RESEARCH ARTICLE https://doi.org/10.58297/XQEK7443

Suitable Fungicides and Bio-Formulation Combination for Management of Sheath Blight Disease in Rice

Surendran M*, Prageetha P Nair, Nimmy Jose and Jyothi Sara Jacob

M S Swaminathan Rice Research Station, Moncompu 688 503, Thekkekara P.O., Alleppey (dst), Kerala, India

*Corresponding author Email: surendran.m@kau.in

Received: 3rd January, 2026, Accepted: 15th March, 2026

Abstract

Field experiments were conducted at M S Swaminathan Rice Research Station, Moncompu, Alappuzha, Kerala, for four consecutive seasons of *Kharif* 2022, *Rabi* 2022-23, *Kharif* 2023 and *Kharif* 2024 with the objective of evaluating the efficiency of commercially available biofertilizer/biocontrol agents and fungicides against rice sheath blight disease. The tested biofertilizer and biocontrol agent combination treatments were *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + PGPR I soil application (1 kg/acre) + PGPR II foliar application (20 g/l), *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + PGPR II foliar spray (20 g/l), and *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + soil application (1 kg/acre) + foliar application (20 g/l). The evaluated fungicides were Hexaconazole 4% + Zineb 68% WP (2.5 g/l), Azoxystrobin 18.2% + Difenoconazole 11.4% SC (1 ml/l), Thifluzamide 24% SC (0.8 ml/l), Difenoconazole 25% EC (0.5 ml/l), Isoprothiolane 40% EC (1.5 ml/l), Carbendazim 12% + Mancozeb 63% WP (1.5 g/l), Copper Hydroxide 77% WP (2 g/l) and Hexaconazole 5% SC (2 ml/l) (Standard Check fungicide). Among eight fungicides tested, Azoxystrobin 18.2% + Difenoconazole 11.4% SC (1 ml/l) was found to be the most promising combination molecule against sheath blight, followed by Thifluzamide 24% SC (0.8 ml/l). The maximum yield was obtained from Difenoconazole 25% EC (0.5 ml/l) (6382 kg/ha), and Azoxystrobin 18.2% + Difenoconazole 11.4% SC (1 ml/l) (6207 kg/ha), followed by Carbendazim 12% + Mancozeb 63% WP (1.5 g/l) (5837 kg/ha), Thifluzamide 24% SC (0.8 ml/l) (5771 kg/ha) and organic treatment such as *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + PGPR I (1 kg/acre) + PGPR II (20 g/l) with an yield of 5746 kg/ha was also recorded. The control plot recorded the lowest yield of 3697 kg/ha.

Keywords: Rice, Sheath blight, biofertilizer, biocontrol agents, combination fungicide

Introduction

Rice (*Oryza sativa L.*) is a member of the Poaceae family, specifically the genus *Oryza*. It emerged as a wild grass prior to establishing as a crop and is now a staple diet for millions of people worldwide (Prasad *et al*., 2018). However, rice production worldwide is affected by various biotic and abiotic stresses. Rice sheath blight disease, caused by *Rhizoctonia solani*, is one of the most destructive diseases affecting rice, leading to large scale yield losses especially in the areas such as the U.S.A, Japan, China, and India, where intensive agricultural practices are being followed (Gautam *et al.,* 2003). Under favourable environmental conditions, sheath blight fungus can reduce yield by up to 50% (Richa *et al.,* 2016). Sclerotia live in the remains of host plants as either mycelia or sclerotia. During the infection process, the sclerotia float to the top of the flooding water in the rice fields and germinate on the rice sheaths to create appressoria or infection cushions. Plants from around 32 families and 188 species can be infected by the pathogen, which has a broad host range (Srinivasachary *et al*., 2011).

Early symptoms of sheath blight include oval-shaped sheath spots at or just above the water level, often at the junction of the leaf and sheath. It frequently attacks and kills both leaves and sheaths. In extreme circumstances, sheath blight can infect the panicle, preventing entire grain fill and adhering panicles into a vertical spike. In the current study, various fungicides and bioagents currently in the market were used in field experiments to control sheath blight of rice, taking into account the severity of the illnesses and their economic significance.

