Mancozeb 63% WP exhibited total inhibition of fungal growth. Field evaluations demonstrated that Tebuconazole 50% + Trifloxystrobin 25% WG significantly reduced disease intensity (PDI ~15%) and achieved the highest disease control (65.59%), followed by Carbendazim 12% + Mancozeb 63% WP and Tricyclazole 75% WP. Bioagents provided moderate disease suppression but were less effective than chemical treatments under field conditions. Notably, *Pseudomonas fluorescens* significantly enhanced grain yield (11.75 q/ha), indicating its dual role in disease suppression and plant growth promotion. The results underscore Tebuconazole 50% + Trifloxystrobin 25% WG as the most potent fungicidal treatment and highlight the promise of *T. harzianum* and *P. fluorescens* for integration into eco-friendly and sustainable blast management strategies in Foxtail millet. Together, these findings advocate for an integrated disease management approach combining chemical and biological agents to mitigate blast incidence and enhance Foxtail millet productivity.

HIGHLIGHTS

- *Tebuconazole + Trifloxystrobin* achieved the greatest blast suppression in Foxtail millet, delivering the lowest disease intensity and highest yield improvement under field conditions, outperforming all other fungicidal treatments.
- *Trichoderma harzianum* completely inhibited *Pyricularia setariae in vitro*, demonstrating strong antagonism, while *Pseudomonas fluorescens* provided moderate inhibition and contributed to yield enhancement through growth-promoting effects.
- Integrated evaluation revealed that fungicides ensured superior field protection, whereas bioagents offered sustainable complementary

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activity, supporting their combined use in environmentally compatible Foxtail millet blast management strategies.

Keywords: *Eleusine coracana*, Foxtail millet, *Pyricularia setariae*, Blast, Fungicides, *In vitro* evaluation, Field evaluation, Yield enhancement

Foxtail millet (*Setaria italica*) is a climate-resilient minor cereal gaining renewed attention for its nutritional value and adaptability to rainfed farming systems. However, its productivity is significantly constrained by blast disease, caused by *Pyricularia setariae* and *P. grisea*. The pathogen primarily infects leaves but can also affect nodes and panicles, resulting in poor grain filling and shriveled seeds.

The disease thrives under warm and humid conditions, with early onset often leading to severe epidemics. According to Ou (1985), "*blast alone can cause yield losses ranging from 30% to 100%, depending on the crop growth stage and severity*," underscoring its destructive potential in susceptible cultivars under favorable environments.

In this context, the present investigation was undertaken to assess the efficacy of selected fungicides and bioagents against *Pyricularia* spp. through *in vitro* and field evaluations, with the goal of developing an integrated and environmentally compatible disease management strategy.

MATERIALS AND METHODS

The research trial was conducted at the Post Graduate Institute (PGI), Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri (413722), MS, during *Kharif* 2024–2025.

Isolation

The leaves exhibiting the typical symptoms of brown spots with straw-colored margin were collected and used for the isolation of *Pyricularia setariae* using tissue isolation on potato dextrose medium, where pathogen was incubated at 28 ± 1 °C.

In Vitro Evaluation of Bioagents and Fungicides

In vitro evaluation study was carried out for bioagents using dual culture technique (Dennis and Webster, 1971). Bioagents namely, *Trichoderma harzianum* and *Pseudomonas fluorescens* were obtained from Liquid Biofertilizer Production Unit, PGI, MPKV, Rahuri. Observations of mycelial growth were recorded 7 days after inoculation. Percent inhibition of mycelium was calculated using the formula (Eq. 1) given by Vincent (1947).

$$X = \frac{(Y - Z)}{Y} \times 100 \quad \ldots(\text{Eq. 1})$$

Where, X = percent inhibition (mm), Y = growth of fungus in control plate (mm), Z = growth of fungus in treatment plate (mm).

In vitro evaluation study was carried out for fungicides using poisoned food technique (Grover and Moore, 1962). Various fungicides viz., Tricyclazole 75% WP, Hexaconazole 5% EC, Azoxystrobin 23% EC, Carbendazim 12% + Mancozeb 63% WP, and Tebuconazole50% + Trifloxystrobin 25% WG were brought from nearby market. Observations of mycelial growth were recorded 7 days after inoculation.

Field Evaluation of Bioagents and Fungicides

Field trial was conducted using the Foxtail millet germplasm line KIFXG-22-02, obtained from the Zonal Agricultural Research Station (ZARS), Kolhapur, MPKV. Seeds were sown at a spacing of 30 × 10 cm. Two sprays of bioagents and fungicides were taken at 45 and 60 days after sowing (DAS). The corresponding observations for the Percent Disease Intensity (%) (PDI) (Eq. 2) were recorded 7 days after each spray, using the disease reaction scale (0–5) given by Patro and Madhuri (2014).

$$\text{Percent Disease Intensity (\%)} = \frac{\text{Sum of all disease ratings}}{\left(\begin{matrix}\text{total number of leaves observed} \times \\ \text{maximum disease grade}\end{matrix}\right)} \times 100 \quad \ldots(\text{Eq. 2})$$

Yield Estimation

Grain yield was recoded after harvesting and yield per hectare was estimated using formula given by Panse and Sukhatme (1967) (Eq. 3).

$$\text{Grain yield } (q/ha) = \frac{\text{Net plot yield } (kg) \times 10{,}000}{\text{Net plot area } (m^2) \times 100} \quad \ldots(\text{Eq. 3})$$

Experimental Design and Statistical Analysis

Completely Randomized Design and Randomized Block Design was used for lab and field studies respectively. The statistical analysis was performed using OPSTAT web-based platform (Sheoran *et al*. 1998) and Duncan's multiple range test was performed on statistically analyzed data using Agricole package available at R software (Mendiburu, 2021).

