



***In vitro* and field evaluation of some sole and combination fungicides against *Rhizoctonia solani* causing sheath blight disease of rice (*Oryza sativa* L.) in Eastern Gangetic Plain zone of West Bengal, India**

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Abstract— *Rhizoctonia solani* causing sheath blight disease of rice is one of the most important and prominent fungus in West Bengal as well as other rice growing areas of the world and cause severe yield loss of rice. Due to lack of resistant donor line, a few resistant variety is available for combating the attack of the pathogen and so screening and selection of suitable fungicides is of utmost importance for effective disease management for ensuring sustainable rice production. Due to continuous application of same chemical and global climate crisis, development of resistance is on an increasing trend. Evaluation and screening of new generation fungicide molecules play a pivotal role in Integrated Disease Management for rice sheath blight. Experiment both in vitro and field evaluation, were conducted during the kharif (wet) seasons of 2024 and 2025 at Rice Research Station, Chinsurah, West Bengal, India to evaluate the relative efficacy of some new fungicide formulations against sheath blight disease of rice caused by *Rhizoctonia solani*. Two sprays of Mancozeb 50% + Thiophanate-methyl 25% WG @ 3.0 g/L were highly effective in reducing sheath blight disease severity and improving grain yield. Under in vitro conditions, the minimum EC₅₀ value (1.69 ppm) was also recorded for Mancozeb 50% + Thiophanate-methyl 25% WG, indicating that it was the most effective fungicide formulation among those tested and can be effectively recommended for Integrated Disease Management in rice for ensuring sustainable rice production.



Keywords— Rice, Sheath Blight, *Rhizoctonia solani*, New Fungicide Formulations, Integrated Disease Management, Resistant Development, Field Evaluation, Resistant Donor

I. INTRODUCTION

Rice (*Oryza sativa* L.), a member of Poaceae, is the staple food for half of the population across the globe and plays a pivotal role in food security and global agricultural economy (Midya, 2025) and feeding more than 9 billion people by 2050 will require doubling of production on sustainable basis (Midya *et al.*, 2021). Being the major cultivated cereal of West Bengal, rice has invariably imbued the social and cultural spheres of Bengali culture, performed pivotal role in religious attainment, spiritual liberation and in all aspects became a ubiquitous symbol

for the Bengali cultural expression (Samaddar, 2006). West Bengal is the richest reservoir of rice bio-diversity and the rice bowl of the country. Among the biotic stresses, drought, weed infestation, insect pest, disease infestation are the predominantly retardant factors limiting productivity of rice (Midya, 2025), rice is attacked by 36 fungal diseases (11 foliar diseases, 11 stem, leaf sheath and root diseases, 3 seedling diseases and 12 grain and inflorescent diseases), 6 bacterial, 21 viral and mycoplasmal, 6 nematode diseases as well as 4 physiological disorders (Ou, 1985). Among these fungal

diseases sheath blight caused by *Rhizoctonia solani* Kuhn is one of the most important diseases of rice during the *kharif* season in West Bengal as well as in almost all rice growing areas of India (Reddy and Reddy, 1986; Biswas, 2000). The disease causes about 11.1- 58 % losses in yield depending on the disease severity and varieties (Chahal et al., 2003). There is also strong relationship between disease severity and yield reduction (Marchetti and Bollich, 1991). Presently, due to lack of resistant donor lines, a very few resistant varieties are available to the farmers so management practice with fungicides is the most important practical solution to control the disease. Due to continuous use of same chemical year after year there may develop resistance against the chemicals. Moreover, due to extreme climate variability resulted in ecological intensification, resistance and modification of the behavior of pest and pathogens under the backdrop of global climate crisis (Midya, 2026). So, for the effective management of rice sheath blight disease to ensure sustainable rice production, under the context of ever increasing resistance development and global warming, new generation fungicidal formulations were evaluated accordingly.

II. MATERIALS AND METHODS

2.1, Isolation of *Rhizoctonia solani* from diseased samples:

The disease samples were cut in small pieces and washed in water to remove the soil particles and other dirt materials. During isolation these bits were surface sterilized by 0.1% HgCl₂ solution for 40 seconds followed by washing 5-6 times in sterile distilled water. The bits were transferred by using forceps on sterile blotting paper to remove the excess moisture through blotting. Then those bits were transferred on to PDA medium in Petri plates which were placed in BOD incubator for incubation at 28 ± 2° C for 24-72 hours. When the fungal growth was visible, a tiny bit of mycelium was taken from the isolation plate and transferred to PDA containing culture slant and incubated again at 28°C with the objective of having pure culture. The pure culture was maintained and stored in refrigerator at 5°C for further studies. The fungi were sub cultured at 20 days interval on PDA medium to maintain vigour and vitality.

