



Impact of Varying Sowing Dates, Fungicides and Bio Formulations on Development of False Smut Disease of Rice

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ABSTRACT

Background: Rice false smut caused by *Ustilaginoidea virens* has been considered as most serious grain disease throughout the world. In recent times, the disease has been observed to show an increasing trend in rice fields of Assam, India.

Methods: The present investigation was conducted at Assam agricultural University, Jorhat, India during *kharif* 2018 and 2019. The experiment was laid out in a randomized block design with an aim to study the effect of different dates of sowing, fungicides and bioformulations on management of false smut of rice under field condition.

Result: Among different date of sowing, highest incidence of false smut (21.55%) and severity (75.06%) with lower grain yield (28.98 q/ha) were recorded in late sown crop (9th July) which flowered during last week of October. The crop sown on 10th May, when the crop flowered during last week of August to first week of September showed lower disease incidence (4.98%) and severity (4.76%) with higher grain yield (35.94 q/ha). Propiconazole (0.1%) as two foliar application (at booting stage and flowering stage) effectively controlled rice false smut disease with a significant reduction of disease severity (91.93%) and increased grain yield up to 18.63 per cent over control. Among the bioformulations, Taegro Eco (*Bacillus* based) was found to be highly effective next to chemicals in controlling rice false smut with a reduction of disease severity (74.94%) and enhanced grain yield up to 11.40 per cent over control. The study suggests that early sowing with foliar application of fungicide, propiconazole is an effective management strategy for rice false smut.

Key words: Bio formulation, Date of sowing, Fungicides, Rice false smut.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most widely grown cereal in the world belonging to the family of grasses, Gramineae (Poaceae) and the primary staple crop for more than half of the world's population. India has the world's largest area under rice with 45.77 million hectares with a total production of 124.37 million metric tonnes (Anonymous, 2022). Rice is the single most important crop in Assam, occupies one-third of the total cropped area and contributes 96 per cent of the total food grain production of the state. In Assam, it is grown in an area of 24.00 lakh hectares with a production of 52.14 lakh metric tonnes (Anonymous, 2021).

Among various biotic stresses, diseases are considered as one of the major constraints in rice production causing considerable yield loss throughout the world *i.e.*, 10-15 per cent per annum (Kumar *et al.*, 2013). Rice false smut (RFS) disease caused by *Ustilaginoidea virens* (Cooke) Takahashi has become the most devastating grain disease in almost all the rice growing areas throughout the world (Ashizawa *et al.*, 2011; Ladhakshmi *et al.*, 2012; Nessa, 2017; Leharwan and Kumar, 2023) that threat to yield and grain quality. The disease affects the grains and the symptoms produced are visible only after flowering. The typical symptoms of the disease is the transformation of individual grains of the panicle into a yellowish smut ball, which changes to yellowish orange, green and finally to greenish black. Usually only few grains are affected in a panicle but the number may rise up to 100 in case of severe disease incidence (Ladhakshmi *et al.*, 2012). In India,

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the disease was recorded to cause yield loss ranging from 0.2 to 49 per cent depending on the disease intensity and varieties grown (Dodan and Singh, 1996).

It has been reported by many workers that the RFS can be avoided by early sowing or planting (Agarwal *et al.*, 1990; Wang *et al.*, 2010; Bag *et al.*, 2016). On the contrary, a group of scientists found that early transplanted rice had higher disease incidence when compared to late planting (Dodan and Singh, 1995; Hegde *et al.*, 2000; Tripathi *et al.*, 2013). Investigations are needed to ascertain if the high incidence of RFS disease can be avoided with changing flowering window of the crop through varying time of sowing or transplanting. As adopted in other crop diseases, chemical

control could be an option for managing RFS. A number of fungicides have been found effective against the RFS disease (Mohiddin *et al.*, 2012; Ladhakshmi *et al.*, 2014; Kumari and Kumar, 2015, Hosagoudar, 2018). Moreover, few biocontrol agents viz., *Bacillus subtilis*, *Trichoderma* spp. either alone or in combination with chemicals have also been found effective in managing the disease (Chen *et al.*, 2011; Liang *et al.*, 2014; Kannahi *et al.*, 2016). In the present study, an experiment was also conducted to elucidate the performance of foliar fungicides and biocontrol agents in order to ascertain their effectiveness in controlling the RFS.