RESULTS AND DISCUSSION

Isolation and Identification of Pathogen

The causal organism was isolated from symptomatic leaves of Foxtail millet and identified as *Pyricularia setariae* based on its distinct colony morphology (Plate 1a) and microscopic characteristics (Plate 1b). Initially, the fungal colonies appeared white, gradually darkening to shades of grey and black as they matured. The conidia observed were pyriform (pear-shaped), hyaline, and typically had two septa, which aligns well with known features of *Pyricularia* species.

These morphological traits parallel descriptions found in the work of Kato *et al*. (2000), who detailed the fungal morphology and life cycle specific to *P. setariae*. In addition to laboratory identification, the typical blast symptoms seen in the field—small, spindle-shaped lesions with straw-colored margins-corroborated the presence of this pathogen. The identification process is critical because understanding the precise pathogen involved enables targeted management, especially given *P. setariae*'s known preference for moist, warm environments that facilitate rapid sporulation and disease development (Prom *et al.* 2013).

In Vitro Efficacy of Bioagents against *Pyricularia setariae*

Significant differences were observed among the tested bioagents in inhibiting the mycelial growth of *Pyricularia setariae* under *in vitro* conditions (Table 1; Fig. 1 and Plate 2). *Trichoderma harzianum* (T_2) recorded zero colony diameter (0.00 mm) with 100% inhibition, and was statistically superior to all other treatments. *Pseudomonas fluorescens* (T_1) recorded a colony diameter of 32.40 mm with 63.51% inhibition, and was statistically significant, forming an intermediate efficacy group. The control (T_3) recorded the highest colony diameter (88.80 mm) and 0% inhibition, and was statistically inferior to both bioagents.

Trichoderma harzianum (T_2) exhibited complete inhibition of *Pyricularia setariae* growth *in vitro*, demonstrating robust antagonistic potential. This biocontrol effect is likely driven by mechanisms such as mycoparasitism, secretion of hydrolytic enzymes like chitinases and glucanases, and production of antibiotic metabolites. Similar strong antagonistic effects of *T. harzianum* against blast-

Plate 1a: Morphological Characteristics of *Pyricularia setariae*

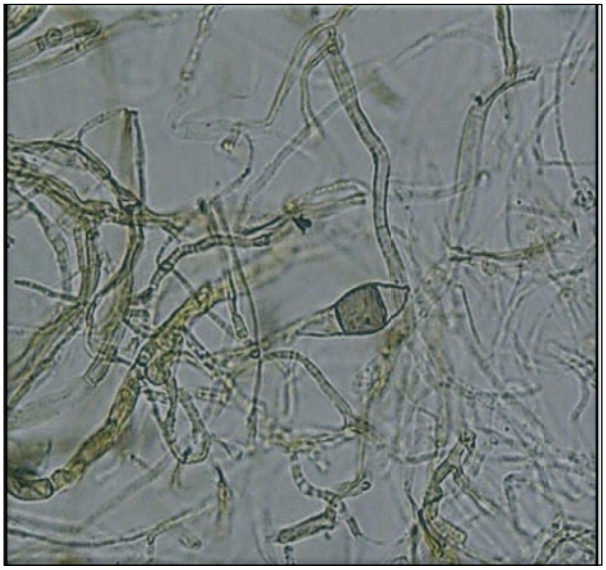

Plate 1b: Microscopic Characteristics of *Pyricularia setariae*

Table 1: Efficacy of bioagents against *Pyricularia setariae* under *in vitro* condition

Tr. No.	Treatment Name	Mean Colony Diameter (mm)	Percent Inhibition over Control (%)
T_1	*Pseudomonas fluorescens*	32.40[b]	63.51
T_2	*Trichoderma harzianum*	0.00[c]	100.00
T_3	Control (untreated)	88.80[a]	0.00
	S.E.(m) ±	0.59	
	CD at 1%	2.54	

