The Pharma Innovation Journal 2022; 11(12): 1881-1889

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 1881-1889

www.thepharmajournal.com
Received: 03-09-2022
Accepted: 07-10-2022

Meghana Suresh Nayak
Department of Plant Pathology, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Hosagoudar GN
AHRS, Ponnampet, Kodagu, Karnataka, India

Ganesha Naik R
Department of Plant Pathology, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Gangadhar Naik B
Department of Plant Pathology, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Dushyantha Kumar BM
Department of Genetics and Plant Breeding, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Thippeshappa GN
Department of Soil Science and Agricultural Chemistry, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Corresponding Author:
Meghana Suresh Nayak
Department of Plant Pathology, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

In vitro and *in vivo* efficacy of botanicals, bioagents and fungicides against sheath rot of rice incited by *Sarocladium oryzae*

Meghana Suresh Nayak, Hosagoudar GN, Ganesha Naik R, Gangadhar Naik B, Dushyantha Kumar BM and Thippeshappa GN

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, *Sarocdadium oryzae* (Sawada) W. Gams & D. Hawksworth, has recently become a serious disease of rice when climatic conditions are unfavorable during flag sheath development. Efficacy of botanicals, bioagents, fungicides: systemic, non-systemic and combi products were tested against *S. oryzae*. Seven botanicals were evaluated for their anti-fungal activity against the pathogen, among them neem oil has recorded maximum inhibition (91.17%) at 0.5%. In non-systemic fungicides, copper oxychloride showed cent% inhibition of radial growth at 0.3%. Maximum inhibition of radial growth (100%) was recorded at 0.05% of Propiconazole fungicide. Among combi product fungicides, Azoxystrobin 11% + Tebuconazole 18.3% SC and Captan 70% + Hexaconazole 5% WP recorded cent% inhibition of radial growth at 0.15%. Dual culture technique was undertaken to assess the potential of five biocontrol agents among them *Pseudomonas fluorescens* (87.20%) and *Trichoderma harzianum* (57.60%) was the most antagonistic organism. From two season (*Kharif* 2020-21 and 2021-22) field experiment, foliar spray with propiconazole was found superior over all other treatments giving reduction in% disease index (5.44%) with increased grain yield (34.07 q/ha) and 1000-grains weight (28 g).

Keywords: Sheath rot, botanicals, bioagents, 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 (Anon, 2021) [1]. 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) [5, 7]. Among the fungal diseases, Sheath rot of rice caused by *Sarocladium oryzae* (Sawada) Gams and Hawksworth (1975) [4] has gained the status of a major disease of rice and yield loss varies from 9.6 to 85%. 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) [11]. In Karnataka, rice is grown under diverse ecosystems and a wide range of climatic conditions. Severe loss due to sheath rot is mainly because of vulnerability of boot leaf sheath that encircles the young panicle. Management of disease before panicle emergence is very much essential. Effective management of this disease by a single method may not be possible. Hence, it is necessary to develop an integrated disease management strategy by combining bioagents, botanicals and chemical fungicides as an effective component. There is large number of chemicals available in the market as fungicides and their efficacy and suitability needs to be verified by *in vitro* and in field studies. Hence, screening of bioagents, botanicals and fungicides to control sheath rot disease is most essential, so as to incorporate the effective ones in the management package.

Material and Methods
In vitro experiment was conducted to evaluate the efficacy of botanicals, bioagents and fungicides against sheath rot disease. *Sarocladium oryzae* was isolated from rice fields of Agricultural and Horticultural Research Station (AHRS), Ponnampet, Karnataka.

Poison food technique was used for evaluating efficacy of botanicals and fungicides and dual culture technique was used for assessing antagonistic potential of biocontrol agents. Based on *in vitro* analysis, best two of each botanicals, bioagents, systemic, contact and combi product fungicides were tested under field conditions during *Kharif* 2020-21 and 2021-22.

In vitro evaluation of botanical/ essential oils and fungicides

Poisoned food technique was followed to test the efficacy of the different botanical/ essential oils and fungicides. Desired concentration of botanicals and fungicides were prepared and mixed with PDA. Twenty ml of poisoned medium will be poured in each of the sterilized Petriplates. Mycelial disc of 5 mm were taken from the periphery of ten days old culture and were placed in the centre of the Petri plate and incubated at 27±1 °C. Control plate was also maintained without addition of any botanical and fungicide and three replications were maintained for each treatment. The diameter of the fungal colony was measured in two directions and average was worked out. The% inhibition of growth was calculated by using the formula given by Vincent (1947) [18].