MATERIALS AND METHODS

Field experiments were conducted with one susceptible variety 'Mahsuri' during *kharif* season (2018) and (2019) at Assam Rice Research Institute (ARRI), Assam Agricultural University (AAU), Titabar (26°34'36''N latitude and 94°10'48''E longitude and an elevation of 99 m above mean sea level), Assam, India in wet land field conditions.

Effect of date of sowing on development of rice false smut

Seeds were sown at an interval of 15 days starting from 10th May, 25th May, 9th June, 24th June and 9th July during both the years of experimentation. Five nursery beds were prepared separately for five different dates of sowing at the experimental farm of ARRI, Titabar, following the standard recommended agronomic practices (Anonymous, 2015). Seeds were soaked for 24 h and incubated for 48 h at room temperature for sprouting. The sprouted seeds were shown in the seedbed uniformly and adequate water was applied to the growing seedlings in the seedbed when required. The experiment was laid out into randomized block design (RBD) with four replications. The individual plot size was 2 m × 2 m. Thirty days old seedlings were transplanted @ two seedlings/hill on their respective dates at a spacing of 20 cm × 15 cm.

Effect of different fungicides and bio formulations on development of rice false smut

Three fungicides viz., Copper oxychloride, Copper hydroxide and Propiconazole along with five commercial bioformulations viz., Biotime (AAU, India) containing *P. fluorescens*, *T. harzianum* and *M. anisopliae*, TNAU-Pf-1 (TNAU, India) containing *P. fluorescens*, G-Derma (Haryana, India) containing *T. flavofusum*, G- Pseudo (Haryana, India) containing *P. biviari* and Taegro Eco (USA) containing *B. subtilis* (Table 1) were evaluated for their efficacy against *U. virens* under field condition. The foliar application of the fungicides and bio formulations were done at two different stages of the crop. The first application was given two days after artificial inoculation of the pathogen at booting stage and another was given at flowering stage. The experiment was laid out into RBD with three replications.

Artificial inoculation

For artificial inoculation, conidial suspension was prepared as described by Ladhakshmi *et al.*, (2012). Pure culture

of the *U. virens* was inoculated into 100 ml Potato Sucrose Broth and incubated in an incubator shaker with 125 rpm at 28°C for 2 weeks. The conidia were then harvested and suspended in sterile distilled water. Four hills of each line were inoculated at the booting stage by spraying conidial suspension (2×10⁵ conidia/ml) on the leaf surface using an atomizer until suspension dropped down as described by Haiyong *et al.*, (2015). The inoculated plants were covered with a polythene bag for 3-4 days to maintain the temperature and humidity and tagged for observation.

Assessment

The per cent disease incidence and disease severity were worked out following the formula given by Singh and Dube (1978).

Disease incidence (%) =

$$\frac{\text{Total number of infected tillers/hill}}{\text{Total number of tillers/hill}} \times 100$$

Infected grains (%) =

$$\frac{\text{Total number of infected grains/panicle}}{\text{Total number of grains/panicle}} \times 100$$

Disease severity (%) =

$$\text{Disease incidence (\%)} \times \text{infected grains (\%)} \times 100$$

Further, chaffy grains percentage per panicle, 1000 grain weight and grain yield from all the treatments were recorded at the time harvest of the crop.

Statistical analysis

The experimental data were analysed by Fisher's method of analysis of variance (ANOVA) and interpretation of data was carried out in accordance with Gomez and Gomez, (1984). Duncan's multiple range test (DMRT) at $p \leq 0.05$ was used to separate treatment means. To test the significance of different sources 'F' test was done and calculated 'F' values were compared with the appropriate value of 'F' at 5 per cent level of probability.

RESULTS AND DISCUSSION

Effect of dates of sowing on rice false smut

The disease incidence, disease severity, chaffy grains, 1000 grain weight and grain yield were significantly differed

Table 1: Details of fungicides and bio formulations evaluated under field condition.

