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Evaluation of fungicides against sheath blight (*Rhizoctonia solani*) and brown spot (*Helminthosporium oryzae*) of rice

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Fungicides were initially evaluated against mycelial growth of *Rhizoctonia solani* and *Helminthosporium oryzae* at four different concentrations i.e. 100, 500, 1000 and 2000 ppm on potato based medium (PDA) using poisoned food technique. The results indicated that fungicides i.e. Metiram 70%WG, Propiconazole 25% EC, Azoxystrobin 18.2% + Difenoconazole 11.4% SC, Hexaconazole 5% SC, Azoxystrobin 11% +Tebuconazole 18.3% SC, Propineb 70% WP, Tebuconazole 50% + Trifloxystrobin 25% WG, Hexaconazole 4% + Zineb 68% WP and Metiram 55% + Pyraclostribin 5% WG showed complete inhibition of all the pathogens at all concentrations. The fungicides which were found effective under *in vitro* conditions were evaluated against sheath blight of rice under field conditions and all tested fungicides were found significantly effective over control (38.51 PDI). However, Azoxystrobin 11% + Tebuconazole 18.3% SC was found highly effective and significantly suppressed the sheath blight (4.44 PDI), while in brown spot of rice Azoxystrobin 11% + Tebuconazole 18.3% SC was found to be highly effective (2.22 PDI). Moreover, all other treatments were also found significantly effective against brown spot of rice over control (84.44 PDI). Similarly plots treated with different fungicides produced significantly higher grain yield compared to control (22.72 q/ha) However, Azoxystrobin 11% + Tebuconazole 18.3% SC (41.57 q/ha) was found to be most effective in increasing grain yield.

Keywords : Brown spot, fungicides, PDI, poison food technique, Sheath blight

INTRODUCTION

Rice (*Oryza sativa L*.) is an annual grass that grows semi-aquatically in a wide range of climates. Rice crop is affected by several biotic factors i.e., viruses, fungus bacteria, nematodes and insect-pests. Many diseases produced by diverse phytopathogens, such as sheath blight, blast, sheath rot, stem rot, bacterial leaf blight (BLB) and brown leaf spot, have a significant impact on rice production.

Among these diseases, rice sheath blight caused by *Rhizoctonia solani* Kuhn and brown spot of rice caused by *Helminthosporium oryzae* is a devastating disease that causes significant yield loss and quality degradation throughout the world (Nagarajkumar *et al*. 2004; Nirmalkar *et al*. 2017).

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A modest estimation of losses due to sheath blight disease alone in India has been upto 54.3% (Gangaram *et al*. 2024). The causal agent of rice sheath blight has a broad host range (Srinivasachary *et al*. 2011). Brown spot disease of rice caused by *Helminthosporium oryzae* (Breda de Haan) is a major fungal disease which has been reported to occur in all rice growing countries. Brown spot disease caused severe yield loss in 1942 in West Bengal and caused Bengal Famine when yield loss reached upto 90% in certain areas (Sarkar *et al*. 2014). Recorded yield losses caused by brown spot of rice vary greatly among upland and lowland ecosystems, as well as across countries/ regions. The disease has been recorded to cause yield reduction from 6% to 90% in Asia (Aryal *et al*. 2016). The pathogen after infection shows the symptoms on the leaves, panicles, glumes and grain causing first as small, circular and dark brown to purple

brown spots and fully developed lesions are circular to oval with a light brown to gray center, surrounded by a reddish-brown margin and ultimately killing the leaf (Manandhar *et al*. 2016). The disease is also known as poor rice farmers disease because it occurs mostly in deficient and poor soils. The pathogen infects coleoptiles, leaves, leaf sheaths, panicle branches, glumes and spikelets.

Several fungicides which were previously recommended are now days banned and did not provide satisfactory results for disease control. Nowadays new generation molecules with different better mode of action are now available. In the present study the investigation was carried out to evaluate some such fungicides under *in vitro* and *in vivo* conditions against sheath blight and brown spot of rice.