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

Where, I =% inhibition of mycelium
C = Diameter of mycelium in control plate
T = Diameter of mycelium in treatment plate

In vitro efficacy of Botanical / Essential oils against *Sarocladium oryzae*

Treatments	Botanical/ Essential oils	Trade name	Concentration (%)
T_1	Neem oil	Multineem	0.1, 0.25, 0.5
T_2	Lemon grass oil	Lemongrass	
T_3	Clove oil	Clover Leaf	
T_4	Pongamia oil	Karanja oil	
T_5	Citronella oil	Citronella	
T_6	Eucalyptus oil	Eucalyptus	
T_7	Nirgundi oil	Nirgundi Tel	

In vitro efficacy of non-systemic fungicides against *Sarocladium oryzae*

Treatments	Common name	Trade name	Formulation (%)
T_1	Copper oxychloride	Bluecopper/Blitox	50% WP
T_2	Chlorothalonil	Kavach	75% WP
T_3	Zineb	Dithane Z-78	70% WP
T_4	Captan	Captaf	50% WP
T_5	Thiram	Thiram	75% WP
T_6	Mancozeb	Indofil M-45	75% WP
T_7	Propineb	Antracol	70% WP

In vitro efficacy of systemic fungicides against *Sarocladium oryzae*

Treatments	Common name	Trade name	Formulation (%)
T_1	Propiconazole	Tilt	25% EC
T_2	Pyraclostrobin	Headline	25% EC
T_3	Tebuconazole	Folicur	25% EC
T_4	Thiophenate methyl	Roko	70% WP
T_5	Hexaconazole	Contaf	5% EC
T_6	Azoxystrobin	Amistar	25% SC
T_7	Carbendazim	Bavistin	50% WP

In vitro efficacy of combi product fungicides against *Sarocladium oryzae*

Treatments	Common name	Trade name	Formulation (%)
T_1	Captan 70% + Hexaconazole 5% WP	Taqat	75% WP
T_2	Carbendazim 12% + Mancozeb 63% WP	Saaf	75% WP
T_3	Azoxystrobin 11% + Tebuconazole 18.3% SC	Custodia	29.3% SC
T_4	Flusilazole 12.5% + Carbendazim 25% SC	Lusture	37.5% SC
T_5	Hexaconazole 5% + Validamycin 2.5% SC	Valxtra	7.5% SC
T_6	Tebuconazole 50% + Trifloxystrobin 25% WG	Nativo	75% WG
T_7	Azoxystrobin 20% + Difenoconazole 12.5% SC	Amistar Top	32.5% SC

In vitro evaluation of bioagents

The antagonistic microorganisms like *Pseudomonas fluorescens*, *Trichoderma harzianum*, *Trichoderma hamatum*, *Trichoderma asperillum* and *Bacillus subtilis* were evaluated for their antagonistic effect under *in vitro* conditions against *Sarocladium oryzae* by dual culture technique. Twenty ml of sterilized and cooled Potato Dextrose Agar (PDA) medium was poured into sterilized Petri plates. Fungal antagonists were evaluated by inoculating the pathogen at one side of Petri plate and the antagonist inoculated at exactly opposite side of the same plate by leaving 3-4 cm gap. For this, actively growing hyphae from the periphery of the mycelial mat were used. In case of bacterial antagonist, mycelial discs of 5mm of pathogen were placed in the cenre of the plate and bacterial antagonist was streaked on both the corners of the plate. After required period of incubation *i.e.* when the pathogen mycelium completely covers the plate, the radial growth of pathogen both in control and isolated plate were measured.% inhibition of the pathogen was worked out according to equation given by Vincent (1947) [18].

In vivo evaluation of botanicals, bioagents and fungicides against *Sarocladium oryzae*

The experiment was conducted during *Kharif* 2020-21 and 2021-22 at Agricultural and Horticultural Research Station (AHRS), Ponnampet, Kodagu on transplanted rice to know the efficacy of fungicides, botanicals and biological agents against sheath rot of rice. Experiment was laid out in Randomized Block Design (RBD) with twelve treatments and three replication and tested on susceptible variety BPT-5204.

Different treatments planned are as follows

Treatments	Descriptions	Dosage (%)
T_1	Foliar spray (FS) with Copper oxychloride 50% WP	0.2
T_2	FS with Propineb 70% WP	0.2
T_3	FS with Azoxystrobin 11% + Tebuconazole 18.3% SC	0.1
T_4	FS with Captan 70% + Hexaconazole 5% WP	0.2
T5	FS with Propiconazole 25% EC	0.1
T_6	FS with Azoxystrobin 25% SC	0.1
T_7	FS with Neem oil	0.3
T_8	FS with Pongamia oil	0.3
T_9	FS with *Trichoderma harzianum*	1.0
T_{10}	FS with *Pseudomonas fluorescens*	1.0
T_{11}	FS with Carbendazim (Recommended check)	0.1
T_{12}	Untreated control	-

Treatments imposed under field experiments influenced the growth and subsequent activity of the pathogen against host plants. In order to determine effects on various parameters under study, following observations% disease index, grain yield, 1000 seed weight,% disease reduction over control and Benefit: Cost ratio were recorded.

$$\text{Per cent disease index} = \frac{\text{Sum of the individual disease ratings}}{\text{Total number of leaves observed} \times \text{maximum disease grade}} \times 100$$

The disease index was recorded by Standard Evaluation System of scale 0-9 (IRRI, 2006) at maturity stage, rice plants were cut down and threshed manually. Grain yield per plot was recorded and converted into hectare basis as kilograms per hectare (kg ha^{-1}). The weight of thousand rice grains was recorded from the grain samples drawn from each treatment. For each treatment% reduction in disease index over control was calculated as

$$\text{Per cent reduction in disease index over control} = \frac{\text{Disease index in control - Disease index in treatment}}{\text{Disease index in control}} \times 100$$

