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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(10): 1021-1025

www.thepharmajournal.com
Received: 15-07-2023
Accepted: 18-08-2023

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Evaluation of fungicides against *Sarocladium oryzae*

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Abstract
Rice (*Oryza sativa* L.) is the principal staple food for more than two billion people, most of them live in rural and urban areas of tropical and subtropical Asia. Sheath rot caused by *Sarocladium oryzae* (Sawada) Gams and Hawksworth, has recently become a serious disease of rice when climatic conditions are favourable during flag sheath development. The present studies were undertaken to investigate the effect of various fungicides *viz*., three contact, three systemic and four combi-products against *S. oryzae*. Ten fungicides were tested against the rice sheath rot pathogen *S. oryzae* under lab conditions at various concentrations *viz*., 500, 750, 1000, 1250 and 1500 ppm for analysing the mycelial growth. The results revealed that, among the various contact fungicides, copper oxychloride 50% WP showed 100 percent inhibition of radial growth at all the concentration tested and minimum inhibition was recorded in mancozeb 75% WP (54.20%). Among the systemic fungicides, all three fungicides *viz*., carbendazim 50% WP, tebuconazole 60 FS, carboxin 75% WP exhibited 100 percent inhibition of mycelial growth at all the tested concentrations. Among the different combi-fungicides tested, carbendazim 50% + mancozeb 25%, flusilazole 12.5% + carbendazim 25% SE and carboxin 37.5% + thiram 37.5% WP fungicides were significantly superior by exhibiting 100 percent inhibition at all the concentration except hexaconazole 5% + captan 70% WP which recorded minimum inhibition of 78.30 percent.

Keywords: Rice, sheath rot, *Sarocladium oryzae*, fungicides

Introduction
Rice (*Oryza sativa* L.) is a versatile crop which is cultivated for its grain and used as staple food in most parts of the world. About 90 percent of the world's rice is grown and consumed in Asia and 60 percent of world's population depends on rice for their half of the calorie intake. The potential yield of rice suffers major setback by natural calamities like flood, dry spell and biotic factors like disease. Rice suffers from 50 diseases including 21 fungal, 6 bacterial, 12 viral, 4 nematodes and 7 miscellaneous diseases and disorders (Hollier *et al*., 1993; Jabeen *et al*., 2012) [3, 4]. Among the fungal diseases, Sheath rot of rice caused by *Sarocladium oryzae* has gained the status of a major disease of rice and yield loss varies from 9.60 to 85%. Yield loss incurred by sheath rot infection was found to be as high as 85% (Bigirimana *et al*., 2015). Caused yield losses are variable from 10 to 85%, depending on the pathosystem conditions (Sakthivel, 2001) [10]. In India, sheath rot was first reported in 1973 and the losses due to the disease were found to be ranging from 50 to 65% (Ravishankar and Revanna, 2008) [7]. In Karnataka, the cultivation of rice takes place across various ecological systems and a wide range of climatic conditions. The significant loss incurred due to sheath rot can primarily be attributed to the susceptibility of the boot leaf sheath, which envelops the nascent panicle. It is imperative to address the management of this disease prior to the emergence of the panicle. The market offers a wide array of chemical fungicides, however, their effectiveness and appropriateness must be corroborated through *in vitro* investigations. Hence, the evaluation of fungicides for the management of sheath rot disease pathogen assumes paramount importance.

Material and Methods
In vitro evaluation of systemic, non-systemic and combination fungicides using different concentrations *viz*., 500, 750, 1000, 1250 and 1500 ppm was done by following standard poison food technique as given by Sinha and Khare (1978) [12] at the laboratory of Department of Plant Pathology, College of Agriculture, Raichur. The experiment was carried out in a completely randomized design with three replications. The details of treatments for *in vitro* evaluation of fungicides are listed in table 1. Twenty ml of PDA medium was initially mixed with the required quantity of fungicides calculated based on the active ingredient listed below

and were poured into 70 mm diameter Petri dishes. After solidification, 5 mm discs of *S. oryzae* pathogen were placed at the centre of the plate and suitable checks were maintained without poisoning the media. Each set of experiments were replicated three times and plates were incubated at 27±1˚C until the control culture reached the periphery of the plates. Observations were taken for the growth of the pathogen in treated plates such as colony diameter and percent inhibition of growth was calculated using the formula given below by Vincent (1947) [14]. The data was analysed statistically.