MATERIALS AND METHODS

Isolation of pathogens from infected plant samples

Fresh samples of sheath blight and brown spot infected plants were brought to the laboratory in paper bags and washed under tap water to remove dust and other inert materials. Small pieces of specimen were then cut, with each piece containing half infected and half healthy portions. These pieces were disinfected with a sodium hypochlorite (0.1%) solution for 1 minute followed by washing with sterilized distilled water. The pieces were placed on blotting paper and allowed to dry. Once properly dried the pieces were transferred into culture slants and subsequently transferred into petri dishes containing PDA media (Neha *et al*. 2016; Tiwari *et al*. 2016).

In vitro evaluation of fungicides against pathogens

The efficacy of 16 fungicides (Metiram 70% WG, Tricyclazole 75% WP, Propiconazole 25% EC, Azoxystrobin 18.2% + Difenoconazole 11.4% SC, Validamycin 3% L, Hexaconazole 5% SC, Iprobenfos 48% EC, Azoxystrobin 11% +Tebuconazole 18.3% SC, Thifluzamide 24% SC, Mancozeb 75% WP, Propineb 70% WP, Tebuconazole 50% + Trifloxystrobin 25% WG, Kasugamycin 3% SL, Tebuconazole 38.39% w/ w SC, Hexaconazole 4% + Zineb 68% WP and Metiram 55% + Pyraclostribin 5% WG) was evaluated *in vitro* at different concentrations of 100, 500, 1000 and 2000 ppm on growth of *Rhizoctonia solani* and *Helminthosporium oryzae* using poisoned food technique (Nene and Thapliyal. 1982)

The pathogens *Rhizoctonia solani* and *Helminthosporium oryzae* were grown on Potato Dextrose Agar (PDA) medium for a period of seven days to be used as inoculum. PDA medium was prepared and melted. Concentrations of fungicide were added to the cooled melted medium. Approximately 25-30 ml of the fungicide containing medium was poured into each Petri plate. To prevent bacterial contamination, 500 ppm of streptomycin was added to the medium while pouring it into the petri plates. A mycelial disc with a diameter of 5 mm was taken from the periphery of a fresh culture of test plant pathogens and placed in the centre of each petri plate. Three replications were maintained for each treatment. The inoculated plates were then incubated at 28 ± 2°C for 4 days. The percentage of inhibition was calculated using the formula developed by Vincent (1947).

$$I = \frac{C - T}{C} \times 100$$

Where,
I = per cent inhibition
C = growth in control
T = growth in treatment

In vivo testing the efficacy of fungicides as foliar application

The field experiment was conducted during Kharif season of 2023 to evaluate the efficacy of different fungicides for the control of sheath blight of rice and brown spot of rice. The experiment was laid out in randomized block design (RBD) with the plot size of 3m x 1m each treatment was replicated thrice.

Preparation of plots and seed sowing

The plot was prepared by tillage operation followed by tractor drawn disc harrowing and

Treatment details :-

	Treatments	Doses ml or g/l
T_1	Metiram 70% WG	3g/l
T_2	Tricyclazole 75% WP	0.7g/l
T_3	Propiconazole 25% EC	2ml/l
T_4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	1ml/l
T_5	Validamycin 3% L	2.5ml/l
T_6	Hexaconazole 5% SC	2ml/l
T_7	Iprobenfos 48% EC	2ml/l
T_8	Azoxystrobin 11% + Tebuconazole 18.3% SC	1.5ml/l
T_9	Thifluzamide 24% SC	0.7ml/l
T_{10}	Mancozeb 75% WP	2.5g/l
T_{11}	Propineb 70% WP	2g/l
T_{12}	Tebuconazole 50% + Trifloxystrobin 25% WG	0.5g/l
T_{13}	Kasugamycin 3% SL	2.5ml/l
T_{14}	Tebuconazole 38.39% w/w SC	2.5g/l
T_{15}	Hexaconazole 4% + Zineb 68% WP	2g/l
T_{16}	Metiram 55% + Pyraclostribin 5% WG	1.5g/l
T_{17}	Control	

planking. Thereafter, the experiment was laid out as per plan and design. The seeds of rice variety “Swarna” were sown manually using line sowing method with distance of 20 cm X 10 cm between rows and plants respectively.

Fertilizer application

Recommended dose of fertilizer 120:60:40 kg N:P:K/ha was applied phosphorus, potash and 25% of nitrogen were applied as basal dose while rest of the nitrogen was given in 3 splits between different plant growth stages.