B: C ratio of all the treatments were calculated to know the profit obtained by each treatment by using the formula

$$\text{B: C ratio} = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

Results and Discussion

In vitro evaluation of botanicals/ essential oil against *Sarocladium oryzae*

Inhibition of mycelia growth varied significantly with different treatments. All botanicals significantly reduced the mycelial growth of *S. oryzae* over untreated. Among the seven essential oils evaluated (Table 1 and Plate 1), Neem oil (89.50%) gave maximum mean% of mycelia inhibition which was significantly superior to other treatments. Neem oil recorded maximum% of mycelial inhibition (87.17, 90.17 and 91.17%) at 0.1, 0.25 and 0.5 percent concentration, respectively followed by Pongamia oil (74.83, 77.67 and 82.67%) at all three concentrations respectively. The least mean% of inhibition of the fungus was recorded in Nirgundi oil (17.44%). Maximum mycelial inhibition was obtained by Neem oil due to the presence of alkaloid *i.e.*, Azadirachtin content in it. The present finding was supported by Sharma *et al*. (2013) [14] stated that among the botanicals, Neem at 50% concentration was found most effective in inhibiting radial growth (56.6%) and reduced the disease index of sheath rot in glass house (49.0%)

In vitro evaluation of non-systemic/contact fungicides against *Sarocladium oryzae*

All the seven test fungicides significantly inhibited mycelial growth of the fungus (Table 2 and Plate 2). Maximum% of mycelial inhibition was recorded in Copper oxychloride 50% WP (95.33, 97.50 and 100.00%) at all three concentration 0.1, 0.2 and 0.3% respectively followed by Propineb 70% WP (52.33, 56.42 and 60.50%, respectively). Least% of mycelial inhibition was recorded in Chlorothalonil 75% WP (12.50, 15.67 and 19.33%), respectively. Copper oxychloride is a multisite, broad-spectrum contact fungicide. Because of its high affinity for bonds with amino acids and carboxyl groups, copper interacts with proteins and inhibits the activity of enzymes in its target organisms. Copper kills spores by combining with sulphahydral groups of certain enzymes. Efficacy of these fungicides was previously reported by Venkateswarlu and Venkateswarlu (2004) among six non-systemic fungicides Copper oxychloride and Methoxyethyl mercuric chloride were effective against the pathogen.

In vitro evaluation of systemic fungicides against *Sarocladium oryzae*

Among seven systemic fungicides evaluated (Table 3 and Plate 2), maximum% of mycelial inhibition was recorded in propiconzole 25% EC and Carbendazim 50% WP (100%) at all three concentration 0.05, 0.1 and 0.15% followed by Azoxystrobin 25% SC (76.83, 83.00 and 89.67%). Least% of mycelial inhibition was recorded in Thiophenate methyl 75% WP (20.33, 27.00 and 34.42%), respectively. Propiconazole and other triazole fungicides interfere with the biosynthesis of fungal sterols and prevent the development of ergosterols. Ergosterol is an essential component of the cell wall of many fungi and its absence results in permanent damage to the cell wall and leads to fungal cell death. Carbendazim involves interference in the biosynthesis of DNA during fungal cell division. Present investigations in the study found conformity with Venkateswarlu and Venkateswarlu (2004), Sowjanya (2012) and Selvaraj and Annamalai (2014).

In vitro evaluation of combi product fungicides against *Sarocladium oryzae*

Among different concentration, highest inhibition of cent% was revealed at 0.2% concentration, whereas least was at 0.1%. Among seven combi product fungicides evaluated (Table 4 and Plate 2), maximum mean% mycelial inhibition was recorded in Captan 70% + Hexaconazole 5% WP and

Azoxystrobin 11% + Tebuconazole 18.3% SC (100%) which was significantly superior to all other fungicides. Maximum cent% of mycelial growth of the fungus was inhibited by Captan 70% + Hexaconazole 5% WP and Azoxystrobin 11% + Tebuconazole 18.3% SC at all three concentrations 0.1, 0.15 and 0.2%, respectively. Combi product fungicides are effective even at lower concentration. Least% of mycelial inhibition was recorded in Azoxystrobin 20% + Difenoconazole 12.5% SC (79.00, 82.17 and 85.00%), respectively. Systemic fungicides only disrupts one or occasionally two roles in fungal physiology, which are easily overridden by a single mutation or by the selection of resistant individuals in a population, combi product fungicides prevent the development of fungi resistance to these chemicals. Non-systemic protectant fungicides disrupt too many physiological processes in the fungus, necessitating too many gene modifications for the fungus to develop resistance. Therefore, combining systemic and non-systemic fungicides offers superior long-term treatment of plant fungal disease (Deising *et al*., 2018) [3]. These results are in accordance with Kumar *et al*. (2012) [8] reported that out of eight fungicides tested Saaf 75 WP (Carbendazim 12% + Mancozeb 63%) inhibited mycelial growth of the fungus *S. oryzae* more than 80 percent at 200 ppm concentration.