Materials and Methods

Field experiments were conducted at M S Swaminathan Rice Research Station, Moncompu, Alappuzha, Kerala for four seasons (*Kharif 2022, Rabi 2022-23, Kharif 2023* and *Kharif 2024)* with the objective of evaluating the efficiency of commercially available biofertilizer/biocontrol agents and fungicides against rice sheath blight disease. The tested biofertilizer and biocontrol agent combination was *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + PGPR I (soil - 1 kg/acre) + PGPR II (foliar - 20 g/l), *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + PGPR II (foliar - 20 g/l), and *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + soil application (1 kg/acre) + foliar (20 g/l). The KAU biofertilizer PGPR I contain *Azospirillum lipoferum, Azotobacter chrooccum, Bacillus megaterium* and *Bacillus sporothermodurans*. The biocontrol agent PGPR mix-II contains *Pseudomonas fluorescens* and *Bacillus subtilis*. The evaluated fungicides were Hexaconazole 4% + Zineb 68% WP (2.5 g/l), Azoxystrobin 18.2% + Difenoconazole 11.4% SC (1 ml/l), Thifluzamide 24% SC (0.8 ml/l), Difenoconazole 25% EC (0.5 ml/l), Isoprothiolane 40% EC (1.5 ml/l), Carbendazim 12% + Mancozeb 63% WP (1.5 g/l), Copper Hydroxide 77% WP (2 g/l) and Hexaconazole 5% SC (2 ml/l). The trial was carried out in the direct sown crop of medium duration susceptible variety, Uma. The experiments were laid out in a randomized block design with 3 replications in a 5x2 m plot with 15x15 cm spacing. The NPK fertilizers and all other cultural operations were applied as per Package of Practices recommendation (90:45:45 kg/ha) by Kerala Agricultural University. The sick plot for sheath blight disease was selected for conducting the experiment. The chemicals were sprayed prophylactically as a single application at the panicle initiation stage, 55 days after transplanting. Three sampling units of 1 sq.m area were fixed in each plot at random. The disease incidence/ severity was recorded before the spray and final observation at fifteen days after spray. Percentage of disease incidence was calculated on 30 plants per sampling unit, by counting the number of infected tillers. Disease incidence was calculated using the following formula (Rajput and Bartaria, 1995; Greer and Webster, 2001)

$$\text{Disease Incidence (\%)} = \frac{\text{Total number of infected plants}}{\text{(Total number of infected plants)/ (Total number of plants observed)}} \times 100$$

Degree of severity was graded on a 0-to-9 scale based on the height of the plant portions affected by the disease and it was expressed as a percentage of the total area according to the Standard Evaluation System (SES) for rice (IRRI, 1996).

SES Scale (2014) for sheath blight disease

Grade	Description
0	No infection
1	Vertical spread of the lesions up to 20% of plant height
3	Vertical spread of the lesions up to 21-30% of plant height
5	Vertical spread of the lesions up to 31-45% of plant height
7	Vertical spread of the lesions up to 45-65% of plant height
9	Vertical spread of the lesions up to 66-100% of plant height

PDI was computed according to Wheeler (1969), using the formula

was computed according to Wheeler (1969), using the formula

$$\text{PDI} = \frac{\text{Sum of the scores}}{\text{Number of observations x highest number in rating scale}} \times 100$$

Grain yield of each plot was recorded and expressed in kg/ha at 14 per cent moisture. Data on percentages were transformed to arcsine and analysis of variance was performed with transformed values. Significance among mean treatments was determined according to Duncan's multiple range tests (Gomez and Gomez, 1984).

Results and Discussion

The results of field trial at M S Swaminathan Rice Research Station, Moncompu during the seasons *Kharif 2022, Rabi 2022-23, Kharif 2023*, and *Kharif 2024* revealed that the plots treated with the combination fungicide Azoxystrobin 18.2% + Difenoconazole 11.4% SC @ 1ml/l recorded lower sheath blight incidence (14.15%), which was followed by Thifluzamide 24% SC 0.8ml/l with an incidence of 20.66% which are effective in reduction of sheath blight disease in rice (**Table 1 and Figure 1**). Among the strobilurins, the fungicide Azoxystrobin was widely used due to their effectiveness against sheath blight pathogen (Pramesh *et al.,* 2017). After spraying with Azoxystrobin 11% + Tebuconazole 18.3% in the tillering stage, the disease incidence decreased to 88% in 2020-21 and 81% in 2021-22 (Chitti babu *et al., 2024*).