Preparation of inoculum

Mass multiplication of *Rhizoctonia solani,* causal agent of sheath blight of rice was done in the laboratory pathogen using Typha grass. The grass was cut into small pieces of the desired size and packed into polythene bags for sterilization in autoclave at 121.6°C at 15 PSI for 15 mins. Aseptic techniques was employed to maintain sterile condition throughout the process. Ten discs, each measuring 5 mm in diameter were taken from 5 day-old culture and were inoculated in sterilized Typha bits kept under polythene bags. The polythene bags incubated for a 3 days in a BOD in at temperature of 28 ± 2°C.

Inoculation of rice plants

Rice plants which exhibited sufficient growth (Maximum tillering stage) were carefully selected and tagged for artificial inoculation with 2-3 typha bits having the mycelium mat and sclerotia of *R. solani* at the base of each rice hill (a group of tillers). To create a suitable environment for the

growth and development of the pathogen, humidity level was maintained at 85-90% by spraying an adequate amount of clean water. Irrigation was continuously given to insured the sufficient moisture period for development of uniform disease symptom of sheath blight on inoculated plant. Rice plants were inoculated with *H.oryzae* also separately using standard inoculating procedure

Disease Assessment Sheath Blight

After inoculation, observations were recorded followed by imposing the different treatment of fungicide. Fungicides were sprayed on the host plants covering all plant parts above ground level. The plants were observed critically for visual scoring of disease severity using the standard evaluation scale (0-9 scale) given by International Rice Research Institute (IRRI, 1996).

Scale	Symptoms
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 46-65% of plant height
9	Vertical spread of the lesions up to 66-100% of plant height

Per cent disease index (PDI) was calculated by using the formulas given by Wheeler (1969).

$$PDI = \frac{\text{Sum of all individual rating}}{\text{Total number of plants observed X Maximum grade value}} X100$$

Brown Spot of rice

The disease severity of brown spot of rice was recorded under natural epiphytotic condition from the same experiment on 0-9 scale at described by IRRI (2002).

Visual scoring of brown spot incidence rating scale given by International Rice Research Institute (IRRI, 1996).

The per cent disease index (PDI) was calculated with following formula given by International Rice Research Institute (IRRI) 2002.

$$PDI = \frac{\text{Sum of all numerical rating}}{\text{Total number of samples observed X Maximum rating}} X100$$

RESULTS AND DISCUSSION

Data presented in Table 1 indicated that fungicides tested at different concentrations (100, 500, 1000 and 2000 ppm) significantly reduced the mycelial growth of *Rhizoctonia solani* over untreated control (90.00 mm). However fungicides i.e. Metiram 70%WG, Propiconazole 25% EC, Azoxystrobin 18.2% + Difenoconazole 11.4% SC, Hexaconazole 5% SC, Azoxystrobin 11% +Tebuconazole 18.3% SC, Propineb 70% WP, Tebuconazole 50% + Trifloxystrobin 25% WG,

Score	Infection rate (%)
0	No disease on plant
1	Less than 1% of leaf area infected
2	1-3% of leaf area infected
3	4-5% of leaf area infected
4	6-10% of leaf area infected
5	11-15% of leaf area infected
6	16-25% of leaf area infected
7	26-50% of leaf area infected
8	51-75% of leaf area infected
9	More than 76% of leaf area infected

Tebuconazole 38.39% w/w SC, Hexaconazole 4% + Zineb 68% WP and Metiram 55% + Pyraclostribin 5% WG were completely inhibitory at 100 ppm concentration showing high potential against *R. solani* compared to other fungicides followed by Iprobenfos 48% EC, Thifluzamide 24% SC and Mancozeb 75% WP which were

completed inhibited the mycelial growth at higher concentration (500, 1000 and 2000 ppm) whereas, Tricyclazole 75% WP, Validamycin 3% L and Kasugamycin 3% SL were ineffective in inhibiting the mycelial growth of even at 2000 ppm. Present study also indicated that the new generation fungicides having combination of two molecules and formulated either in wettable powder (WP), emulsifiable concentrate (EC) and suspension concentrate (SC) were found to be significantly more effective compared to other systemic or non-systemic fungicides already recommended against *R.solani*. The findings of present study is confirmed by Yadav *et al*. (2021) who reported the complete inhibition of *R. solani* by the fungicides i.e. Propineb, Propiconazole, Hexaconazole and Carbendazim. Similarly, Sundravadana *et al*. (2007) reported the highly effectiveness of Azoxystrobin against the mycelial growth of *R. solani* and gave complete inhibition even at 10 ppm concentration.