In vitro **evaluation of bio-agents against *Sarocladium oryzae***

Biological control through the use of antagonistic micro-organisms is a potential, non-chemical means of controlling plant disease by reducing inoculum levels of the pathogens. Results stated that the bio-agents significantly reduced the growth of the pathogen (*Sarocladium oryzae*) either by competition (over growing) or by antibiosis (exhibiting inhibition zones). Maximum reduction in colony growth of *S. oryzae* was observed in *Pseudomonas fluorescens* (87.20%) and *Bacillus subtilis* (75.30%) which were significantly superior over all other bio-agents tested. Among the fungal antagonistic bioagents, *T. harzianum* (57.60%) significantly reduced colony growth (Table 5 and Plate 1). The antibiotics produced by the bio control agents may be the cause of the pathogen's slower mycelial development. *S. oryzae* growth suppression may be primarily caused by antibiosis or hyper parasitism (Pal and Gardener, 2006) [9]. Observation is similar to the findings of Bora and Ali (2019) [2] who reported that out of all the tested antagonists, *Pseudomonas fluorescens* showed highest (82.06%) inhibition of the mycelial growth of the *S. oryzae* and among the fungal antagonists, *T. harzianum* was found to be most effective with 65.21% inhibition over the other species.

In vivo **evaluation of botanicals, bioagents and fungicides against sheath rot of rice during *Kharif* 2020-21 and 2021-22 (Pooled)**

The results of pooled data during *Kharif* 2020-21 and 2021-22 (Table 6, Fig. 1 and Plate 3) revealed that foliar spray (FS) with Propiconazole (0.1%) significantly lowered sheath rot% Disease Index (5.44 PDI) followed by FS with Carbendazim (0.1%) (6.66 PDI), Captan + Hexaconazole (0.2%) (9.21 PDI) and FS with Azoxystrobin (0.1%) (10.87 PDI) while FS with Pongamia oil (0.3%) (28.95 PDI) was the least effective. Maximum% Disease over Control (PDC) recorded in case of FS with Propiconazole (0.1%) (81.23 PDC) followed by Carbendazim (0.1%) (76.99 PDC) whereas, minimum% disease over control (PDC) was recorded in Pongamia oil (0.3%) (15.21 PDC). Maximum 1000 grain weight observed in treatment sprayed with Propiconazole at 0.1% (28.38 g) followed by Carbendazim at 0.1% (26.31 g), Captan + Hexaconazole at 0.2% (25.02 g) and Azoxystrobin at 0.1% (24.02 g). Minimum 1000 grain weight was observed in the treatment in untreated control (15.78 g).

The yield variation among the treatments was non-significant. The maximum yield of (34.07 q/ha) was recorded in FS with Carbendazim (0.1%) which was on par with FS with Propiconazole (0.1%) (33.08 q/ha) followed by FS with Captan + Hexaconazole (0.2%) (31.24 q/ha) and minimum yield of (18.41 q/ha) was recorded in untreated control plot. Highest B: C ratio (2.23) was recorded in T_5: FS with Propiconazole (1g/l) which was on par with T_{11}: foliar spray with Carbendazim (1 ml/l) (2.15) and T_4: FS with Captan + Hexaconazole (2g/l) (2.00), as compared to untreated control plot (1.22). Present findings are in accordance with Thapak *et al.* (2003) where among nine fungicides tested tilt, bavistin and antracol were found to be superior in reducing the index of sheath rot disease. Sharma *et al*. (2013) [14] found that foliar spray of tebuconazole was found superior overall other treatments giving reduction in disease index (59.01-64.33%), which was followed by carbendazim (48.70-55.28%) and also increased grain yield per plant (45.06-65.84%), grain yield per plot (45.57-65.85%), 1000-grains weight (10.80-52.58%) and reduction in chaffiness (48.07-53.80%). Pramesh *et al.* (2017) [10] tested new combination fungicide TAQAT 75% WP (Captan 70% + Hexaconazole 5%) in different doses and recorded least percent disease index (PDI) of 14.44% in both *Kharif* and *Rabi* season.

Table 1: *In vitro* evaluation of botanicals/ essential oil against *Sarocladium oryzae*

Treatment	Botanicals	% inhibition of mycelial growth in different concentration			Mean inhibition (%)
		0.1%	0.25%	0.5%	
T_1	Neem oil	87.17 (69.02)*	90.17 (71.75)	91.17 (72.77)	89.50 (71.18)
T_2	Lemon grass oil	55.92 (48.40)	59.00 (50.18)	65.58 (54.08)	60.16 (50.88)
T_3	Nirgundi oil	11.17 (19.50)	18.00 (25.10)	23.17 (28.77)	17.44 (24.45)
T_4	Pongamia oil	74.83 (59.89)	77.67 (61.80)	82.67 (65.40)	78.39 (62.36)
T_5	Clove oil	19.33 (26.08)	23.67 (29.10)	27.50 (31.63)	23.50 (28.94)
T_6	Citronella oil	25.33 (30.22)	29.33 (32.79)	34.00 (35.67)	29.56 (32.89)
T_7	Eucalyptus oil	18.67	22.00	27.33	22.67