Table 1: Evaluation of different fungicides and biofertilizer/biocontrol agent against sheath blight disease incidence (%) of rice during *Kharif* 2022, *Rabi* 2022-23, *Kharif* 2023 and *Kharif* 2024 (pooled data of four season)

Treat-ments	Fungicides	Dose/l/acre	*Disease Incidence (%)				Mean
			Kharif 2022	*Rabi 2022-23*	*Kharif 2023*	*Kharif 2024*	
1	*Pseudomonas fluorescens* seed treatment + PGPR I + PGPR II	10 g/kg seed +soil @ 1 kg /acre + 20 g/l	8.53 (16.98)	20.03 (26.58)	32.2 (34.57)	38.18 (38.16)	24.73 (29.82)
2	*Pseudomonas fluorescens* seed treatment + PGPR II	10 g/kg seed + 20 g/l	12.71 (20.88)	21.479 (27.62)	29.74 (33.04)	27.28 (31.50)	22.8 (28.52)
3	Hexaconazole 4% + Zineb 68% WP	2.5 g	21.09 (27.35)	16.08 (23.66)	14.4 (22.30)	17.14 (24.50)	17.17 (24.50)
4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	1 ml	3.43 (10.63)	11.08 (19.46)	8.82 (20.26)	2.45 (9.10)	6.44 (14.65)
5	Thifluzamide 24% SC	0.8 ml	18.74 (25.62)	22.13 (28.06)	8.93 (17.36)	17.43 (24.65)	20.66 (20.06)
6	Difenoconazole 25% EC	0.5 ml	14.62 (22.46)	14.45 (22.38)	20.39 (26.85)	16.34 (23.81)	16.45 (23.97)
7	Isoprothiolane 40% EC	1.5 ml	31.51 (34.14)	29.9 (33.15)	38.3 (38.82)	31.1 (33.90)	13.52 (21.56)
8	Carbendazim 12% + Mancozeb 63% WP	1.5 g	12.68 (20.88)	17.39 (24.65)	31.65 (34.27)	27.61 (31.69)	22.33 (28.18)
9	Copper Hydroxide 77% WP	2 g	41.3 (39.98)	18.64 (25.55)	34.75 (36.15)	34.41 (35.97)	32.85 (35.00)
10	Hexaconazole 5% SC (Standard Check)	2 ml	19.97 (26.49)	5.09 (13.05)	26.12 (30.72)	20.26 (26.78)	17.86 (25.03)
11	*Pseudomonas fluorescens* Seed +Soil +Foliar (Organic Check)	10 g/kg seed +1 kg/ acre + 20 g	29.73 (33.02)	19.88 (26.42)	23.27 (28.86)	32.23 (34.57)	26.27 (30.85)
12	Control	-	46.34 (42.82)	47.24 (43.39)	49.97 (44.48)	52.17 (46.24)	52.97 (46.27)
	LSD @ 5% (P=0.05)		7.270	8.720	15.186	6.187	7.270
	CV (%)		16.422	20.211	29.731	12.026	18.288

*Mean of three replications. Figures in the parentheses are arc sine transformed values.

The pooled data of the results showed that the prolonged effect on the disease severity was obtained as 6.56% for Azoxystrobin 18.2% + Difenoconazole 11.4% SC followed by Thifluzamide 24% SC as 13.23% and Difenoconazole 25% EC (16.56%) **(Table 2 and Figure 2)**. The fungicide combination Azoxystrobin 18.2% + Difenoconazole 11.4% SC (Strobilurin + Triazole) was more effective against sheath blight than the other individual fungicides reported by Bhuvaneswari *et. al.,* 2012. Current research results have also confirmed the superior efficacy of Azoxystrobin 18.2% + Difenoconazole 11.4% SC in reducing the sheath blight severity.