Different fungicides tested at varying concentrations (100, 500, 1000 and 2000 ppm) significantly reduced the mycelial growth of *Helminthosporium oryzae* over untreated control (90.00 mm) (Table 2). However, fungicides i.e. Metiram 70%WG, Propiconazole 25% EC, Azoxystrobin 18.2% + Difenoconazole 11.4% SC, Hexaconazole 5% SC, Azoxystrobin 11% +Tebuconazole 18.3% SC, Mancozeb 75% WP, Propineb 70% WP, Tebuconazole 50% + Trifloxystrobin 25% WG, Hexaconazole 4% + Zineb 68% WP and Metiram 55% + Pyraclostribin 5% WG were completely inhibitory at 100 ppm concentration showing high potential against *H. oryzae* compared to other fungicides followed by Tebuconazole 38.39% w/w SC which were completed inhibited the mycelial growth at higher concentration (500, 1000 and 2000 ppm), whereas, Tricyclazole 75% WP, Iprobenfos 48% EC, Thifluzamide 24% SC, Validamycin 3% L and Kasugamycin 3% SL were ineffective in inhibiting the mycelial growth of *H. oryzae* even at 2000 ppm. Present study also indicated that the new generation fungicides having combination of two molecules and formulated either in wettable powder (WP), emulsifiable concentrate (EC) and suspension concentrate (SC) were found to be significantly more effective compared to other systemic or non-systemic fungicides already recommended against Helminthosporium oryzae. The results of is it accordance to Yadav *et al.* (2020) evaluated the efficacy of fungicides against the Helminthosporium oryzae under in-vitro condition. All three fungicides i.e. Tricyclazole 75%WP, Propiconazole 25%EC and Hexaconazole 5% EC were found significantly effective against the Helminthosporium oryzae.

In vivo testing the efficacy of fungicides as foliar application for disease control Sheath blight of rice

The field experiment was conducted in Kharif season using randomized block design for the management of sheath blight of rice. Results revealed that all fungicides were found significantly effective in suppressing the sheath blight severity and increasing the grain yield over control plot (38.51 PDI) (Table 3). Lowest per cent disease index (PDI) was observed in Azoxystrobin 11% + Tebuconazole 18.3% SC (4.44 PDI) which was found to be the most effective and closely followed by Azoxystrobin 18.2% + Difenoconazole 11.4% SC (5.18 PDI) and found significantly more effective over other fungicides including control. Treatments i.e. Hexaconazole 4% + Zineb 68% WP (5.92 PDI), Metiram 55% + Pyraclostribin 5% WG (5.92 PDI), Hexaconazole 5% SC (6.66 PDI), Tebuconazole 50% + Trifloxystrobin 25% WG (7.40 PDI), Tebuconazole 38.39% w/w SC (8.88 PDI), Metiram 70% WG (9.62 PDI), Propiconazole 25% EC (10.36PDI), Propineb 70% WP (11.85 PDI), Mancozeb 75% WP (12.59 PDI), Thifluzamide 24% SC (12.59 PDI), Tricyclazole 75% WP (13.33 PDI), Validamycin 3% L (14.81 PDI), and Kasugamycin 3% SL (15.55 PDI) was found significantly effective.

Most of the treatments produced significantly grain yield over control. However, Azoxystrobin 11% + Tebuconazole 18.3% SC treated plots provided significant higher grain yield (41.57 q/ha) over control (22.72q/ha) and found at par with Azoxystrobirn 18.2% + Difenoconazole 11.4% SC (40.22 q/ha), Hexaconazole 4% + Zineb 68% WP (37.92 q/ha), Metiram 55% + Pyraclostribin 5% WG (36.87 q/ha). Moreover other fungicides i.e. Hexaconazole 5% SC (36.27 q/ha), Tebuconazole 50% + Trifloxystrobin 25% WG

Table 1. Effect of fungicides at different concentrations against mycelial growth of *Rhizoctonia solani* (at 96 HAI).