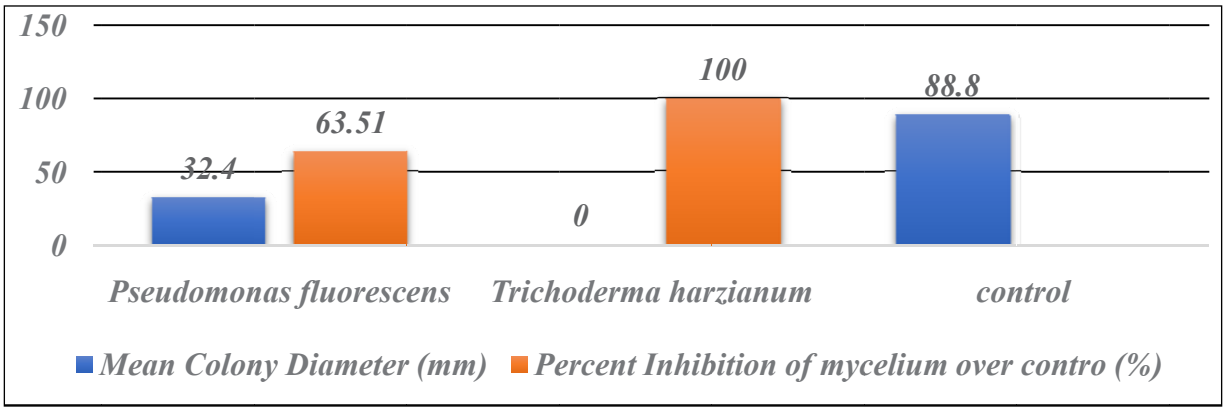

Fig. 1: Efficacy of bio-agents against *Pyricularia setariae in vitro*

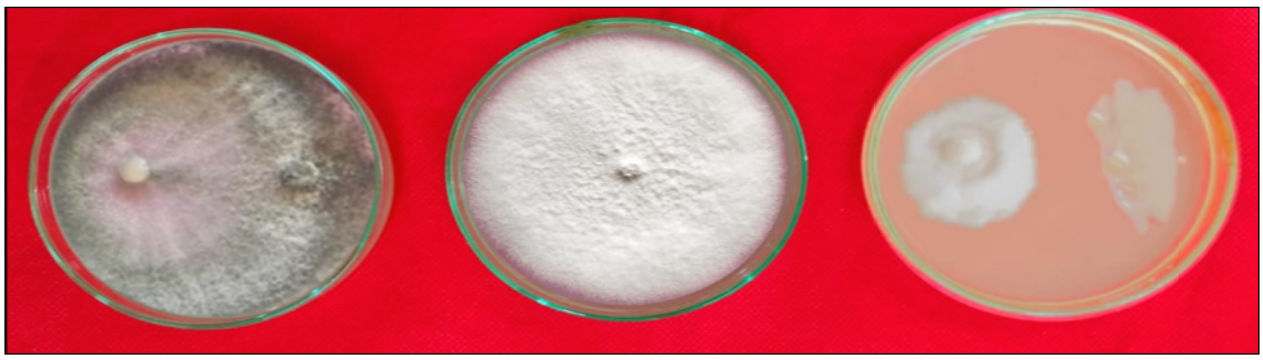

Plate 2: *In vitro* exploration of bio-agents against *Pyricularia setariae*

causing fungi have been widely documented, confirming its broad-spectrum potential for fungal pathogen suppression (Harman *et al*. 2004).

Pseudomonas fluorescens (T_1), while less effective than *T. harzianum*, still achieved significant 63.51% inhibition of pathogen growth. Its mode of action involves synthesis of antimicrobial compounds such as 2,4-diacetylphloroglucinol (2,4-DAPG), production of siderophores that sequester iron limiting pathogen growth, and competitive colonization of ecological niches unfavorable to the pathogen (Haas and Defago, 2005). Although *P. fluorescens* shows moderate efficacy alone, it plays a valuable complementary role in integrated biocontrol strategies (Vinale *et al*. 2008; Compant *et al*. 2010).

The untreated control (T_3) showed uninhibited growth, reaffirming the pathogen's virulence and the need for effective biological control

In Vitro Efficacy of Fungicides against *Pyricularia setariae*

The tested fungicides exhibited significant variation in their efficacy against the mycelial growth of *Pyricularia setariae* under *in vitro* conditions, as given in Table 2 with graphical representation in Fig. 2 and pictorial presentation in Plate 3. Tricyclazole 75% WP (T_1), Carbendazim 12% + Mancozeb WP 63% (T_4), and Tebuconazole 50% + Trifloxystrobin 25% WG (T_5) recorded complete inhibition (0.00 mm) and were statistically superior to all other treatments. Azoxystrobin 23% EC (T_3) showed

Table 2: Efficacy of fungicides against *Pyricularia setariae* under *in vitro* condition

Tr. No.	Treatment Name	Conc. (%)	Mean Colony Diameter (mm)	Percent Inhibition over Control (%)
T_1	Tricyclazole 75% WP	0.05	00.00[d]	100
T_2	Hexaconazole 5% EC	0.10	31.66[c]	64.82
T_3	Azoxystrobin 23% EC	0.04	41.66[b]	53.71
T_4	Carbendazim 12% + Mancozeb 63% WP	0.20	00.00[d]	100
T_5	Tebuconazole 50% + Trifloxystrobin 25 WG	0.04	0.00[d]	100
T_6	Control (untreated)	—	90.00[a]	
C.D 1%		S.E.(m) ±	0.38	—
		1.67		