2.2, Preparation of mass culture of *Rhizoctonia solani* for field inoculation:

Rice leaf sheath was collected and cut it into small pieces of 2 -3 cm. Cut pieces were water soaked 12 hours; excess water was drained out; water-soaked pieces were transferred to open mouth bottles and closed with a cotton wool plug. The bottles with water-soaked straw were sterilized at 15 psi for 20 minutes for two successive days.

The six mycelial discs of 9 mm diameter of 3 days old culture of *R. solani* grown on the PDA medium was cut and used to inoculate sterilized water-soaked straw kept in the bottles. The bottles were then incubated at room temperature (28 ± 2°C) for 14 days and the inoculum thus prepared was used for subsequent studies.

2.3, Artificial inoculation of *Rhizoctonia solani* in the field:

R. solani pathogen grown on sterilized straw bits was used as a source of inoculum for artificial inoculation of rice plant under field condition. The tillers to be inoculated with the pathogen were tied using rubber band or piece of rope. At tillering stage, the test entries were inoculated by placing the colonized straw at the centre of the hill just above the water line.

2.4, Fungicide sensitivity analysis:

Five varying concentrations (excluding) of six fungicides viz, Mancozeb 50% + Thiophanate methyl 25% WG, Picoxystrobin 7.05% + Propiconazole 11.7 SC, Azoxystrobin 14% + Epoxiconazole 9% SC, Tebuconazole 50% + Trifloxystrobin 25% WG, Propiconazole 25EC and Mancozeb 75 WP were prepared from their respective stock solution. Then the required and calculated volume of each fungicide concentration was poured in sterile Petri plate in triplicate. Then, the molten PDA medium of 20 ml was poured inside the Petriplate with the help of sterilized micro tips with 200 µ and 1000 µ capacities, mixed thoroughly to obtain the desired concentrations of active ingredients. Control plates were maintained by the addition of same volume of PDA medium in the Petri plates without the addition of any fungicide. Then five mm mycelial discs were cut out from the periphery of 3 days old actively growing cultures with the help of sterilized cork borer and placed at the centre of the Petri plates. Plates were incubated at 28±1° C temperature in BOD till the fungal growth covers the entire Petri plate used as control. Radial growth of the fungus on different fungicide concentrations and control was recorded. Extent of inhibition of mycelial growth by each fungicide was calculated by estimating the percent reduction in mean mycelial radial growth over the control (Vincent, 1947). Effective concentration for 50% mycelial growth inhibition (EC₅₀) by the fungicides for the fungus was determined by plotting the log values of the fungicide concentration against the probit values of percent inhibition on a log-probit scale (Horsefall, 1956). A regression equation $Y = a + bx$ (Y = antilog of concentration of the fungicide, x = probit value of percent inhibition, b = regression co-efficient/ slope, a = intercept). was worked out and then fitness of the equation was judged comparing the level of significance with the simple

correlation coefficient (r) value at 5% or 1% level. Percent inhibition was measured with the formula, which is given below,

Percent inhibition

$$= \frac{\text{Radial growth in control (C)} - \text{Radial growth in treatment (T)}}{\text{Radial growth in control (C)}} \times 100$$

2.5, Evaluation of fungicides for the management of sheath blight disease under field condition:

Besides *in vitro* efficacy testing, the fungicides were evaluated under field condition for two consecutive *kharif* (wet) seasons at Rice Research Station, Govt of West Bengal, Chinsurah (Elevation – 8.62 m above mean sea level, latitude- 22° 52' N, longitude – 88°24' E), West Bengal. Seven treatments comprising of the said six fungicides with a suitable control were considered, Out of six, four combination fungicides viz, Mancozeb 50% + Thiophanate methyl 25% WG @ 3.0g/L, Picoxystrobin 7.05% + Propiconazole 11.7 SC @2.0 ml /L, Azoxystrobin 14% + Epoxiconazole 9% SC @1.5 ml/L, Tebuconazole 50% + Trifloxystrobin 25% WG @0.4 g/L and two sole fungicides viz. Propiconazole 25EC @ 1.0 ml/L and Mancozeb 75 WP @ 1.0 ml/L were evaluated against sheath blight disease of rice. Twenty-five days old seedlings of sheath blight susceptible cultivar Swarna (MTU-7029) were transplanted with 15×15 cm spacing in a randomized complete block design with four replications (plot size 2.1 m× 2.0 m). Uniform fertilizer dose of 120 kg N, 50 kg P₂O₅ and 30 kg K₂O ha⁻¹ (both basal and split) was applied in all the trial plots and standard agronomic practices were followed.