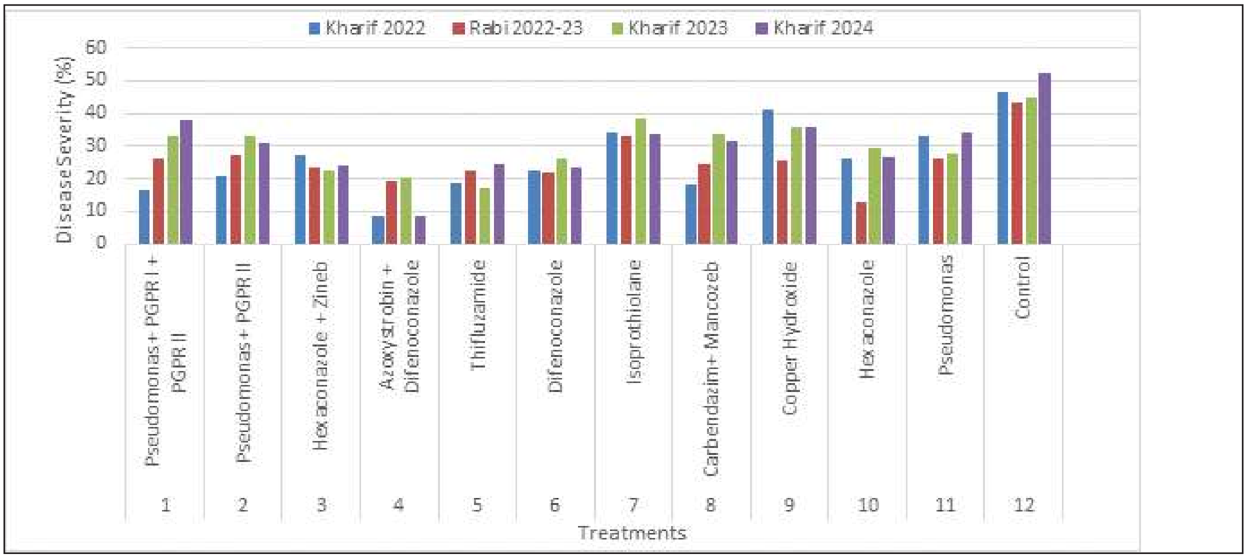

Figure 1: Effectiveness of different fungicides and biofertilizer/biocontrol agent on sheath blight disease incidence (%) of rice during *Kharif* 2022, *Rabi* 2022-23, *Kharif* 2023 and *Kharif* 2024 (pooled data of four seasons)

Table 2: Evaluation of different fungicides and biofertilizer/biocontrol agent against sheath blight disease severity (%) of rice during *Kharif* 2022, *Rabi* 2022-23, *Kharif* 2023 and *Kharif* 2024 (pooled data of four seasons)

Treat-ments	Fungicides	Dose/l/acre	*Disease Severity (%)				Mean
			Kharif 2022	*Rabi 2022-23*	*Kharif 2023*	*Kharif 2024*	
1	*Pseudomonas fluorescens* seed treatment + PGPR I + PGPR II	10 g/kg seed +soil @ 1 kg /acre + 20 g/l	7.03 (15.68)	20.73 (27.06)	29.62 (32.96)	41.78 (40.28)	25.45 (30.26)
2	*Pseudomonas fluorescens* seed treatment + PGPR II	10 g/kg seed + 20 g/l	9.99 (18.34)	19.25 (26.06)	28.88 (32.52)	32.58 (34.82)	22.67 (28.45)
3	Hexaconazole 4% + Zineb 68% WP	2.5 g	18.51 (25.47)	14.81 (22.63)	15.18 (22.87)	18.88 (25.77)	16.84 (24.20)
4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	1 ml	3.70 (11.09)	9.99 (17.56)	9.99 (17.56)	2.59 (9.28)	6.56 (14.89)
5	Thifluzamide 24% SC	0.8 ml	8.88 (18.42)	12.58 (20.79)	8.88 (17.36)	22.59 (28.39)	13.23 (21.30)
6	Difenoconazole 25% EC	0.5 ml	14.81 (22.63)	14.80 (22.06)	19.25 (26.06)	17.40 (24.43)	16.56 (24.04)
7	Isoprothiolane 40% EC	1.5 ml	35.55 (36.63)	32.58 (34.88)	38.82 (39.25)	37.40 (37.52)	36.19 (36.99)
8	Carbendazim 12% + Mancozeb 63% WP	1.5 g	10.74 (19.09)	12.21 (20.44)	39.62 (39.00)	33.69 (35.49)	24.06 (29.40)
9	Copper Hydroxide 77% WP	2 g	39.47 (38.92)	14.07 (22.06)	36.66 (37.29)	42.21 (40.51)	33.32 (35.24)
10	Hexaconazole 5% SC (Standard Check)	2 ml	19.99 (26.49)	4.44 (12.11)	29.25 (32.77)	27.73 (31.76)	20.35 (26.85)
11	*Pseudomonas fluorescens* Seed +Soil +Foliar (Organic Check)	10 g/kg seed +1 kg/ acre + 20 g	28.51 (32.27)	14.06 (22.06)	26.29 (30.85)	37.77 (37.94)	26.65 (31.11)
12	Control	-	70.36 (57.04)	52.27 (46.26)	59.99 (50.71)	71.10 (57.48)	63.41 (52.71)
	LSD @ 5% (P=0.05)		9.377	17.182	25.541	11.452	11.109
	CV (%)		24.752	54.898	52.779	20.892	30.339