Plate 3: *In vitro* exploration of fungicides against *Pyricularia setariae*

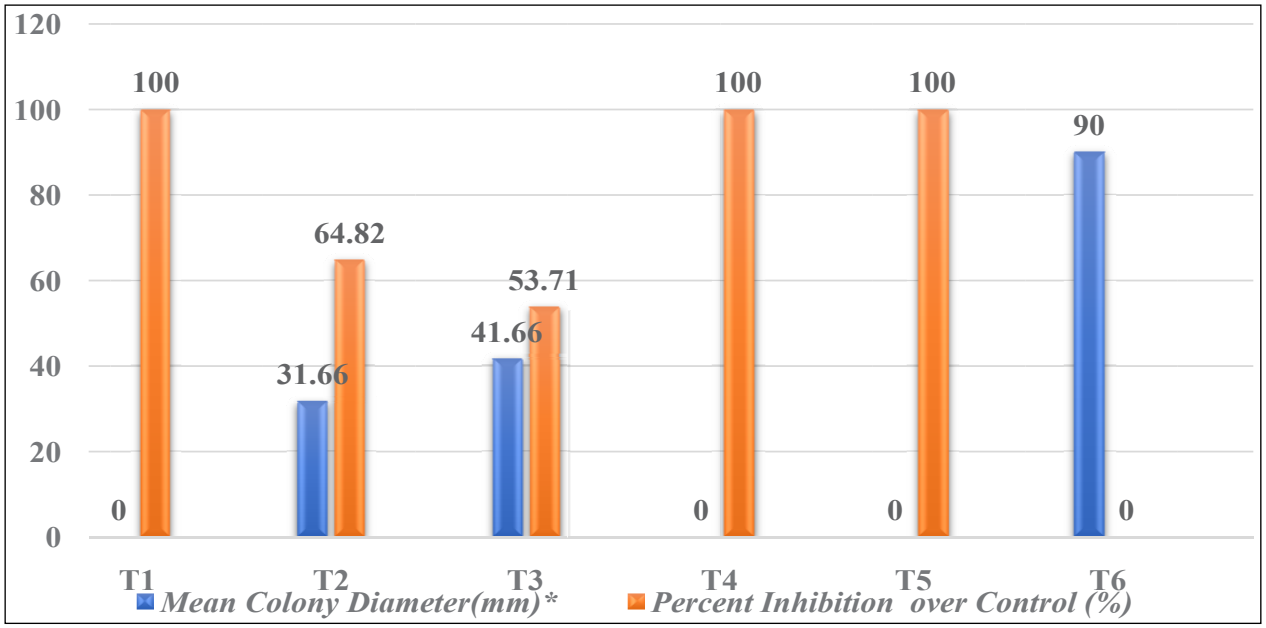

Fig. 2: Efficacy of fungicides against *Pyricularia setariae in vitro*

moderate efficacy with a colony diameter of 41.66 mm and 53.71% inhibition, and was statistically at par with Hexaconazole 5% EC (T_2), which recorded 31.66 mm diameter and 64.82% inhibition. The untreated control (T_6) recorded the maximum mycelial growth (90.00 mm) and was statistically inferior to all treatments.

Tricyclazole 75%WP (T_1), known as a melanin biosynthesis inhibitor, demonstrated complete inhibition of *Pyricularia setariae in vitro*. This aligns with its well-documented mode of action targeting melanin-dependent appressorium formation, which is essential for fungal penetration and infection (Kojima *et al*. 1987; Talbot, 2003). The disruption of these infection structures explains its high antifungal efficacy observed in laboratory conditions.

The combination of Carbendazim 12 and Mancozeb 63% WP (T_4) also resulted in total fungal growth inhibition. Carbendazim acts systemically by interfering with fungal mitosis through binding to β-tubulin, while Mancozeb serves as a broad-spectrum contact fungicide disrupting fungal enzymatic functions (Bartlett *et al.* 2002). Their combined curative and protective actions provide effective dual-layer control.

Similarly, the mixture of Tebuconazole 50% WG and Trifloxystrobin 25% WG (T_5) achieved complete inhibition. Tebuconazole, a demethylation inhibitor (DMI), disrupts ergosterol biosynthesis critical for fungal cell membrane integrity, whereas Trifloxystrobin, a quinone outside inhibitor (QoI), impedes mitochondrial respiration by blocking electron transport (Yin *et al*. 2011; Lucas *et al*. 2015). The synergistic effect of these two fungicides is well established and enhances both efficacy and durability of blast disease management.

In contrast, Hexaconazole 5% EC (T_2) and Azoxystrobin 23% EC (T_3) exhibited moderate fungal inhibition. Hexaconazole, also a DMI fungicide, partially suppresses ergosterol synthesis, while Azoxystrobin (a QoI fungicide) targets mitochondrial electron transport but may have limited contact action in vitro (Maskell *et al.* 2006). This reduced efficacy under laboratory conditions may not fully reflect their potential under field application, where systemic translocation and environmental factors influence performance (Bartlett *et al*. 2002).