	Treatments	Mycelial growth (mm) of *R. solani*				Mean
		100 ppm	500 ppm	1000 ppm	2000 ppm	
T_1	Metiram 70% WG	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_2	Tricyclazole 75% WP	71.33	53.67	44.67	37.33	51.75
		(57.63)	(47.10)	(41.93)	(37.65)	
T_3	Propiconazole 25% EC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_5	Validamycin 3% L	90.00	90.00	90.00	90.00	90.00
		(71.56)	(71.56)	(71.56)	(71.56)	
T_6	Hexaconazole 5% SC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_7	Iprobenfos 48% EC	14.67	0.00	0.00	0.00	3.67
		(22.43)	(0.20)	(0.20)	(0.20)	
T_8	Azoxystrobin 11% +Tebuconazole 18.3% SC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_9	Thifluzamide 24% SC	10.00	9.33	0.00	0.00	4.83
		(18.37)	(17.75)	(0.20)	(0.20)	
T_{10}	Mancozeb 75% WP	17.33	12.67	0.00	0.00	7.50
		(24.59)	(20.80)	(0.20)	(0.20)	
T_{11}	Propineb 70% WP	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{12}	Tebuconazole 50% + Trifloxystrobin 25% WG	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{13}	Kasugamycin 3% SL	90.00	90.00	90.00	90.00	90.00
		(71.56)	(71.56)	(71.56)	(71.56)	
T_{14}	Tebuconazole 38.39% w/w SC	12.67	0.00	0.00	0.00	3.17
		(20.82)	(0.20)	(0.20)	(0.20)	
T_{15}	Hexaconazole 4% + Zineb 68% WP	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{16}	Metiram 55% + Pyraclostribin 5% WG	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{17}	Control	90.00	90.00	90.00	90.00	90.00
		(71.56)	(71.56)	(71.56)	(71.56)	
	Mean	23.29	20.33	18.51	18.08	
		Fungicide	Concentration	F x C		
	C.D. (5%)	0.23	0.48	0.96		
	SEm (±)	0.07	0.16	0.33		
	CV%	3.49				

*Figures in the parentheses indicate arc sine transformed

Table 2. Effect of fungicides at different concentrations against mycelial growth of *Helminthosporium oryzae* (at 288 HAI).

	Treatments	Mycelial growth (mm) of *H.oryzae*				Mean
		100ppm	500ppm	1000ppm	2000ppm	
T_1	Metiram 70% WG	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_2	Tricyclazole 75% WP	61.00	33.00	30.50	30.50	38.75
		(51.35)	(35.06)	(33.51)	(33.51)	
T_3	Propiconazole 25% EC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_5	Validamycin 3% L	84.00	71.50	66.00	62.00	70.88
		(66.47)	(57.73)	(54.34)	(51.94)	
T_6	Hexaconazole 5% SC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_7	Iprobenfos 48% EC	60.00	35.00	30.00	28.00	38.25
		(50.76)	(36.26)	(33.20)	(31.94)	
T_8	Azoxystrobin 11% +Tebuconazole 18.3% SC	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_9	Thifluzamide 24% SC	31.00	25.00	24.00	23.00	25.75
		(33.82)	(29.99)	(29.32)	(28.63)	
T_{10}	Mancozeb 75% WP	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{11}	Propineb 70% WP	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{12}	Tebuconazole 50% + Trifloxystrobin 25% WG	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{13}	Kasugamycin 3% SL	52.50	53.00	48.00	45.00	49.63
		(46.43)	(46.72)	(43.85)	(42.12)	
T_{14}	Tebuconazole 38.39% w/w SC	58.00	47.00	0.00	0.00	26.25
		(49.60)	(43.27)	(0.20)	(0.20)	
T_{15}	Hexaconazole 4% + Zineb 68% WP	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{16}	Metiram 55% + Pyraclostribin 5% WG	0.00	0.00	0.00	0.00	0.00
		(0.20)	(0.20)	(0.20)	(0.20)	
T_{17}	Control	90.00	90.00	90.00	90.00	90.00
		(71.56)	(71.56)	(71.56)	(71.56)	
	Mean	25.68	20.85	16.97	16.38	
		Fungicide	Concentration	F x C		
	C.D.5%	0.26	0.53	1.07		
	SEm (±)	0.08	0.17	0.36		
	CV%	3.71				

*Figures in the parentheses indicate arc sine transformed

Table 3. Efficacy of fungicides as foliar spray for the management of sheath blight of rice caused by *Rhizoctonia solani* under natural epiphytotic condition