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

Where,
I = Percent inhibition
C = Growth in control
T = Growth in treatment

Table 1: List of fungicides used against *Sarocladium oryzae* for *in vitro* studies

Sl. No.	Fungicides	
	Contact fungicides	
	Chemical name	**Trade name**
01.	Copper oxy chloride 50% WP	Blitox 50W
02.	Mancozeb 75% WP	Mancoban M-45
03.	Chlorothalonil 75% WP	Kavach
	Combi fungicides	
04.	Carbendazim 50% + Mancozeb 25%	Sprint
05.	Flusilazole 12.5% + Carbendazim 25% SE	Lustre 37.5 SE
06.	Hexaconazole 5% + Captan 70% WP	Taquat
07.	Carboxin 37.5% + Thiram 37.5% WP	Vitavax power
	Systemic fungicides	
08.	Carbendazim 50% WP	Bavistin
09.	Tebuconazole 60 FS	Raxil Easy 60 FS
10.	Carboxin 75% WP	Vitavax

Results and Discussion

The efficacy of ten different fungicides (systemic, contact and combination) were evaluated against *S. oryzae* under *in vitro* at different concentrations *viz.*, 500, 750, 1000, 1250 and 1500 ppm by poison food technique as described in Material and Methods. The effect of different fungicides and their different concentrations were found to be significantly effective in inhibition of fungal growth. The untreated control showed no inhibition of mycelial growth, confirming the necessity of fungicidal treatments to effectively hinder the growth of *S. oryzae* (Table 2, Plate 1).

The results of the experiments revealed that, among contact fungicides tested at different concentrations, copper oxy chloride 50% WP recorded 100 percent mean mycelial inhibition at all concentrations tested, which is significantly superior over all other treatments followed by chlorothalonil 75% WP (59.20%) and minimum inhibition was recorded in mancozeb 75% WP (54.20%). The interaction effect of fungicides and concentration indicated that copper oxy chloride had shown cent percent inhibition at all the five concentrations and significantly superior over other treatments followed by mancozeb which had shown 85.70 percent inhibition at 1500 ppm concentration. In case of chlorothalonil, 78.60 percent inhibition was recorded at 1500 ppm concentration.

Among the systemic fungicides, all three fungicides *viz.*, carbendazim 50% WP, tebuconazole 60 FS, carboxin 75% WP exhibited 100 percent inhibition of mycelial growth at all the tested concentrations. The effectiveness of these fungicides can vary based on factors such as the specific type of fungus, fungicide concentration, application method and the plant species being treated. Systemic fungicides function by being absorbed by the plant tissue. Once absorbed, they are distributed internally throughout the plant, affording protection from fungal infections. This mode of action sets them apart from contact fungicides that remain on the plant surface. Carboxin operates by inhibiting the activity of succinate dehydrogenase, a key enzyme in the citric acid cycle of fungal cells. By disrupting this vital metabolic process, Carboxin halts fungal growth and development. Carbendazim, on the other hand, acts as a mitosis inhibitor. It interferes with microtubule assembly during fungal cell division, leading to the prevention of proper chromosome segregation and ultimately hindering fungal reproduction. Tebuconazole operates by inhibiting the biosynthesis of ergosterol, an essential component of fungal cell membranes. Without adequate ergosterol, fungal cells are rendered structurally compromised and incapable of maintaining their integrity. (Hewitt, 2000) [2].