The untreated control (T_6) displayed unrestricted fungal growth, confirming the virulence of *P. setariae* and validating the observed fungicidal activities.

Efficacy Bioagents and Fungicides Against Blast Disease of Foxtail Millet Under field Condition

The severity of blast disease under field conditions varied significantly across different treatments as mentioned in Table 3 and Fig. 3. Tebuconazole 50% WG + Trifloxystrobin 25% WG (T_3) recorded the lowest PDI after both sprays (14.30% and 15.85%), and was statistically superior to all other treatments, with the highest disease control (65.59%). It was followed by Carbendazim 12% WP+ Mancozeb 63% WP (T_1) and Tricyclazole 75% WP (T_2), which recorded PDI values of 17.41% and 19.52%, and 21.48% and 22.93%, respectively, and were statistically at par with each other but inferior to T_3. Hexaconazole 5% EC (T_4) and Azoxystrobin 23% EC (T_5) recorded higher disease intensities (22.45% and 25.26% and 27.85% and 28.15%, respectively), and showed moderate control (45.17% and 38.89%). Among bioagents, *Trichoderma harzianum* (T_6) and *Pseudomonas fluorescens* (T_7) recorded PDI values ranging from 29.63% to 36.00%, with lower disease control (27.80% and 21.85%), and were statistically at par with each other, but inferior to all fungicidal treatments. The untreated control (T_8) recorded the highest disease intensity (38.07% and 46.07%), and was statistically inferior to all treatments.

Among all treatments tested, the fungicide combination of Tebuconazole 50% WG + Trifloxystrobin 25% WG (T_3) demonstrated the highest level of disease suppression. The synergistic interaction between Tebuconazole, a demethylation inhibitor (DMI) that impedes ergosterol biosynthesis critical for fungal cell membrane integrity, and Trifloxystrobin, a quinone outside inhibitor (QoI) that disrupts mitochondrial respiration, provides broad-spectrum efficacy coupled with prolonged residual activity (Bartlett *et al.* 2002; Yin *et al.* 2011). Comparable results highlighting the superior performance of this combination against *Magnaporthe* species under field conditions have been documented by Kumar *et al.* (2020) and corroborated in similar pathosystems (Harman *et al.* 2004).

Table 3: Efficacy of fungicides and bioagnets against *Pyricularia grisea* under field condition

Tr. No	Treatment Name	Conc. (%)	Percent Disease Intensity (%) (7 days after spray)		Percent Disease Control (%)
			1st spray	2nd spray	
T_1	Carbendazim 12% + Mancozeb 63% WP	0.20	17.41 (24.59)^{de}	19.52 (26.08)^{ef}	57.62
T_2	Tricyclazole 75% WP	0.05	21.48 (27.59)^{cd}	22.93 (28.55)^{de}	50.22
T_3	Tebuconazole 50% + Trifloxystrobin 25 WG	0.04	14.30 (22.11)^{e}	15.85 (23.37)^{f}	65.59
T_4	Hexaconazole 5% EC	0.10	22.45 (28.25)^{c}	25.26 (30.15)^{d}	45.17
T_5	Azoxystrobin 23% EC	0.04	27.85 (31.83)^{b}	28.15 (32.02)^{cd}	38.89
T_6	*Trichoderma harzianum*	0.50	29.63 (32.97)^{b}	33.26 (35.19)^{bc}	27.80
T_7	*Pseudomonas fluorescens*	1.00	32.52 (34.76)^{b}	36.00 (36.85)^{b}	21.85
T_8	Control (untreated)	—	38.07 (38.07)^{a}	46.07 (42.74)^{a}	—
S.E.(m) ±			1.02	1.25	
C.D at 5%			3.13	3.85	