		PDI Index of *R. solani*				%	
			7th DAS	7th DAS	7th DAS	Reduction	
		BS	1st Spray	2nd Spray	3rd Spray	Over	
	Treatments					control	Yield (q/ha)
T_1	Metiram 70% WG	13.33	21.48	14.81	9.62	75.07	34.46
		(21.37)	(27.58)	(22.62)	(18.04)	(60.06)	
T_2	Tricyclazole 75% WP	14.07	26.66	18.51	13.33	65.38	31.66
		(21.97)	(31.07)	(25.47)	(21.41)	(53.96)	
T_3	Propiconazole 25% EC	13.33	22.22	15.55	10.36	73.13	33.69
		(21.37)	(28.10)	(23.19)	(18.75)	(58.80)	
T_4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	14.07	15.56	11.85	5.18	86.61	40.22
		(22.02)	(23.13)	(20.11)	(13.01)	(68.71)	
T_5	Validamycin 3% L	15.56	28.14	21.48	14.81	61.55	29.01
		(23.23)	(32.03)	(27.60)	(22.62)	(51.69)	
T_6	Hexaconazole 5% SC	12.59	18.52	13.33	6.66	82.80	36.27
		(20.76)	(25.45	(21.41)	(14.81)	(65.66)	
T_7	Iprobenfos 48% EC	11.85	27.40	19.26	13.33	65.47	29.98
		(20.11)	(31.56)	(26.02)	(21.37)	(54.04)	
T_8	Azoxystrobin 11% +Tebuconazole 18.3% SC	13.33	14.07	10.37	4.44	88.52	41.57
		(21.41)	(22.02)	(18.75)	(12.08)	(70.28)	
T_9	Thifluzamide 24% SC	14.07	25.18	17.77	12.59	67.34	29.67
		(21.97)	(30.11)	(24.93)	(20.77)	(55.14)	
T_{10}	Mancozeb 75% WP	13.33	24.44	17.03	12.59	67.43	32.12
		(21.37)	(29.62)	(24.36)	(20.72)	(55.25)	
T_{11}	Propineb 70% WP	14.07	22.96	16.29	11.85	69.40	32.64
		(21.97)	(28.62)	(23.79)	(20.01)	(56.52)	
T_{12}	Tebuconazole 50% + Trifloxystrobin 25% WG	12.59	18.52	14.07	7.40	80.84	34.89
		(20.72)	(25.47)	(22.01)	(15.74)	(64.07)	
T_{13}	Kasugamycin 3% SL	14.07	29.62	23.70	15.55	59.70	27.53
		(21.97)	(32.97)	(29.12)	(23.19)	(50.61)	
T_{14}	Tebuconazole 38.39% w/w SC	14.07	20.74	14.07	8.88	77.03	33.63
		(22.02)	(27.03)	(22.07)	(17.25)	(61.45)	
T_{15}	Hexaconazole 4% + Zineb 68% WP	14.07	16.30	12.59	5.92	84.76	37.92
		(21.97)	(23.79)	(20.76)	(14.02)	(67.26)	
T_{16}	Metiram 55% + Pyraclostribin 5% WG	12.59	17.04	13.33	5.92	84.65	36.87
		(20.72)	(24.11)	(21.37)	(13.88)	(67.01)	
T_{17}	Control	15.56	34.81	36.29	38.51	0.00	22.72
		(23.23)	(36.15)	(37.04)	(38.35)	(0.40)	
	CD	NS	2.68	1.83	1.63	2.97	4.80
	SEm (±)	-	0.92	0.63	0.54	0.99	1.60
	CV	NS	5.73	4.55	5.12	3.16	8.69

*Figures in the parentheses indicate arc sine transformed PDI= Percent disease index, BS= Before spray, DAS = Day after spray

Table 4. Efficacy of fungicides as foliar spray for the management of brown spot of rice caused by *Helminthosporium oryzae* under natural epiphytotic condition.