		(25.59)	(27.97)	(31.52)	(28.36)
	Mean	41.77 (39.81)	45.69 (42.67)	50.20 (45.69)	45.88 (42.72)
		Botanicals (B)	Concentration (C)	Interactions (B × C)	
	S.Em. ±	0.28	0.18	0.48	
	C.D. @ 1%	1.05	0.69	1.82	

***Figures in parenthesis are Arc sine transformed values

Table 2: *In vitro evaluation of non-systemic/contact fungicides*

Treatment	Fungicides		% inhibition of mycelial growth in different concentration			Mean (%)
	Common name	Trade name	0.1	0.2	0.3	
T_1	Copper oxy chloride	Blitox 50% WP	95.33 (77.54) *	97.50 (81.01)	100.00 (90.00)	97.61 (82.85)
T_2	Chlorothalonil	Kavach 75% WP	12.50 (20.70)	15.67 (23.31)	19.33 (26.07)	15.83 (23.36)
T_3	Zineb	Dithane Z-78 70% WP	34.83 (36.16)	38.67 (38.45)	42.83 (40.88)	38.78 (38.50)
T_4	Propineb	Antracol 70% WP	52.33 (46.34)	56.42 (48.69)	60.50 (51.06)	56.42 (48.70)
T_5	Captan	Captaf 50% WP	47.00 (43.28)	50.17 (45.10)	53.25 (46.86)	50.14 (45.08)
T_6	Thiram	Thiridae 75% WP	38.33 (38.25)	42.00 (40.40)	44.17 (41.65)	41.50 (40.10)
T_7	Mancozeb	Dithane M- 45 75% WP	25.00 (30.00)	28.17 (32.05)	31.08 (33.88)	28.08 (31.98)
	Mean		43.61 (41.75)	46.94 (44.14)	50.16 (47.20)	46.90 (44.36)
			Fungicides (F)	Concentration (C)	Interactions (F × C)	
	S.Em. ±		0.29	0.19	0.50	
	C.D. @ 1%		1.10	0.72	1.90	

*Figures in parenthesis are Arc sine transformed values

Table 3: *In vitro* evaluation of systemic fungicides

Treatment	Fungicides		% inhibition of mycelial growth in different concentration			Mean (%)
	Common Name	Trade name	0.05	0. 1	0.15	Mean
T_1	Propiconazole	Tilt 25% EC	100.00 (90.00)*	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
T_2	Pyraclostrobin	Headline 20% WG	65.50 (54.03)	70.17 (56.89)	75.83 (60.56)	70.50 (57.16)
T_3	Tebuconazole	Folicure 250 EC	60.17 (50.87)	64.67 (53.53)	71.00 (57.42)	65.28 (53.94)
T_4	Thiophenate methyl	Topsin-M 75% WP	20.33 (26.78)	27.00 (31.30)	34.42 (35.92)	27.25 (31.33)
T_5	Azoxystrobin	Amitsar 25% SC	76.83 (61.25)	83.00 (65.67)	89.67 (71.31)	83.17 (66.08)
T_6	Hexaconazole	Contaf 5% EC	57.00 (49.03)	63.83 (53.03)	67.58 (55.30)	62.81 (52.45)
T_7	Carbendazim	Bavistin 50% WP	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
	Mean		68.54 (60.28)	72.66 (62.91)	76.92 (65.78)	72.70 (62.99)
			Fungicides (F)	Concentration (C)	Interactions (F × C)	
	S.Em. ±		0.31	0.20	0.54	
	C.D. @ 1%		1.18	0.78	2.07	

*Figures in parenthesis are Arc sine transformed values

Table 4: *In vitro* evaluation of combi product fungicides against *Sarocladium oryzae*

Treatment	Fungicides		% inhibition of mycelial growth in different concentration			Mean (%)
	Common name	Trade name	0.05	0.15	0.2	Mean
T_1	Captan 70% + Hexaconazole 5% WP	Taqat 75%WP	100.00 (90.00)*	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
T_2	Carbendazim 12% + Mancozeb 63% WP	SAAF 75% WP	86.00 (68.04)	88.42 (70.11)	90.17 (71.73)	88.19 (69.96)
T_3	Azoxystrobin 11% + Tebuconazole 18.3% SC	Custodia 29.3% SC	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
T_4	Flusilazole 12.5% + Carbendazim 25% SC	Lusture 37.5% SC	89.08 (70.72)	91.00 (72.56)	92.17 (73.76)	90.75 (72.35)
T_5	Hexaconazole 5% + Validamycin 2.5% SC	Valxtra 7.5% S C	94.33 (76.24)	95.92 (78.40)	98.00 (82.05)	96.08 (78.90)
T_6	Tebuconazole 50% + Trifloxystrobin 25% WG	Nativo 75% WG	96.33 (78.98)	97.75 (81.43)	100.00 (90.00)	98.03 (83.47)
T_7	Azoxystrobin 20% + Difenoconazole 12.5% SC	Amistar Top 32.5% SC	79.00 (62.73)	82.17 (65.03)	85.00 (67.22)	82.06 (64.99)
	Mean		96.51 (81.45)	97.77 (83.31)	99.07 (86.44)	97.78 (83.73)
			Fungicides (F)	Concentration (C)	Interactions (F × C)	
	S.Em. ±		0.29	0.19	0.50	
	C.D. @ 1%		1.11	0.72	1.92	