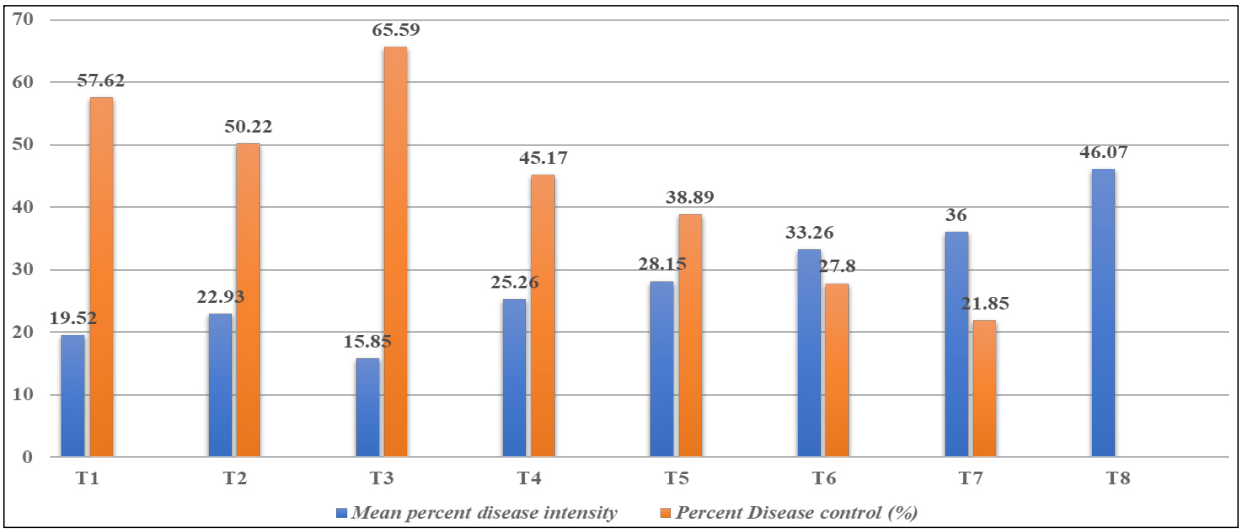

Fig. 3: Efficacy of fungicides and bioagnets against *Pyricularia grisea* under field condition

The treatments Carbendazim 12% + Mancozeb 63% WP (T_1) and Tricyclazole 75% WP (T_2) showed moderate but notable effectiveness. Carbendazim, a benzimidazole fungicide, acts by interfering with mitotic spindle formation, thereby disrupting fungal cell division, whereas Mancozeb serves as a protective contact fungicide providing a shield against initial infection (Bartlett *et al.* 2002). Tricyclazole functions specifically as a melanin biosynthesis inhibitor, hampering the formation of appressoria essential for fungal penetration in *Pyricularia* species (Kojima *et al.* 1987; Talbot, 2003). While these treatments achieved respectable disease control, their performance was consistently below that of the Tebuconazole 50% + Trifloxystrobin 25% WG combination.

Hexaconazole 5% EC (T_4) and Azoxystrobin 23% EC (T_5) were less effective in suppressing disease, possibly due to reduced persistence, incomplete inhibition of pathogen growth, or partial fungicide resistance within the *Pyricularia* population (Maskell *et al.* 2006; Sharma *et al.* 2021). Azoxystrobin, although known for its systemic and translaminar activity, has exhibited variable efficacy under field conditions, underscoring the complexity of blast disease management (Bartlett *et al.* 2002).

Biological treatments with *Trichoderma harzianum* (T_6) and *Pseudomonas fluorescens* (T_7) achieved moderate suppression of blast disease, likely through antagonistic mechanisms such as mycoparasitism, production of antifungal enzymes and metabolites,

induced systemic resistance (ISR), and competitive exclusion within the rhizosphere (Harman *et al.*, 2004; Haas and Defago, 2005). However, under high disease pressure, their efficacy was significantly lower compared to chemical fungicides, emphasizing the importance of integrating biological agents with chemical and cultural controls for sustainable disease management.

The untreated control plots (T_8) exhibited the highest percent disease index (PDI), confirming the aggressive nature of *Pyricularia grisea* under conducive environmental conditions and validating the substantial protective effects attained by the tested treatments.

Impact of Bioagents and Fungicides on Yield of Foxtail Millet

All treatments produced statistically significant improvements in grain yield compared to the untreated control (Table 4, Fig. 4), reflecting the effectiveness of both fungicides and bioagents in managing *Pyricularia setariae* and enhancing Foxtail millet productivity.

Among all the treatments, Carbendazim 12% + Mancozeb 63% WP (T_1) and Tricyclazole 75% WP (T_2) recorded the highest grain yields of 13.91 q/ha and 13.85 q/ha respectively, each showing about a 36% increase over the control. These yields were statistically similar to Tebuconazole 50% + Trifloxystrobin 25% WG (T_3), which produced a slightly higher yield of 14.32 q/ha (41.01% increase). Following closely was Hexaconazole 5% EC (T_4) with 13.60 q/ha, reflecting a 33.88% gain over the control. These results suggest that the systemic fungicides and fungicide combinations effectively suppressed blast disease, leading to notable yield enhancements.

In contrast, biological treatments with *Trichoderma harzianum* (T_6) and *Pseudomonas fluorescens* (T_7) yielded 12.04 q/ha and 11.75 q/ha respectively, corresponding to 18.51% and 15.68% increases over the control. While these increases are significant, yields from bioagents were somewhat lower compared to the best-performing fungicide treatments, indicating that bioagents provide moderate disease suppression coupled with potential growth-promoting effects.

The fungicide combination of Carbendazim 12% + Mancozeb 63% WP (T_1) produced a grain yield of 13.91 q/ha, representing a 36.92% increase over the untreated plots. Carbendazim acts systemically by disrupting fungal cell division through interference with mitotic spindle formation (Bartlett *et al*. 2002), while Mancozeb provides broad-spectrum contact protection by inhibiting spore germination (Bartlett *et al.* 2002). The synergy of these curative and protective actions likely contributed to effective disease control, leading to significant yield improvements. However, its slightly lower yield compared to some newer fungicides may be due to limited residual activity or reduced mobility within plant tissues, which restricts its ability to provide prolonged protection under field conditions.