All the plants except the border rows were inoculated with ten days old highly virulent culture of the pathogen by the 'straw-bit' plugging method (Rao and Kannaiyan, 1973) during the active tillering stage. Fungicides were sprayed twice at an interval of ten days starting from the initial symptom development. After ten days of last spray, final disease incidence was recorded from ten randomly affected plants in each treatment. Plants were assessed individually using SES (0-9) scale (IRRI, 1996).

SES (0-9) scale (1996) for sheath blight disease:

Scale	Description of the scale
0	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

Disease severity was calculated using the following formula:

$$\frac{0(N)_0 + 5(N)_1 + 10(N)_3 + 30(N)_5 + 50(N)_7 + 100(N)_9}{\text{Total no. of tillers of the hill observed}} \times 100$$

Where, N₀-N₉ = No. of tillers / hill, classified as 0-9 grades respectively, according to SES (0-9) scale for rice. Grain yield recorded on plot basis were converted to kg ha⁻¹ for statistical analysis.

III. RESULTS AND DISCUSSION

Determination of effective concentration of fungicides for 50% mycelial growth inhibition (i.e. EC₅₀) of *Rhizoctonia solani*:

Based on regression equation of high correlation value, the effective concentrations of six fungicides for 50% growth inhibition (EC₅₀) of *Rhizoctonia solani* using six concentrations including control were calculated to assess the degrees of its sensitivity towards the fungicides. The EC₅₀ values were found to be ranged between 1.23 ppm and 30.19 ppm, with Propiconazole 25% EC being lowest and Mancozeb 75% WP being highest. Among combo products maximum value was noted for Picoxystrobin 7.05% + Propiconazole 11.7 SC (7.07ppm) and minimum value was noted for Mancozeb 50% + Thiophanate methyl 25% WG (1.69 ppm), intermediate values were noted for Tebuconazole 50% + Trifloxystrobin 25% WG (5.75ppm) and Azoxystrobin 14% + Epoxiconazole 9% SC (2.13ppm). Between two sole products Mancozeb 75% WP showed the highest EC₅₀ value of 30.19 ppm and Propiconazole 25% EC showed the lowest EC₅₀ value of 1.23 ppm. The literature on EC₅₀ value of all the combo products used at the present experiment against *R. solani* was not available. However, Gong *et al.* (2022) mentioned the EC₅₀ range for Epoxiconazole to be between 0.03 and 0.15 µg/mL, with an average EC₅₀ value of 0.100 µg/ml and the EC₅₀ values for Tebuconazole ranged from 0.02 to 0.23 µg/ml with an average EC₅₀ of 0.109 µg/ml. Panja *et al.* (2013) when attempted to determine the EC₅₀ value of 10 isolates of *R. solani* using Propiconazole and Mancozeb, they found EC₅₀ value within the range of 0.327 to 4.385 and 7.980 to 23.067 ppm respectively.

Table1. Determination of effective concentration of different fungicides (in ppm) for 50% growth inhibition (EC_{50}) of *Rhizoctonia solani* using regression equation

Name of the chemicals	Regression equations	Simple correlation coefficients (r)	EC_{50} (in ppm)
T1- Mancozeb 50% + Thiophanate methyl 25% WG	$Y = 3.3723x + 4.2224$	0.829*	1.69
T2- Picoxystrobin 7.05% + Propiconazole 11.7% SC	$Y = 4.3151x + 1.3111$	0.783	7.07
T3- Azoxystrobin 14% + Epoxiconazole 9% SC	$Y = 2.15x + 4.2787$	0.721	2.13
T4- Tebuconazole 50% + Trifloxystrobin 25% WG	$Y = 5.7446x + 0.6514$	0.869*	5.75
T5- Propiconazole 25% EC	$Y = 3.3187x + 4.6972$	0.885*	1.23
T6-Mancozeb 75% WP	$Y = 3.2592x + 0.1525$	0.999**	30.19