*Figures in parenthesis are Arc sine transformed values

Table 5: *In vitro* evaluation of bio-agents against *Sarocladium oryzae*

Treatment	Bio-agents	Percent inhibition of mycelial growth
T_1	*Pseudomonas fluorescens*	87.20 (69.04)*
T_2	*Bacillus subtilis*	75.30 (60.20)
T_3	*Trichoderma asperillum*	37.80 (37.94)
T_4	*Trichoderma harzianum*	57.60 (49.37)
T_5	*Trichoderma hamatum*	28.40 (32.20)
	Mean	57.26 (49.75)
	S.Em. ±	0.95
	C.D. at 1%	3.82

*Figures in parenthesis are Arc sine transformed values

Table 6: *In vivo* evaluation of botanicals, bioagents and fungicides against sheath rot of rice during *Kharif* 2020-21 and 2021-22 (Pooled)

Tr. No.	Treatments	Dosage (%)	PDI		Pooled	PDC	1000 seed weight (g)		Pooled	Yield (q/ha)		Pooled	B:C ratio
			2020-21	2021-22			2020-21	2021-22		2020-21	2021-22		
T_1	Foliar spray (FS) with Copper oxychloride 50% WP	0.2	15.00 (22.79)*	16.56 (24.01)	15.78 (23.40)	45.49	21.20	20.65	20.93	27.08	26.38	26.73	1.73: 1
T_2	FS with Propineb 70% WP	0.2	17.67 (24.85)	19.50 (26.21)	18.59 (25.53)	35.80	20.05	19.53	19.79	26.24	25.56	25.9	1.68: 1
T_3	FS with Azoxystrobin 11% + Tebuconazole 18.3% SC	0.1	12.67 (20.85)	13.98 (21.96)	13.33 (21.40)	53.97	22.56	21.97	22.27	28.65	27.91	28.28	1.72: 1
T_4	FS with Captan 70% + Hexaconazole 5% WP	0.2	8.75 (17.21)	9.66 (18.11)	9.21 (17.66)	68.20	25.35	24.69	25.02	31.65	30.83	31.24	2.00: 1
T_5	FS with Propiconazole 25% EC	0.1	5.17 (13.14)	5.70 (13.82)	5.44 (13.48)	81.23	28.75	28.00	28.38	34.52	33.62	34.07	2.23: 1
T_6	FS with Azoxystrobin 25% SC	0.1	10.33 (18.75)	11.41 (19.94)	10.87 (19.34)	62.45	24.52	23.88	24.20	29.50	28.73	29.115	1.87: 1
T_7	FS with Neem oil	0.3	21.00 (27.27)	23.18 (28.78)	22.09 (28.05)	23.69	18.52	18.04	18.28	23.56	22.95	23.255	1.52: 1
T_8	FS with Pongamia oil	0.3	23.33 (28.88)	25.76 (30.50)	24.55 (29.69)	15.21	17.24	16.79	17.02	21.56	21.00	21.28	1.39: 1
T_9	FS with *Trichoderma harzianum*	1.0	20.00 (26.57)	22.08 (28.03)	21.04 (27.30)	32.17	19.22	18.72	18.97	25.08	24.43	24.755	1.61: 1
T_{10}	FS with *Pseudomonas fluorescens*	1.0	18.67 (25.60)	20.61 (27.00)	19.64 (26.30)	27.32	20.00	19.48	19.74	25.80	25.13	25.465	1.66: 1
T_{11}	FS with Carbendazim 50% WP (Recommended check)	0.1	6.33 (14.58)	6.99 (15.33)	6.66 (14.95)	76.99	26.65	25.96	26.31	33.52	32.65	33.085	2.15: 1
T_{12}	Untreated control		27.65 (31.72)	30.25 (33.27)	28.95 (32.27)	0.00	16.20	15.78	15.99	18.65	18.17	18.41	1.22: 1
	CD at 5%		1.82	1.72	1.82		2.94	2.84	2.89	3.42	3.33	3.37	
	SEm ±		0.62	0.59	0.60		1.00	0.97	0.98	1.17	1.13	1.15	