Similarly, Tricyclazole 75% WP (T_2) achieved a grain yield of 13.85 q/ha, marking a 36.34% increase over the control. Tricyclazole works by inhibiting melanin biosynthesis, which is essential for proper formation of appressoria—the fungal structures

Table 4: Impact of fungicides and bioagnets on yield of Foxtail millet against *Pyricularia setariae*

Tr. No	Treatment Name	Conc. (%)	Grain Yield (q/ha)	Percent Grain Yield Increase over Control (%)
T_1	Carbendazim 12% + Mancozeb 63% WP	0.20	13.91^{ab}	36.92
T_2	Tricyclazole 75% WP	0.05	13.85^{ab}	36.34
T_3	Tebuconazole 50% + Trifloxystrobin 25% WG	0.04	14.32^{a}	41.01
T_4	Hexaconazole 5% EC	0.10	13.60^{ab}	33.88
T_5	Azoxystrobin 23% EC	0.04	12.41^{ab}	22.13
T_6	*Trichoderma harzianum*	0.50	12.04^{bc}	18.51
T_7	*Pseudomonas fluorescens*	1.00	11.75^{bc}	15.68
T_8	Control (untreated)	—	10.16^{c}	0.00
S.E.(m) ±			0.68	
C.D at 5%			2.05	

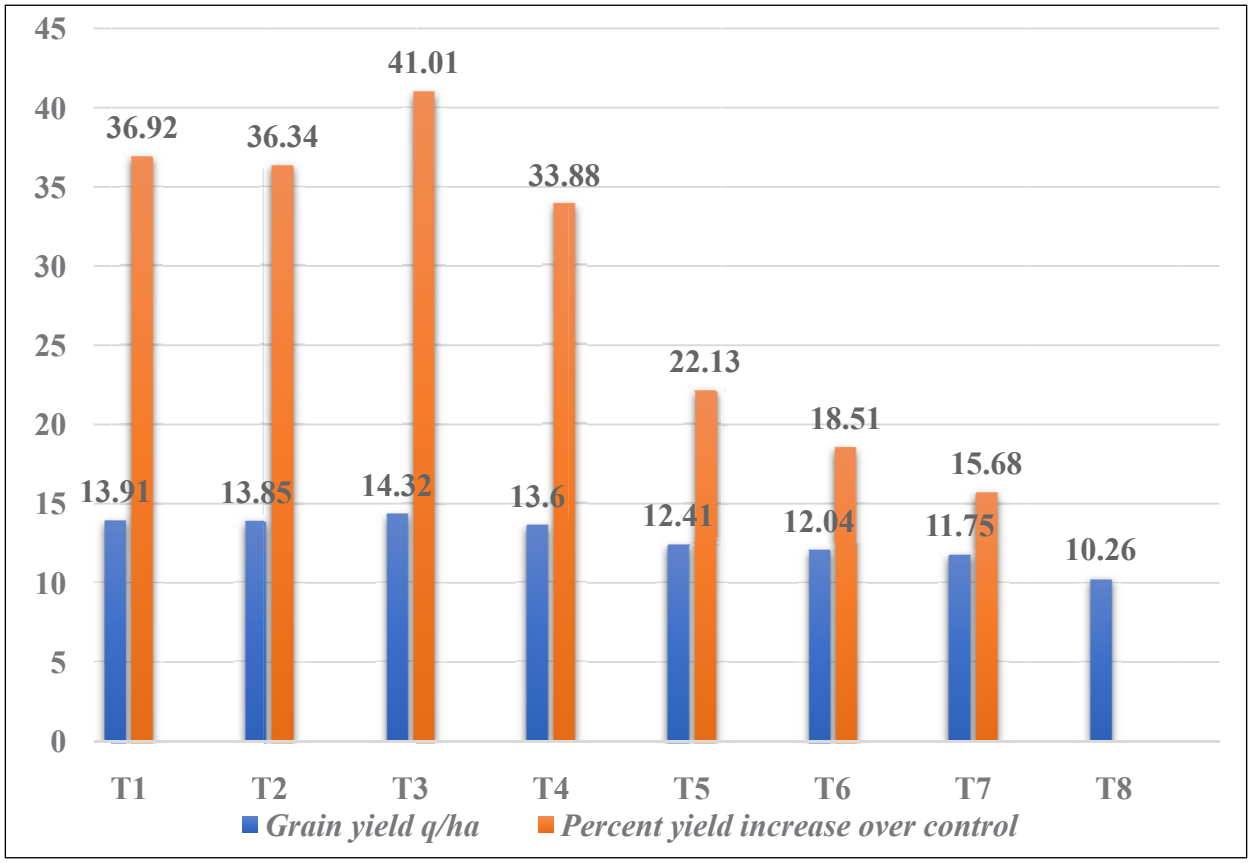

Fig. 4: Efficacy of fungicides and bioagnets on yield of Foxtail millet

that allow penetration into host tissues (Kojima *et al.* 1987; Talbot, 2003). This disruption effectively prevents pathogen invasion and reduces disease severity. Although it has moderate systemic activity, the narrower scope of its action and possibly shorter protective duration may explain why its yield results were slightly less than those achieved with the Tebuconazole 50% + Trifloxystrobin 25% WG combination (Kojima *et al.* 1987).