*Mean of three replications. Figures in the parentheses are arc sine transformed values

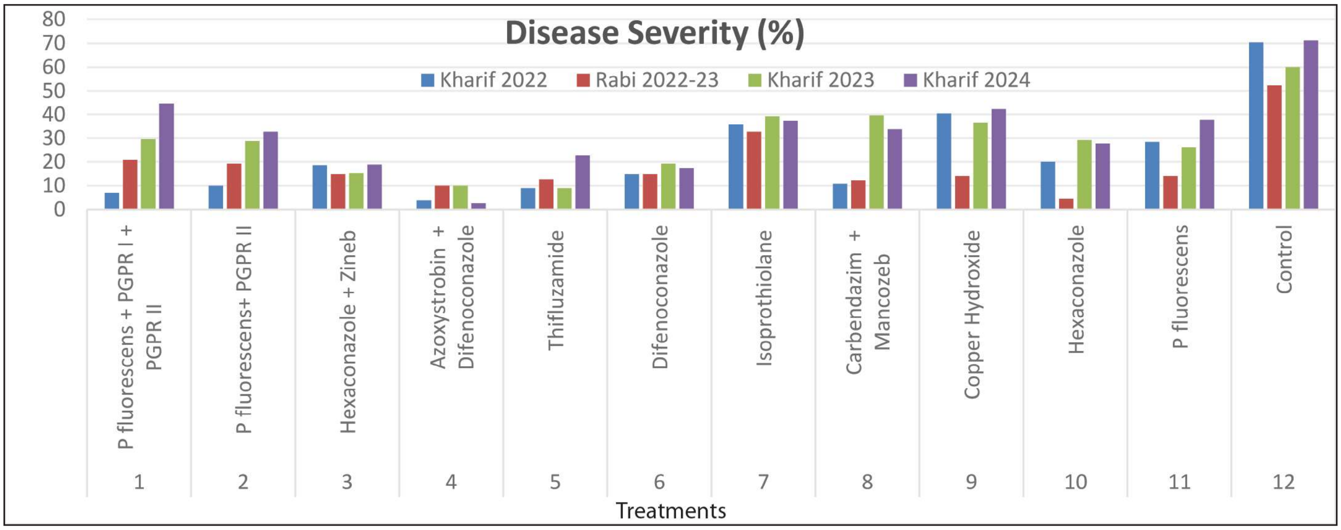

Figure 2: Effectiveness of different fungicides and biofertilizer/biocontrol agent on sheath blight disease severity (%) of rice during *Kharif* 2022, *Rabi* 2022-23, *Kharif* 2023 and *Kharif* 2024 (pooled data of four seasons)

The results on yield data showed that the systemic fungicides Difenoconazole 25% EC and Azoxystrobin 18.2% + Difenoconazole 11.4% SC combination fungicide produced highest yield in the study **(Table 3 and Figure 3)**. Application of fungicides at various crop stages has been reported to increase yield by reducing disease burden (Pramesh *et al.,* 2017). Previous scientific studies by Bag *et al.,* (2016) also reported that Azoxystrobin 11% + Tebuconazole 18.3% was effective in reducing the incidence of sheath blight and increasing rice yield. In the study, the highest yield was obtained from Difenoconazole 25% EC (6382 kg/ha), Azoxystrobin 18.2% + Difenoconazole 11.4% SC (6207 kg/ha), followed by Carbendazim 12% + Mancozeb 63% WP (5837 kg/ha) and Thifluzamide 24% SC (5771 kg/ha).