*Figures in parenthesis are Arc sine transformed values

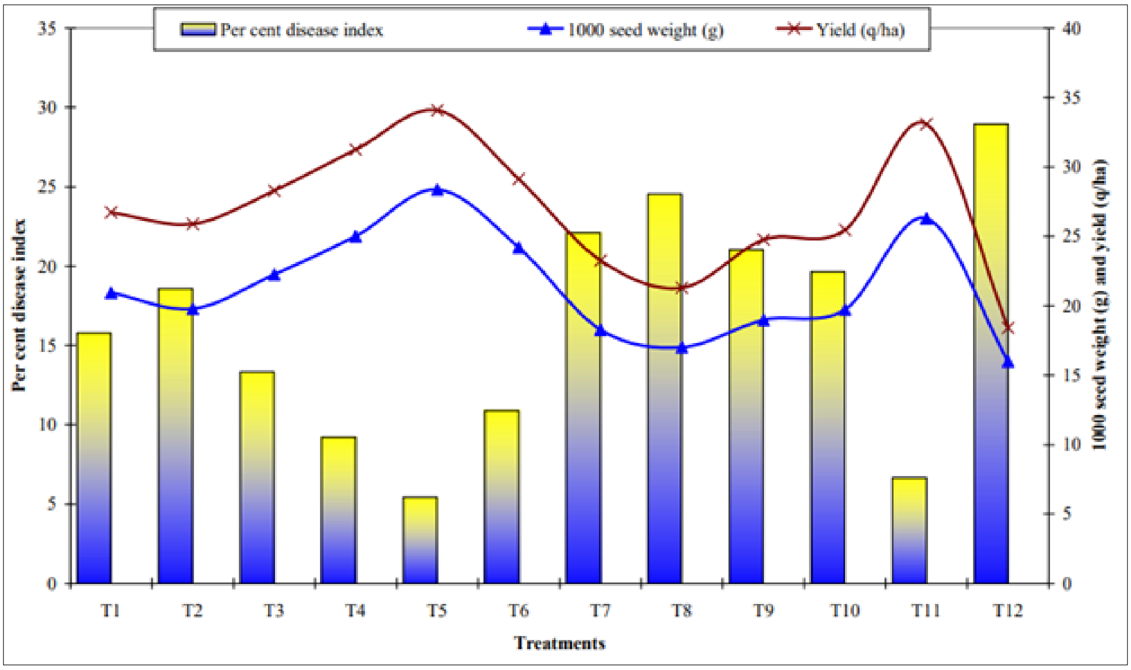
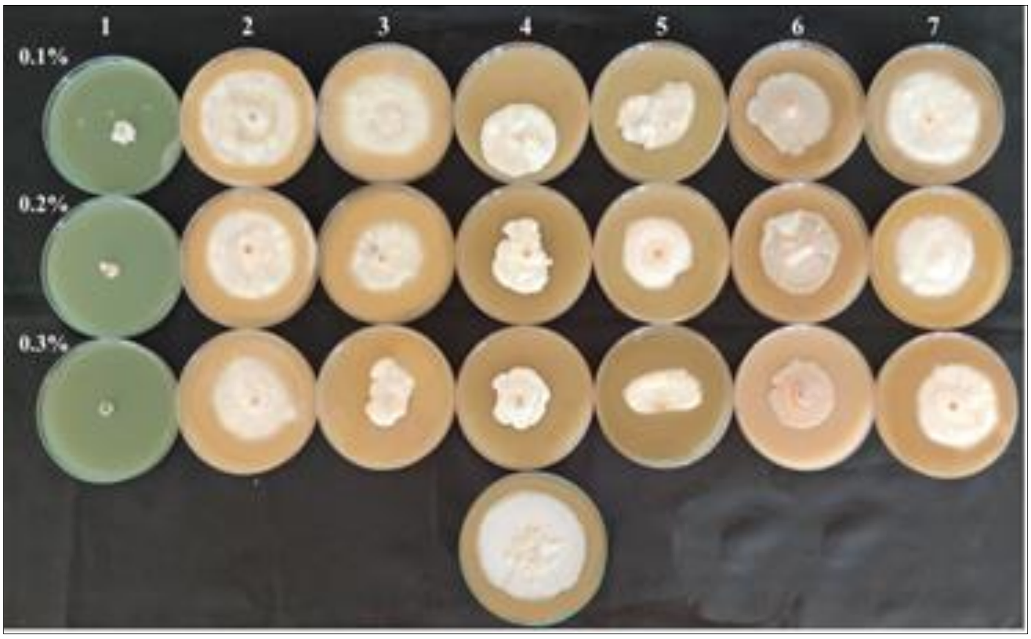
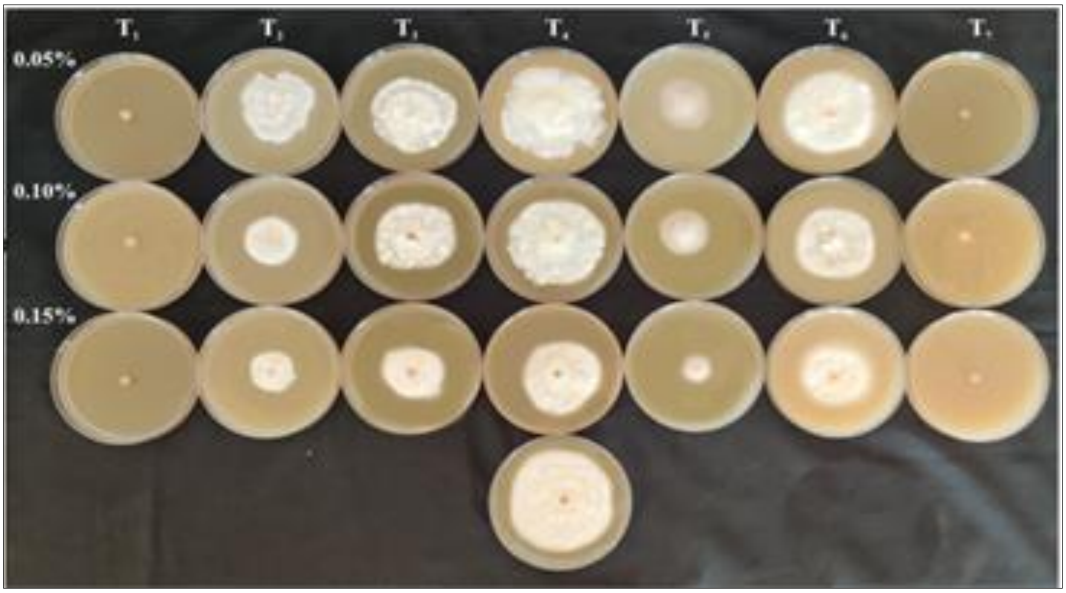