EC= Effective concentration and ppm = Parts per million; Y = Probit value of percent growth inhibition; x = Log of fungicide concentration; EC_{50} (ppm) = Antilog of x

WG = Wettable granules, WP = Wettable powder, SC = Soluble concentrate, EC = Emulsifiable concentrates

Table value of simple correlation for 4 df at 5% = 0.811(*) and at 1% = 0.917(**)

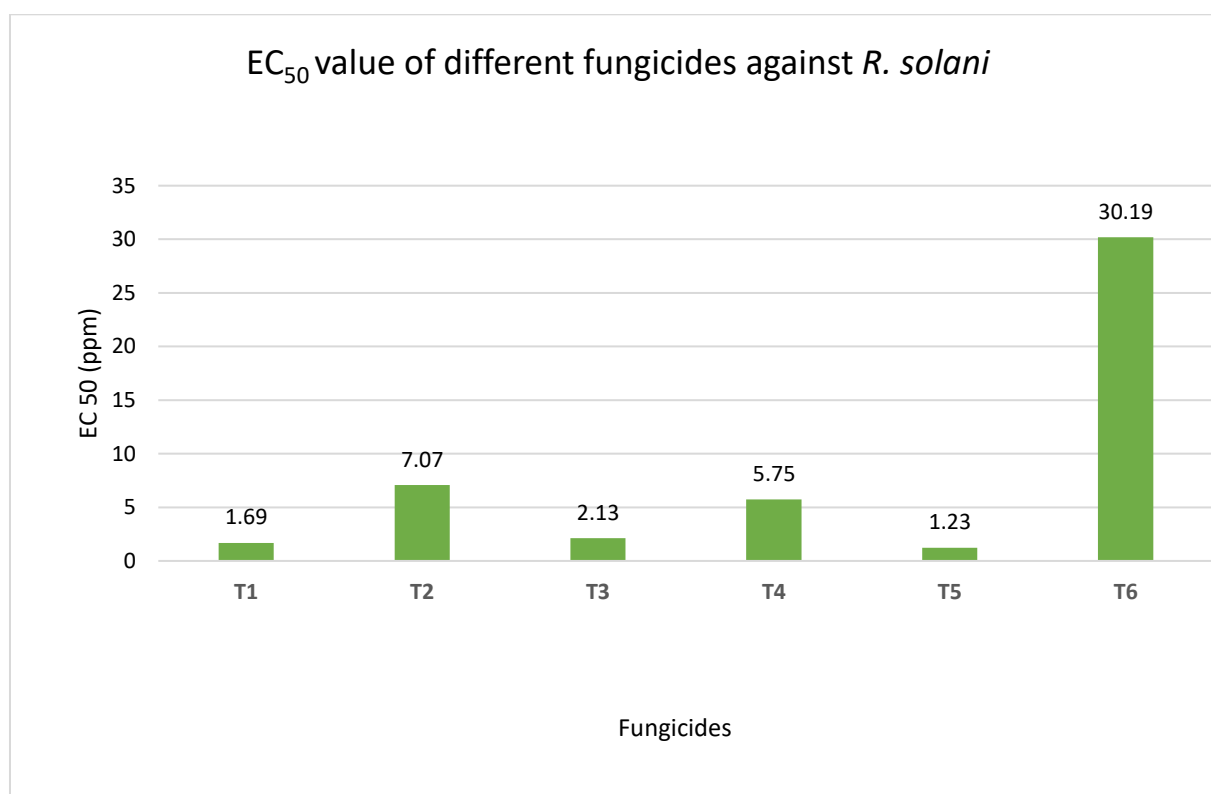
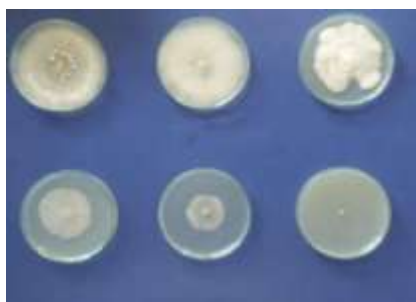