Table 3: Evaluation of different fungicides and biofertilizer/biocontrol agent on grain yield (kg/ha) of rice during *Kharif* 2022, *Rabi* 2022-23, *Kharif* 2023 and *Kharif* 2024 (pooled data of four seasons)

Treat-ments	Fungicides	Dose/l/acre	Grain Yield (kg/ha)				Mean
			Kharif 2022	*Rabi* 2022-23	*Kharif* 2023	*Kharif* 2024	
1	*Pseudomonas fluorescens* seed treatment + PGPR I + PGPR II	10 g/kg seed +soil @ 1 kg /acre + 20 g/l	5367	5991	6522	5103	5746
2	*Pseudomonas fluorescens* seed treatment + PGPR II	10 g/kg seed + 20 g/l	5767	5604	6891	4658	5730
3	Hexaconazole 4% + Zineb 68% WP	2.5 g	4883	5776	5667	5604	5483
4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	1 ml	5433	5303	5862	8227	6206
5	Thifluzamide 24% SC	0.8 ml	5000	4687	7963	5432	5771
6	Difenoconazole 25% EC	0.5 ml	4850	4529	7763	8385	6382
7	Isoprothiolane 40% EC	1.5 ml	5117	3942	6899	6622	5645
8	Carbendazim 12% + Mancozeb 63% WP	1.5 g	5223	4945	6533	6636	5837
9	Copper Hydroxide 77% WP	2 g	4643	4314	6178	4730	4966
10	Hexaconazole 5% SC (Standard Check)	2 ml	5167	4500	5804	6995	5616
11	*Pseudomonas fluorescens* Seed +Soil +Foliar (Organic Check)	10 g/kg seed +1 kg/ acre + 20 g/l	3670	5199	4487	6966	5080
12	Control	-	2333	3841	4327	4286	3697
	LSD @ 5% (P=0.05)		1570	NS	1025	NS	1329
	CV (%)		19.366	22.832	9.701	28.918	16.749

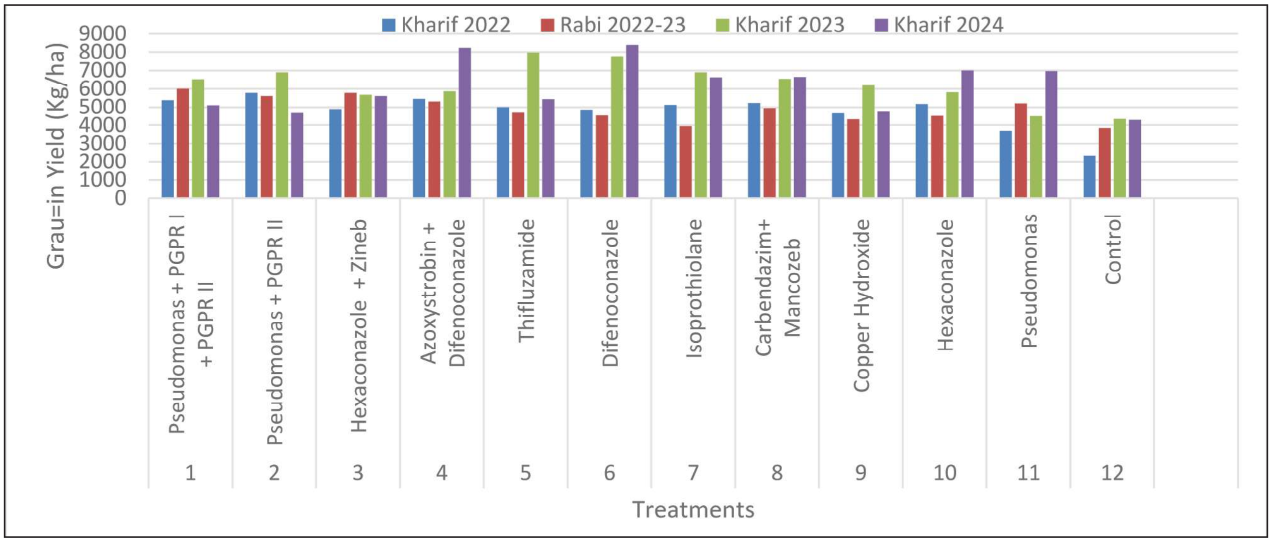

Figure 3: Effectiveness of different fungicides and biofertilizer/biocontrol agent on grain yield(kg/ha) of rice during *Kharif* 2022, *Rabi* 2022-23, *Kharif* 2023 and *Kharif* 2024 (pooled data of four seasons)