Name	Dose per lit. water
Copper oxychloride (Blue Copper 50)	4.0 g
Copper hydroxide (Kocide 2000)	2.5 g
Proconazole 25% EC (Tilt)	1.0 ml
Biotime (1×10 ⁷ cfu/g)	2.0 g
TNAU-Pf (1×10 ⁹ cfu/g)	2.0 g
G- Derma (1×10 ⁹ cfu/ml)	2.0 ml
G-Pseudo (1×10 ⁹ cfu/ml)	2.0 ml
Taegro Eco (1×10 ¹⁰ cfu/g)	2.0 g

Table 2: Effect of date of sowing on RFS, chaffiness, 1000 grain weight and yield of rice (Pooled for 2018 and 2019)

Date of sowing	Disease incidence (%)	Disease severity (%)	Chaffy grains (%)	1000 grain weight (g)	Yield (q/ha)
D ₁ (10 th May)	4.98 (12.90) ^d	4.76 (12.61) ^d	9.38 (17.84) ^e	15.74 ^a	35.94 ^a
D ₂ (25 th May)	6.08 (14.28) ^d	6.35 (14.60) ^d	12.50 (20.71) ^d	15.13 ^b	34.98 ^a
D ₃ (09 th June)	9.83 (18.28) ^c	22.14 (28.08) ^c	17.75 (24.93) ^c	14.71 ^b ^c	33.24 ^b
D ₄ (24 th June)	13.91 (21.91) ^b	43.62 (41.35) ^b	21.63 (27.72) ^b	14.13 ^c	31.65 ^c
D ₅ (9 th July)	21.55 (27.67) ^a	75.06 (60.07) ^a	25.63 (30.43) ^a	13.20 ^d	28.98 ^d
SEd (±)	1.378	3.489	0.958	0.278	0.728
CD (0.05)	2.844	7.201	1.977	0.575	1.503

Figures in the parentheses arc sine transformed value.

Means in the same column followed by different letter are significantly different at P=0.05 by DMRT technique.

Table 3: Effect of fungicides and bio formulations on RFS, chaffiness, 1000 grain weight and yield of rice (Pooled for 2018 and 2019)

Date of sowing	Disease incidence (%)	Disease severity (%)	Chaffy grains (%)	1000 grain weight (g)	Yield (q/ha)
T ₁ : Copper oxychloride	7.61 (16.02) ^e	7.66 (16.07) ^d	10.33 (18.76) ^{de}	15.07 ^{bc}	34.82 ^{ab}
T ₂ : Copper hydroxide	6.11 (14.32) ^{ef}	5.69 (13.80) ^d	9.50 (17.96) ^{de}	15.37 ^{ab}	35.46 ^a
T ₃ : Propiconazole	5.64 (13.74) ^f	5.22 (13.21) ^d	9.17 (17.63) ^e	15.67 ^a	35.79 ^a
T ₄ : Biotime	15.89 (23.50) ^{bc}	22.79 (28.53) ^c	14.17 (22.12) ^c	14.52 ^d	32.40 ^{bc}
T ₅ : TNAU-Pf1	15.24 (22.99) ^c	22.64 (28.42) ^c	14.00 (21.98) ^c	14.52 ^d	32.54 ^{bc}
T ₆ : G-Derma	17.32 (24.61) ^{abc}	41.75 (40.27) ^b	20.33 (26.81) ^b	14.05 ^e	31.33 ^c
T ₇ : G- Pseudo	17.94 (25.07) ^{ab}	42.39 (40.64) ^b	20.83 (27.17) ^b	14.02 ^e	31.22 ^c
T ₈ : Taegro Eco	11.96 (20.24) ^d	16.21 (23.75) ^c	11.75 (20.06) ^{cd}	14.82 ^{cd}	33.61 ^b
T ₉ : Control	19.60 (26.29) ^a	64.69 (53.57) ^a	24.92 (29.96) ^a	13.62 ^f	30.17 ^d
SEd (±)	0.927	2.649	1.104	0.185	0.661
CD (0.05)	1.889	5.397	2.248	0.378	1.346

Figures in the parentheses arc sine transformed value.

Means in the same column followed by different letter are significantly different at P=0.05 by DMRT technique.

in different dates of sowing (Table 2). The maximum disease incidence (21.55%) and severity (75.06%) were recorded when sowing was done at 9th July followed by 13.91 and 43.62 per cent, respectively at seeds sown on 24th June. The minimum disease incidence and severity (4.98 and 4.76, respectively) were recorded when the date of sowing was adjusted to 10th May and was statistically at par with seeds sown at 25th May with a values of 6.08 and 6.35 per cent, respectively. The highest chaffy grains (25.63%), and minimum 1000 grain weight (13.20 g) and grain yield (28.98 q/ha) were recorded at 9th July sown crop. 10th May sown crop recorded lowest chaffy grains (9.38%) with maximum 1000 grain weight and grain yield (15.74 g and (35.94 q/ha, respectively).