The combination of Tebuconazole 50% + Trifloxystrobin 25% WG (T_3) resulted in the highest grain yield of 14.32 q/ha, showing a 41.01% improvement over the untreated plots. This superior effect is due to the complementary mechanisms of these fungicides: Tebuconazole 75% WP inhibits ergosterol biosynthesis, vital for fungal cell membrane integrity (Bartlett *et al.* 2002), while Trifloxystrobin disrupts mitochondrial electron transport, impeding fungal respiration (Yin *et al.* 2011). Together, they offer broad-spectrum, systemic control with extended residual action, protecting key photosynthetic tissues such as the flag leaf during critical grain-filling stages. This preservation supports enhanced photosynthate production and its translocation, accounting for the higher grain yields observed under this treatment (Kumar *et al.* 2020).

Hexaconazole 5% EC (T_4), a systemic demethylation inhibitor fungicide similar to Tebuconazole, produced a grain yield of 13.60 q/ha, which was a 33.88% increase over the control. Differences in uptake, translocation efficiency, or environmental stability may have led to slightly reduced residual activity compared to the Tebuconazole 50%+ Trifloxystrobin 25% WG mix, causing a modest drop in performance. Nonetheless, Hexaconazole effectively suppressed *Pyricularia setariae*, contributing significantly to yield improvement (Maskell *et al.* 2006).

Azoxystrobin 23% EC (T_5) produced a moderate grain yield of 12.41 q/ha, representing a 22.13% gain over the untreated control. Although it acts as a QoI fungicide with systemic and translaminar properties by inhibiting fungal mitochondrial electron transport (Bartlett *et al.* 2002), its field efficacy can be inconsistent. Environmental factors

such as temperature and rainfall as well as possible pathogen sensitivity shifts or resistance development may have diminished its practical effectiveness in this study (Sharma *et al.* 2021; Bartlett *et al.* 2002). These factors likely contributed to the moderate disease suppression and yield improvement observed.

Biological treatments with *Trichoderma harzianum* (T_6) and *Pseudomonas fluorescens* (T_7) resulted in yields of 12.04 q/ha and 11.75 q/ha, corresponding to 18.51% and 15.68% increases, respectively. These beneficial microbes suppress pathogens through several mechanisms: *Trichoderma harzianum* employs mycoparasitism, produces hydrolytic enzymes, and secretes antifungal metabolites (Harman *et al.* 2004), while *Pseudomonas fluorescens* synthesizes antibiotics such as 2,4-diacetylphloroglucinol, produces siderophores to sequester iron, and competes with pathogens for ecological niches (Haas and Defago, 2005). Both also stimulate induced systemic resistance in plants and promote growth by releasing phytohormones and enhancing nutrient uptake (Compant *et al.* 2010; Harman *et al.* 2004). Though their biocontrol effects may be less pronounced than fungicides under high disease pressure, their ability to sustain yield demonstrates their value in integrated and eco-friendly disease management strategies aimed at minimizing chemical inputs and improving soil and plant health.

The untreated control (T_8) produced the lowest grain yield of 10.16 q/ha, highlighting the detrimental impact of unmanaged blast infection on Foxtail millet productivity. This clear contrast underscores the importance of timely and effective disease management to prevent substantial yield losses.

CONCLUSION

The present investigation elucidated the comparative efficacy of various bioagents and fungicidal treatments against *Pyricularia setariae*, the causal agents of blast in Foxtail millet. Laboratory assays revealed that *Trichoderma harzianum* achieved complete inhibition of mycelial growth *in vitro*, closely followed by *Pseudomonas fluorescens*, highlighting their potential as reliable biocontrol agents. Among fungicides tested using the poisoned food technique, Tebuconazole 50% + Trifloxystrobin 25% WG exhibited the highest inhibition, confirming its potent systemic and protective properties.

Field evaluations corroborated the *in vitro* findings. Tebuconazole 50% + Trifloxystrobin 25% WG significantly reduced disease severity across both sprays and outperformed all other treatments. It was followed by Carbendazim 12% + Mancozeb 63% WP and Tricyclazole 5% EC, which showed moderate efficacy. Bioagents also provided measurable disease suppression under epiphytotic conditions, with *T. harzianum* and *P. fluorescens* exhibiting consistent performance.

All treatments significantly enhanced grain yield over the untreated control. Notably, *P. fluorescens* recorded the highest yield, suggesting its dual role in disease mitigation and plant growth promotion. Among fungicides, Tebuconazole 50% + Trifloxystrobin 25% WG led to substantial yield gains, reaffirming its agronomic relevance.

In conclusion, Tebuconazole 50% + Trifloxystrobin 25% WG emerged as the most efficacious fungicidal option for blast management in Foxtail millet. Meanwhile, *T. harzianum* and *P. fluorescens* demonstrated promising biological potential, supporting their inclusion in integrated disease management strategies. The study advocates for a synergistic approach that combines chemical and biological interventions to sustainably control blast and improve crop productivity.

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