Among the different combi-fungicides tested, carbendazim 50% + mancozeb 25%, flusilazole 12.5% + carbendazim 25% SE and carboxin 37.5% + thiram 37.5% WP fungicides were significantly superior by exhibiting 100 percent inhibition at all the concentration except hexaconazole 5% + captan 70% WP which recorded minimum inhibition of 78.30 percent. The interaction effect of fungicides and concentration indicated that, carboxin 37.5% + thiram 37.5% WP, flusilazole 12.5%+ carbendazim 25% SE and carbendazim 50% + mancozeb 25% had shown cent percent inhibition followed by hexaconazole 5% + captan 70% WP which recorded 85.70 percent inhibition at 1250 ppm and 1500 ppm concentration and was found to be on par with each other.

In vitro evaluation of fungicides provides useful preliminary information regarding its efficacy against a pathogen within the shortest period of time and therefore serves as a guide for further testing. Non-systemic fungicides directly have contact with the diseased part of the plant and they are mostly multi-site inhibitors and are not absorbed by the plant and only stick to plant surfaces. These fungicides provide a barrier and it prevents the fungus from entering and damaging the plant tissues. Systemic fungicides translocate to plant parts and they are not covered by the application and protect the plant from inside. They are effective in smaller amounts and these fungicides are less prone to rain wash or photodegradation. (Mohamed *et al*., 2018) [5] Combo or combination fungicides are formulated by mixing two or more active ingredients with different modes of action. This approach is often used to enhance the efficacy of the fungicides and reduce the risk of developing resistance in target pathogens. The combi-fungicides are with low risk and having multi-site action on the pathogen which will contribute to the avoidance of resistance development (Rieke *et al*., 2014) [9]. The different fungicides in the mixture must be active against the target fungi so that subgroups that are resistant to one mode of action are controlled by the fungicide partner with a different mode of action. A similar study was reported for the effectiveness of triazoles, which inhibit the biosynthesis pathway in fungi. Similar works were reported by Mohan (1976) [6]; Vijayaraghavan (1976) [13]; Reddy *et al*. (1985) [8] and Sharma *et al*. (2013) [11].

Table 2: Efficacy of fungicides on the mycelium growth of *Sarocladium oryzae*

Sl. No.	Fungicides	Percent inhibition over control					
		Concentration (ppm)					
		500	750	1000	1250	1500	Mean
1	Mancozeb 75% WP	21.40 (27.57)*	42.50 (40.67)	50.00 (45.00)	71.40 (57.68)	85.70 (67.78)	54.20 (47.41)
2	Copper-oxy-chloride 50% WP	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
3	Chlorothalonil 75% WP	35.70 (36.70)	51.70 (46.00)	58.60 (49.93)	71.40 (57.68)	78.60 (62.42)	59.20 (50.35)
4	Carboxin 75% WP	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
5	Carbendazim 50% WP	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
6	Tebuconazole 60 FS	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
7	Carboxin 37.5% + Thiram 37.5% WP	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
8	Hexaconazole 5% + Captan 70% WP	70.00 (56.79)	71.40 (57.68)	78.60 (62.42)	85.70 (67.79)	85.70 (67.79)	78.30 (62.24)
9	Flusilazole 12.5%+ Carbendazim 25% SE	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
10	Carbendazim 50% + Mancozeb 25%	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
	Mean	82.71 (65.42)	86.56 (68.49)	88.72 (70.38)	92.85 (74.49)	95.00 (77.08)	-