Effect of fungicides and bio formulations on rice false smut

All the treatments significantly reduced the per cent disease incidence and severity of RFS as compared to control (Table 3). Amongst all the treatments, two foliar applications of propiconazole was highly effective in managing RFS with least disease incidence (5.64%) and severity (5.22%). This was followed by the treatment with copper hydroxide (6.11% and 5.69%, respectively) and copper oxychloride (7.61% and 7.66%, respectively). The maximum percentage of disease incidence (19.60%) and severity (64.69%) were observed in control. Maximum reduction in disease incidence (71.22%) and severity (91.93%) over control were

recorded in the treatment with propiconazole followed by treatment with copper hydroxide (68.83% and 91.20%) and copper oxychloride (61.17% and 88.16%, respectively) (Fig 1). Among the bioformulations tested, Taegro Eco was found to be highly effective resulting 38.98 and 74.94 per cent reduction in disease incidence and severity, respectively.

The study showed that application of propiconazole resulted in minimum chaffy grains (9.17%) followed by treatment with copper hydroxide (9.50%) and copper oxychloride (10.33%). Treatment with propiconazole also recorded maximum 1000 grain weight (15.67 g) and grain yield (35.79 q/ha) followed by treatment with copper hydroxide (15.37 g and 35.46 q/ha, respectively) and copper oxychloride (15.07 g and 34.82 q/ha, respectively). The application of propiconazole resulted maximum decrease in chaffy grains (63.20%) and maximum increase in 1000 grain weight (15.05%) and grain yield (18.63%) over control. This was followed by copper hydroxide and copper oxychloride Taegro Eco was also found to be effective with decreased chaffy grains (52.85%), and increased 1000 grain weight (8.81%) and grain yield (11.40%) among the different bio formulations tested (Fig 2 and 3).

Correlation of false smut incidence and severity with weather parameters

The correlation matrix (Table 4) showed that except for morning relative humidity (RH-I) and BSSH (bright

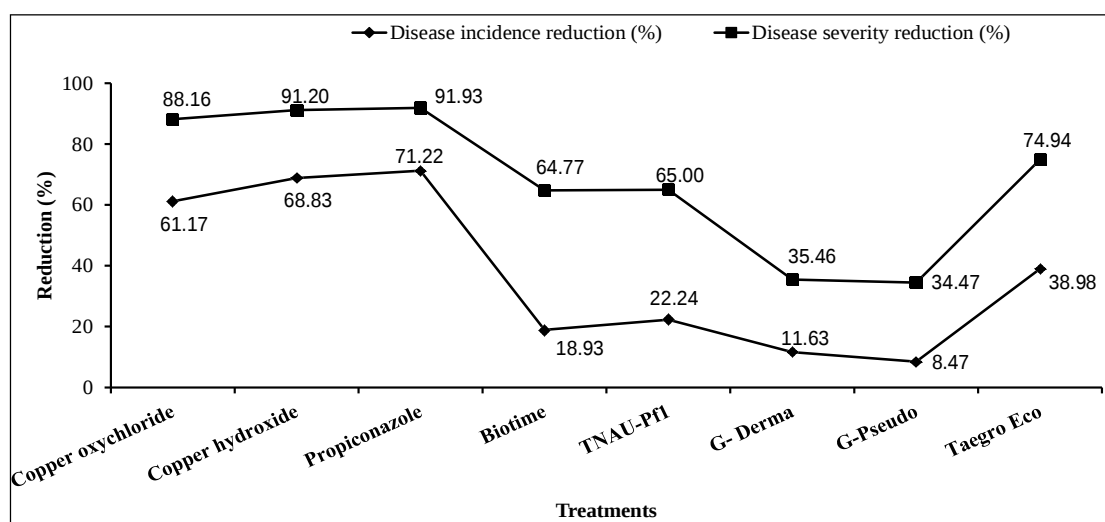


Fig 1: Effect of different fungicides and bio formulations on per cent reduction in disease incidence and severity of rice false smut over control.