Fig 1: Field efficacy of fungicides, botanicals and bioagents on% disease index of sheath rot and yield (Pooled data) during *Kharif* 2020-21 and 2021-22

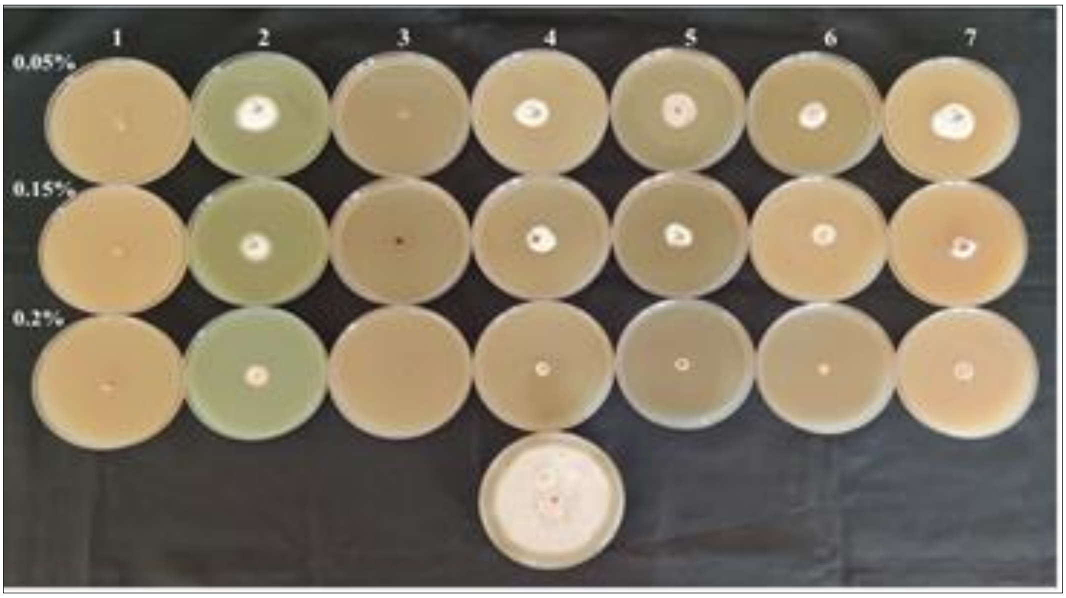
Plate 1: *In vitro* evaluation of botanicals and bioagents against *Sarocladium oryzae*



Contact/ Non systemic fungicides
1. Copper oxy chloride, 2. Chlorothalonil, 3. Zineb, 4 Propineb, 5. Captan, 6. Thiram, 7. Mancozeb



Systemic fungicides
1. Propiconazole, 2. Pyraclostrobin, 3. Tebuconazole, 4. Thiophenate methyl, 5. Azoxystrobin, 6. Hexaconazole, 7. Carbendazim



Combi product fungicides
1. Captan 70% + Hexaconazole 5% WP, 2. Carbendazim 12% + Mancozeb 63% WP, 3.Azoxystrobin 11% + 3. Tebuconazole 18.3% SC, 4. Flusilazole 12.5% + Carbendazim 25% SC, 5. Hexaconazole 5% + Validamycin 5. 2.5% SC, 6.Tebuconazole 50% + Trifloxystrobin 25% WG, 7. Azoxystrobin 20% + Difenoconazole 12.5% SC

Plate 2: *In vitro* evaluation of fungicides against *Sarocladium oryzae*

Propiconazole @ 0.1% Control

Plate 3: Management of sheath rot of rice under field condition

Conclusion

Disease management is very much essential in order to stop the further spread of the disease. Too much dependence on chemicals/ fungicides not only causes toxic residues on the produce also increases the cost of cultivation. Along with chemicals, using of naturally available plant products as well as antagonistic microorganisms reduces the toxicity effect. In present *in vitro* study, maximum inhibition of radial growth of pathogen was observed with usage of Propiconazole and Carbendazim. *In vivo* studies from two seasons *Kharif* 2020-21 and 2021-22 stated that spraying with Propiconazole @ 0.1% reduced% disease index

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