		PDI Index of *H. oryzae*				%	
			7th DAS	7th DAS	7th DAS	Reduction	
	Treatments	BS	1st Spray	2nd Spray	3rd Spray	Over control	Yield (q/ha)
T_1	Metiram 70% WG	22.96	11.11	11.11	11.07	86.89	34.46
		(28.59)	(19.45)	(19.47)	(19.43)	(68.77)	
T_2	Tricyclazole 75% WP	24.44	12.33	11.85	11.85	85.97	31.66
		(29.61)	(20.54)	(20.11)	(20.12)	(68.00)	
T_3	Propiconazole 25% EC	23.70	8.14	6.66	5.92	92.96	33.69
		(29.02)	(16.54)	(14.91)	(14.02)	(74.69)	
T_4	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	23.70	8.88	7.40	5.18	93.86	40.22
		(29.09)	(17.33)	(15.53)	(13.09)	(75.72)	
T_5	Validamycin 3% L	23.70	22.22	26.33	41.66	50.58	29.01
		(29.09)	(28.11)	(30.86)	(40.19)	(45.33)	
T_6	Hexaconazole 5% SC	23.70	11.85	11.11	10.37	87.71	36.27
		(29.12)	(20.11)	(19.40)	(18.77)	(69.48)	
T_7	Iprobenfos 48% EC	23.70	21.14	25.18	37.03	56.11	29.98
		(29.06)	(27.31)	(30.11)	(37.48)	(48.51)	
T_8	Azoxystrobin 11% +Tebuconazole 18.3% SC	24.44	5.92	4.44	2.22	97.37	41.57
		(29.62)	(14.02)	(12.08)	(8.56)	(80.66)	
T_9	Thifluzamide 24% SC	24.44	22.22	24.44	45.18	46.51	29.67
		(29.61)	(28.10)	(29.62)	(42.23)	(42.99)	
T_{10}	Mancozeb 75% WP	24.44	12.59	11.85	11.85	85.98	32.12
		(29.61)	(20.76)	(20.10)	(20.11)	(68.02)	
T_{11}	Propineb 70% WP	25.18	11.85	10.36	9.62	88.62	32.64
		(30.08)	(20.09)	(18.75)	(18.04)	(70.31)	
T_{12}	Tebuconazole 50% + Trifloxystrobin 25% WG	25.92	11.11	8.88	6.66	92.10	34.89
		(30.57)	(19.40)	(17.33)	(14.91)	(73.72)	
T_{13}	Kasugamycin 3% SL	25.18	24.44	29.63	40.96	51.45	27.53
		(30.05)	(29.61)	(32.97)	(39.78)	(45.83)	
T_{14}	Tebuconazole 38.39% w/w SC	25.18	10.36	9.62	8.14	90.35	33.63
		(30.08)	(18.77)	(18.04)	(16.57)	(71.90)	
T_{15}	Hexaconazole 4% + Zineb 68% WP	26.66	11.85	9.63	9.29	89.01	37.92
		(31.07)	(20.05)	(18.05)	(17.73)	(70.64)	
T_{16}	Metiram 55% + Pyraclostribin 5% WG	23.70	11.85	8.14	8.14	90.31	36.87
		(29.12)	(20.11)	(16.54)	(16.46)	(72.00)	
T_{17}	Control	24.44	30.37	46.66	84.44	0.00	22.72
		(29.61)	(33.43)	(43.08)	(66.80)	(0.40)	
	CD	NS	2.40	2.56	2.27	2.42	4.80
	SEm (±)	-	0.80	0.88	0.75	0.80	1.60
	CV	NS	6.58	6.95	5.46	2.36	8.69

*Figures in the parentheses indicate arc sine transformed PDI= Percent disease index, BS= Beforespray, DAS = Day after spray

(34.89 q/ha) Tebuconazole 38.39% w/w SC (33.63 q/ha), Metiram 70% WG (34.46 q/ha), Propiconazole 25% EC(33.69 q/ha), Propineb 70% W(32.64 q/ha), Mancozeb 75% WP (32.12 q/ha), Thifluzamide 24% SC (29.67 q/ha), Tricyclazole 75% WP (31.66 q/ha), Moreover, significantly higher grain yield was recorded from other treatments. Fungicides i.e. Validamycin 3% L (29.01 q/ha), and Kasugamycin 3% SL (27.53 q/ha) were least effective but produced significantly higher grain yield over control (22.72 q/ha). Results of the present study are all in accordance with the findings of Sudhakar *et al*. (2005) and Nirmalkar *et al.* (2017) who reported the higher efficacy of Hexaconazole, Propiconazole and Carbendazim in controlling the sheath blight of rice. Similarly, Naik *et al*. (2017) and Awasthi *et al.* (2024) also reported the higher efficacy of fungicides i.e. Propiconazole 25 EC, Thiophenate methyl 75 WP, Tricyclazole 75 WP, Hexaconazole 5 EC, Thifluzamide 2% SC, Mancozeb75% WP, Iprobenphos and Carbendazim 12% + Mancozeb 63% in controlling the sheath blight of rice under field condition. The new generation of systemic fungicides specially the formulation having combination of two molecules used under the present study used for the control of sheath blight of rice. In the present study these new generation fungicides were found to be more effective in controlling the sheath blight severity over other fungicides which are already in recommended for the management of sheath blight of rice.