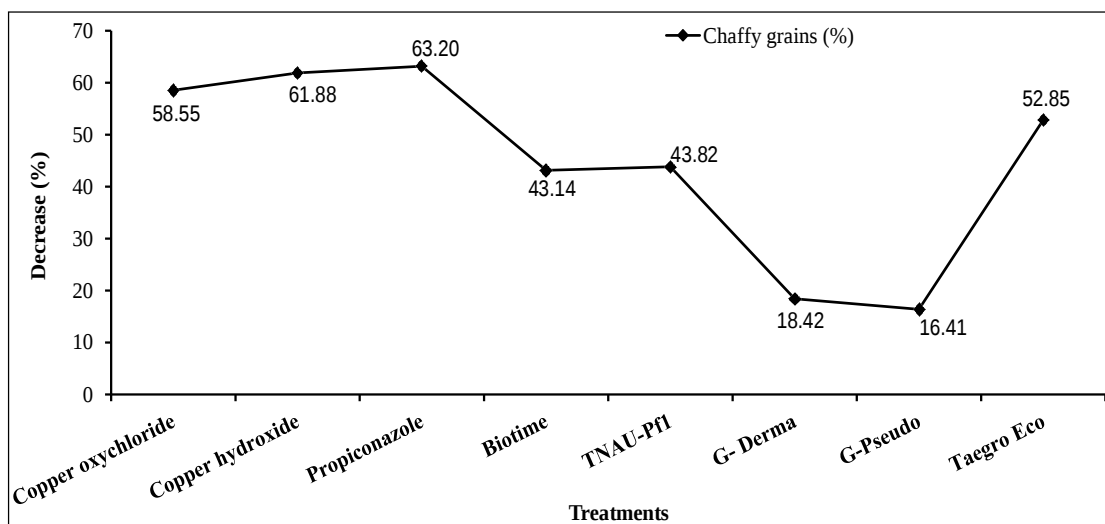


Fig 2: Effect of different fungicides and bio formulations on per cent decrease in chaffy grains of rice over control.

sunshine hours), the other meteorological parameters were negatively correlated with false smut incidence. The correlation coefficient of minimum temperature (Tmin), afternoon relative humidity (RH-II) and rainy days (RD) were statistically significant, indicating strong association with the disease development. A similar trend was observed to false smut severity, except rainy days, which was negatively correlated but not significant.

Results of the present study showed that the early sown rice (between 10 and 25 May) showed low disease incidence and severity while rice sown between 24 June and 9 July, were found highly infected with high disease severity. The variation in disease development in different sowing dates may be due to the prevailing weather parameters during the cropping period that played a strong role in the development of RFS (Jia *et al.*, 2015; Chaudhari

et al., 2019). The present results are in conformity with the findings of Singh *et al.*, (2019) who reported that the false smut disease incidence and severity increased steadily with delay in sowing. Sing and Kang, (1987) also observed that the early transplanted rice, found less incidence *i.e.* 47% and 48.2% when transplanted on 5th and 25th July, respectively. Atia, (2004) also reported that rice plants transplanted at the beginning of June exhibited the lowest disease incidence and number of smutted grains during 2001 and 2002 while the disease was increased at the late transplantation. Wamishie *et al.* (2013) suggested early sowing *i.e.*, before 10th May to escape from the greater incidence of late May and June.

In the present study, the results indicated that RFS disease could be effectively managed with significant increase in yield and 1000 grain weight by application of