Conclusion

It is concluded that the most successful combination molecule against sheath blight was determined to be the new systemic combination product of Azoxystrobin 18.2% + Difenoconazole 11.4% SC@ 1 ml/l, which was followed by Thifluzamide 24% SC@ 0.8 ml/l. Difenoconazole 25% EC (6382 kg/ha) produced the highest yield followed by Azoxystrobin 18.2% + Difenoconazole 11.4% SC (6207 kg/ha). Carbendazim 12% + Mancozeb 63% WP (5837 kg/ha) and Thifluzamide 24% SC (5771 kg/ha) were next in line, and organic treatments like *Pseudomonas fluorescens* seed treatment (10 g/kg seed) + PGPR I (1 kg/acre) + PGPR II (20 g/l) also produced a yield of 5746 kg/ha found to be efficient in controlling the disease and contributing to productivity.

Acknowledgements

The authors thank the Director of Research, Kerala Agricultural University, Vellanikkara and Professor and Head, M S Swaminathan Rice Research Station, Moncompu for necessary facilities in carrying out the present investigations.

References

Bag MK, Yadav M. and Mukherjee AK. 2016. Bioefficacy of Strobilurin Based Fungicides against Rice Sheath Blight Disease. *Transcriptomics: Open Access*, 4(1): 1-2.

Bhuvaneswari V. and Krishnam Raju S. 2012. Efficacy of new combination fungicide against rice sheath blight caused by *Rhizoctonia solani* (Kuhn). *Journal of Rice Research*, 5(1&2): 57-61.

Chitti Babu G, Amara Jyothi P, Venkatarao P. and Chinnam Naidu D. 2024. Management of Rice Sheath Bligh with New Chemicals in Srikakulam District of Andhra Pradesh, India. *Journal of Plant and Soil Science*, 36(9): 188-193.

Gautam K, Rao, PB. and Chauhan SVS. 2003. Efficacy of some botanicals of the family Compositae against *Rhizoctonia solani Kuhn. Journal of Mycology and Plant Pathology,* 33(2): 230-235.

Gomez KA. and Gomez AA. 1984. Statistical Procedures for Agricultural Research. John Willey and Sons, New York, USA.

Greer CA and Webster RK. 2001. Occurrence, distribution, epidemiology, cultivar reaction and management of rice blast disease in California. *Plant Disease,* 85(10): 1096-1102.

IRRI. 2014. *Standard Evaluation Systems for Rice*, International Rice Research Institute, Manila, Philippines, pp. 25-26.

Naik GR, Naik GB, Naik BT. and Naik KR. 2012. Fungicidal management of leaf blast disease in rice. *Journal of Bioscience and Bio-Technology,* 1(1): 18-21.

Pramesh D, Maruti K, Muniraju M, Mallikarjun K, Guruprasad GS, Mahanta shiva yogayya K, Reddy BGM, Gowdar S. and Chetana BS. 2016. Bio-efficacy of combination fungicide against Blast and Sheath Blight disease of Paddy. *Journal of Experimental Agricultural International,* 14(4): 1-8.

Prasad VSS, Hymavathi A, Babu RV. and Longvah T. 2018. Nutritional composition in relation to glycemic potential of popular Indian rice varieties. *Food Chemistry*, 238: 29-34.

Rajput LS, Sharma T, Madhusudhan P. and Sinha P. 2017. Effect of temperature on rice blast infection process with emphasis on appressoria formation by *Magnaporthe oryzae*. *International Journal of Current Microbiology and Applied Sciences,* 6(4): 1931-1939.

Richa K, Tiwari, IM, Kumari M, Devanna BN, Sonah H, Kumari A, Nagar R, Sharma V, Botel JR. and Tilak Sharma TR. 2016. Functional Characterization of Novel Chitinase Genes Present in the Sheath Blight Resistance QTL: qSBR11-1in Rice Line Tetep. *Frontiers in Plant Science,* 7: 244.

Srinivasachary S, Willocquet L. and Savary S. 2011. Resistance to rice sheath blight (*Rhizoctonia solani Kuhn*) [(Teleomorph-*Thanatephorus cucumeris* (AB Frank) Donk.] disease: current status and perspectives. *Euphytica*, 178(1): 1-22.

Wheeler BEJ. 1969. An Introduction to Plant Disease. John Wiley & Sons Ltd., London.