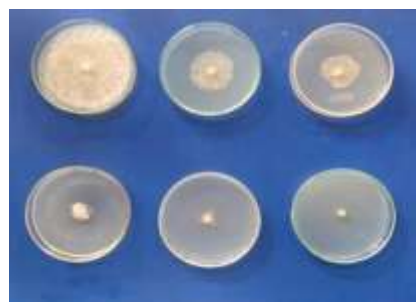
Fig.1: EC_{50} values of different fungicides in laboratory condition against *R. solani*



Mancozeb 50% + Thiophanate methyl 25% WG



Propiconazole 25% EC

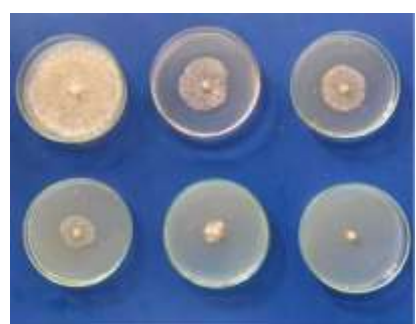


Azoxystrobin 14% + Epoxiconazole 9% SC

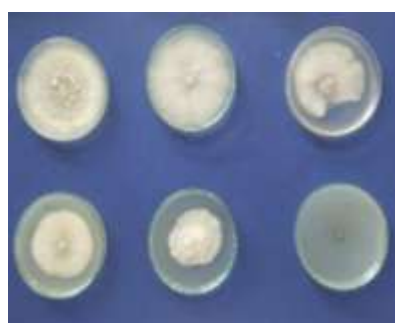


Mancozeb 75 % WP

Plate 1: In vitro percent mycelial growth inhibition of *Rhizoctonia solani* by different fungicides at various concentrations



Picoxystrobin 7.05% + Propiconazole 11.7% SC



Tebuconazole 50% + Trifloxystrobin 25% WG

3.2, Management of sheath blight disease by reduction of PDI using fungicides under field condition:

Under field condition the efficacy of seven fungicides e.g. Mancozeb 50% + Thiophanate methyl 25% WG @ 3.0g/L, Picoxystrobin 7.05% + Propiconazole 11.7 SC @ 2.0 ml /L, Azoxystrobin 14% + Epoxiconazole 9% SC @1.5 ml/L, Tebuconazole 50% + Trifloxystrobin 25% WG @0.4 g/L and two sole products of fungicides viz. Propiconazole 25% EC @ 1.0 ml /L as systemic fungicide and Mancozeb 75 WP @ 2.5 g /L as non-systemic fungicide was tested against sheath blight disease of rice. Plants were artificially inoculated in the field with *Rhizoctonia solani* at maximum tillering stage of growth by Straw-bit-Plugging method. After emergence of disease symptoms two sprayings of the above said chemicals were given at ten days interval.

All the fungicides significantly reduced the sheath blight infection over untreated control (Table 2). Mancozeb 50% + Thiophanate methyl 25% WG @ 3.0 g/L was the best effective fungicide in checking sheath blight infection (Mean disease severity 22.75 %) and increasing grain yield by more than 5510 kg ha⁻¹ over untreated check. This was followed by Propiconazole 25EC @ 1.0 ml/L and Tebuconazole 50% + Trifloxystrobin 25% WG

@ 0.4 g/L and Azoxystrobin 14% + Epoxiconazole 9% SC @ 1.5 ml /L having 26.0, 28.25 and 34.62 percent disease severity respectively.

A maximum increase of 77.73 percent grain yield was achieved with Mancozeb 50% + Thiophanate methyl 25% WG @ 3.0 g/L, followed by Propiconazole 25EC @ 1.0

ml/L with an increase of 74.32 percent, Tebuconazole 50% + Trifloxystrobin 25% WG @ 0.4 g/L with an increase of 67.25 percent and Azoxystrobin 14% + Epoxiconazole 9% SC @ 1.5 ml /L with an increase of 64.52 percent over untreated control.