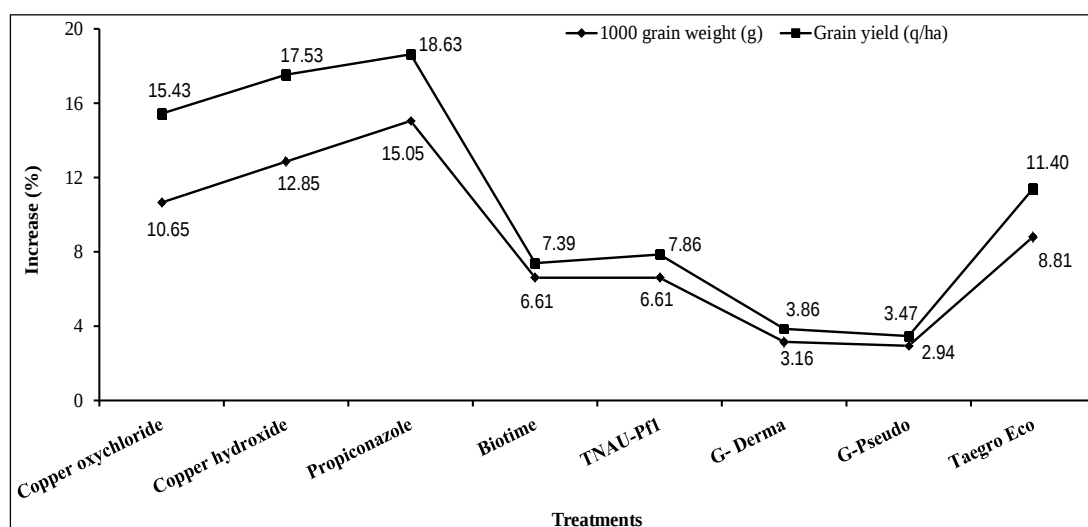


Fig 3: Effect of different fungicides and bio formulations on per cent increase in 1000 grain weight and yield of rice over control.

Table 4: Correlation matrix of disease incidence with weather parameters (Pooled for 2018 and 2019).

Variables	Disease incidence	Disease severity	Tmax	Tmin	RH-I	RH-II	RF	RD	BSSH
Tmax	-0.896	-0.875	1						
Tmin	-0.983	-0.976	0.942	1					
RH-I	0.238	0.197	-0.616	-0.316	1				
RH-II	-0.950	-0.958	0.768	0.939	0.031	1			
RF	-0.851	-0.831	0.953	0.858	-0.696	0.653	1		
RD	-0.957	-0.945	0.962	0.952	-0.501	0.822	0.967	1	
BSSH	0.251	0.291	0.167	-0.174	-0.879	-0.503	0.284	0.035	1

Values in bold are different from 0 with a significance level $\alpha=0.05$.

propiconazole (as two foliar applications) followed by copper hydroxide and copper oxychloride. The present results are in conformity with the findings of several researchers (Chen *et al.*, 2013; Wamishe *et al.*, 2013; Ladhalakshmi *et al.*, 2018) who claimed that propiconazole was the best fungicides for the management of RFS with enhanced grain yield. Similar results were also reported by Muniraju *et al.* (2017) who noted that two foliar sprays of propiconazole 25EC (0.1%) at booting stage and post flowering stage reduced false smut severity upto 91.38% with increase in yield of 38.20% over control. Kumari and Kumar, (2015) reported that the spraying of propiconazole at 0.1% during booting stage recorded maximum decrease in false smut infected tillers (83.79% and 86.57%) and increase in yield (16.29% and 16.91%), respectively as compared to control. In case of rice, increased grain yield after application of fungicides due to reduction in biotic stress on plant during critical growth stages has been reported (Bhuvaneswari and Raju, 2012; Pramesh *et al.*, 2016).

Among the bio formulations, Taegro Eco (*B. subtilis* based) was found to be best in controlling RFS disease next to chemicals. Bacterial antagonist (*B. subtilis*) contribute to reduction of RFS incidence and severity may be attributed either due to the secretion of chitinases and chitin-binding

protein, production of antimicrobial compounds including polypeptides that leads to lysis or disintegration of mycelium and suppress the mycelial growth. *Bacillus* spp. colonizes rice plants and competes with plant pathogens for colonization sites and nutrients, and also stimulates induced systemic resistance (ISR) to promote plant resistance to disease and abiotic stress (Sha *et al.*, 2020). Wenqun (a suspension of *B. subtilis* Bs-916 in solution of 2.5% validamycin) has been widely used in China for the control of RFS disease (Liu *et al.*, 2007). The collective production of biologically active compounds by the biological control agent (BCA) may be the contributing factor for the higher level effect of Taegro Eco. Jayaraj *et al.*, (2004) stated that rice plants treated with *B. subtilis* led to an increase in the activities of phenylalanine ammonia-lyase (PAL) and peroxidase (PO) and an accumulation of pathogenesis-related (PR) proteins in rice leaves, and also induced an accumulation of a thaumatin-like protein (17 kDa) and two β -1-3-glucanases (30 kDa and 33 kDa). The coordinate upregulation of different defence mechanisms in induced plants suggests that these defense responses may be involved in the restriction of *R. solani*. Manonmani *et al.*, (2008) reported that gypsum based formulations of *B. subtilis* was the most efficient in suppressing the sheath rot disease of rice.

CONCLUSION

From the present investigation it can also be concluded that high incidence of false smut disease can be avoided by early sowing or the disease can be managed through two foliar sprays with propiconazole based on the planting date particularly in case of late planting. Moreover *Bacillus* based bio formulations can be used in managing the false smut in organic rice cultivation.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content

Conflict of interest

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