*Figures in parenthesis are arc sine values

	S. Em±	CD @ 1%
Fungicides (F)	0.57	1.85
Concentration (C)	0.40	1.29
Interaction (F×C)	1.27	3.91

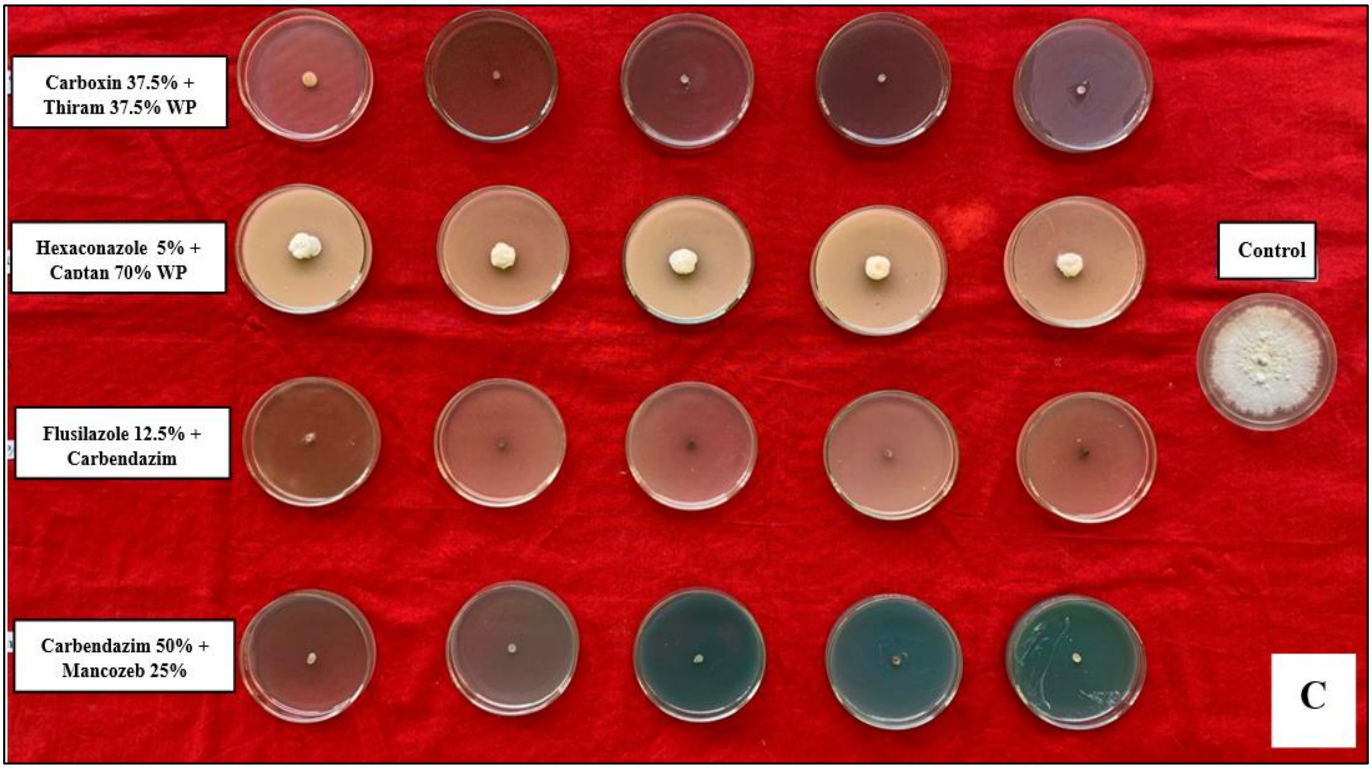

Plate 1: Efficacy of fungicides against *Sarocladium oryzae* Contact fungicides, B- Systemic fungicides, C- Combi fungicides)

Conclusion

The management is very much essential in order to prevent the further spread of the disease. From the *in vitro* studies conducted it is clear that the Copper oxy chloride 50% WP, carbendazim 50% WP, tebuconazole 60 FS, carboxin 75% WP, carbendazim 50% + mancozeb 25%, flusilazole 12.5% + carbendazim 25% SE and carboxin 37.5% + thiram 37.5% WP exhibited 100 percent inhibition at all the concentrations tested and these can be further tested in the field for its efficacy in managing the sheath rot disease.

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