Table 2: Effect of some commercially available fungicides against sheath blight disease severity and yield of rice during kharif, 2024 & 2025

Treatments	Dosages	Mean disease severity (%)	Percentage reduction of disease severity over control	Average grain yield (kg ha ⁻¹)	Per cent yield increase over control
T1-Mancozeb 50% + Thiophanate methyl 25% WG	3.0g/L	22.75 (28.43)	49.75	5510.5	77.73
T2- Picoxystrobin 7.05% + Propiconazole 11.7 SC	2.0ml/L	37.12 (37.46)	35.38	4795.5	54.69
T3- Azoxystrobin 14% + Epoxiconazole 9% SC	1.5ml/L	34.62 (36.00)	37.88	5101.0	64.52
T4- Tebuconazole 50% + Trifloxystrobin 25% WG	0.4g/L	28.25 (32.07)	44.25	5185.5	67.25
T5- Propiconazole 25EC	1.0ml/L	26.0 (30.62)	46.5	5404.75	74.32
T6- Mancozeb 75 WP	2.5g/L	41.88 (40.29)	30.62	4320.0	39.33
T7- Untreated control	--	72.50 (58.41)	00	3100.5	—
SEm(±)		1.88		93.65	
CD(P=0.05)		5.54		275.47	

Figures in parentheses indicate angular transformed values and statistics applied to them

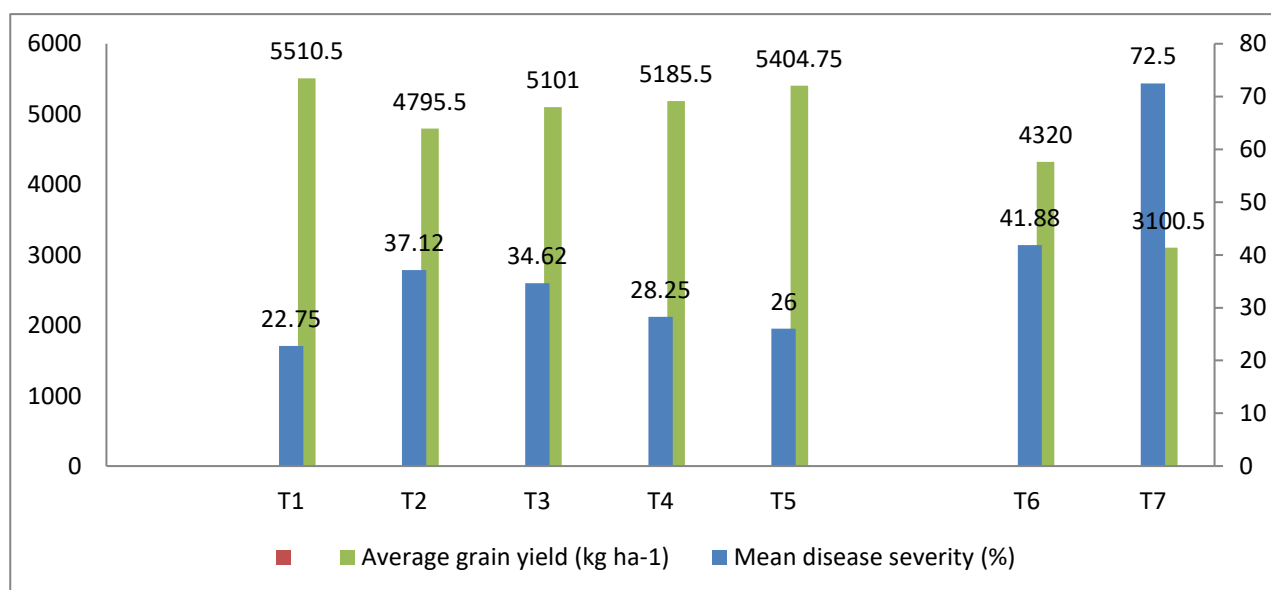


Fig.2: Bar Diagram showing Mean disease severity(%) and average grain yield(kg ha⁻¹)

Under AICRIP, Mancozeb 50% + Thiophanate methyl 25% WG @ 3.0 g/L was also tested along with other commercially available fungicides against sheath blight disease of rice during *kharif*, 2023 and 2024 at several locations. Mancozeb 50% + Thiophanate methyl 25% WG was also proved highly effective at Chiplima, Moncompu and Rajendranagar (Anonymous, 2024).

IV. CONCLUSION

Two sprays of Mancozeb 50% + Thiophanate-methyl 25% WG @ 3.0 g/L were highly effective in reducing sheath blight disease severity and improving grain yield. Under *in vitro* conditions, the minimum EC₅₀ value (1.69 ppm) was also recorded for Mancozeb 50% + Thiophanate-methyl 25% WG, indicating that it was the most effective fungicide formulation among those tested and can be effectively recommended for Integrated Disease Management in rice for ensuring sustainable rice production.

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