Brown Spot disease

The field experiment was conducted in Kharif season using randomized block design for the management of brown spot of rice. All treatments were found significantly effective in suppressing the disease severity of brown spot of rice and increasing the yield over control (Table 4). Lowest per cent disease index (PDI) was observed in Azoxystrobin 11% + Tebuconazole 18.3% SC (2.22 PDI) which was found to be the most effective and followed by Azoxystrobin 18.2% + Difenoconazole 11.4% SC (5.18 PDI), Tebuconazole 50% + Trifloxystrobin 25% WG (6.66 PDI), Propiconazole 25% EC (6.66 PDI), Metiram 55% + Pyraclostribin 5% WG (8.14 PDI), Tebuconazole 38.39% w/w SC (8.14 PDI), Hexaconazole 4% + Zineb 68% WP (9.29 PDI), Propineb 70% WP (9.62PDI), Hexaconazole 5% SC (10.37 PDI), Metiram 70% WG (11.07PDI), Mancozeb 75% WP (11.85PDI) and Tricyclazole 75% WP (PDI-11.85%), were also found significantly highly effective controlling brown spot disease over untreated control (84.44 PDI). Validamycin 3% L (41.66 PDI), Iprobenfos 48% EC (37.03 PDI), Kasugamycin 3% SL (40.96 PDI), Thifluzamide 24% SC (45.18 PDI) was found moderate effective controlling brown spot disease over untreated control (84.44 PDI).

Most of the treatments produced significantly grain yield over control. However, Azoxystrobin 11% +Tebuconazole 18.3% SC treated plots provided significant higher grain yield (41.57 q/ha) over control (22.72 q/ha) and found at par Azoxystrobin 18.2% + Difenoconazole 11.4% SC (40.22 q/ha), Hexaconazole 4% + Zineb 68% WP (37.92 q/ha), Metiram 55% + Pyraclostribin 5% WG (36.87 q/ha). Moreover other treatments i.e. Hexaconazole 5% SC (36.27 q/ha), Tebuconazole 50% + Trifloxystrobin 25% WG (34.89 q/ha), Tebuconazole 38.39% w/w SC (33.63 q/ha), Metiram 70% WG (34.46 q/ha), Propiconazole 25% EC (33.69 q/ha), Propineb 70% W (32.64 q/ha) and Mancozeb 75% WP (32.12 q/ha). Fungicides i.e. Thifluzamide 24% SC (29.67 q/ha), Tricyclazole 75% WP (31.66 q/ha), Validamycin 3% L (29.01 q/ha), and Kasugamycin 3% SL (27.53 q/ha) were found to be least effective but produced significantly highest grain yield over control (22.72 q/ha).

Results of the present study indicated that there was significant drastic effect of disease on the grain yield of rice. The findings of Hunjan *et al*. (2007) who reported the efficacy of some new fungicides namely Trifloxystrobin + Tebuconazole (Nativo 75 WG), Tebuconazole (Folicur 25 EC), Propiconazole (Tilt 25 EC), Pencycuron (Monceren 250SC) and Thifluzamide (Spencer 24SC) against economically important rice diseases namely sheath blight (*Rhizoctonia solani*) and brown spot (*Helminthosporium oryzae)* under field conditions under artificial inoculation conditions during Kharif seasons. Fungicides viz. Trifloxystrobin + Tebuconazole, Tebuconazole, and Propiconazole showed higher level of efficacy against sheath blight of rice and

brown spot of rice caused by R. solani and H. oryzae respectively in the present study.

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DECLARATION

Conflict of Interest. Authors declare no conflict of interest.

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