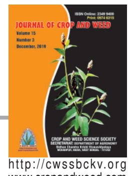
Journal of Crop and Weed, 18(1): 151-159 (2022)

ISSN- O : 2349 9400 ; P : 0974 6315



http://cwssbckv.org
www.cropandweed.com

Improving yield of rice (*Oryza sativa* L.) by managing blast disease through On Farm Trial (OFT) in old alluvial zone of West Bengal

***P. BHOWMIK AND [1]P. BISWAS**

Malda Krishi Vigyan Kendra, Block Seed Farm, Uttar Banga Krishi Viswavidyalaya, Ratua, Malda, West Bengal- 732 205, India

[1]Regional Research Sub Station (OAZ), Uttar Banga Krishi Viswavidyalaya, Mathurapur, Malda, West Bengal-732 203, India

Received : 19.11.2021 ; Revised : 12.02.2022 ; Accepted : 22.02.2022

DOI: https://doi.org/10.22271/09746315.2022.v18.i1.1546

ABSTRACT

An On Farm Trial was conducted to analyze rice production, yield characteristics, growth features, association between rice blast disease incidence and meteorological parameters and economics during kharif season of 2016 and 2017 with rice variety MTU-1010 in old alluvial zone of West Bengal. With four treatments and seven replications, a randomized block design was used to set up the experiment.Treatments included were T_1 (seed treatment with carbendazim 50WP), T_2 (seedling root dipping in hexaconazole 5EC), T_3 (T_1+T_2) and farmers' practice (FP) or control. Plant height at different growth stages, effective tillers hill^{-1}, spikelet panicle^{-1} and test weight were maximum during both years in T_3. It also exhibited slower progression of disease incidence with average incidence of 4.4% (2016) and 4.0% (2017) and disease control over farmers' practice of 84.9% (2016) and 86.7% (2017) with lowest AUDPC of 199.3% (2016) and 180% (2017). Blast showed insignificant positive (average relative humidity) and negative (maximum and minimum temperature and rainfall) correlation in all treatments during both years; only treatment T_1 and T_3 (2017) exhibited an insignificant positive correlation with rainfall. The highest yield (6513 and 6653 kg ha^{-1}) and increased yield over control (42.9% and 45.1%) were in treatment T_3 during respective years. For subsequent years, benefit-cost ratios were found to be 46.83% and 48.36% higher in contrast to farmers' practice. The overall assessment confirms the significant superior performances of T_3 in all respect.

Keywords**:** Carbendazim, hexaconazole, rice blast, seedling root dip treatment and seed treatment

Rice (*Oryza sativa* L.), known as the "Global Grain," is an essential staple of the Asian diet. Around 90 percent of it farmed in Asia (USDA, 2021). India is the second most rice producer after China and contributes about 20 percent of global rice production (FAOSTAT, 2020). In 2017-18 total area under rice cultivation and total rice productivity of India were 43.77 million hectares and 112.8 million tonnes, respectively; whereas in West Bengal, they were 5.12 million hectares and 14.97 million tonnes, respectively (Anonymous, 2019). The vigour, viability, and yield of the crop reduces due to the seeds' absorption of substantial amount of moisture from the humid environment during monsoon months, which corresponds with high temperatures, hastening the seeds aging process (Teckrony and Egli, 1991). One of the most economically devastating abiotic causes, *Pyricularia oryzae*-caused rice blast disease, has been identified as one of the most significant global constraints on rice farming (Wang *et al.,* 2015). It damages the leaf and panicle of rice, causing 70-80% yield loss (Nasruddin and Amin, 2013), indicating harm to both vegetative and reproductive phases. The fungus can occur at any growth stage, and symptoms can be detected in any aerial section, notably on nodes and leaves (Seebold *et al.,* 2004). Conidia emerge on the leaves of early seedlings, and spores form later in the growth season, causing collar and neck blasts (Wang *et al.,* 2014), which reduce rice grain production by about 30% (Spence *et al.,* 2014). Grains those are partly or completely unfilled are the product of an infected panicle (IRRI, 2014). The rice blast pathogen is difficult to control since it is seed borne (Hubert *et al*., 2015). Seedlings those are infected with blast disease are the product of contaminated seeds which die and become the primary inoculum for the illness (Faivre-Rampant *et al*., 2013). Chemical seed treatment is the most effective, ecologically friendly and cost-effective method of maintaining healthy seeds, as it uses a much lower dose (1-1.5 g kg^{-1}) of chemicals than foliar spray. Moderate blast infections might result in a 50% reduction in grain output. Rice blast can exhibit its incidence from early development stages to seed production stage on all shoot parts. The most susceptible period for leaves to rice blast occurs between 20 and 55 days after emergence of seedlings during the vegetative stage, while panicles are most susceptible between 10 and 20 days after the start of panicles during the grain filling stage. From 55 to 60 days following emergence, plant resistance to the blast fungus rises, reducing rice blast incidence on the leaves. The losses caused by the

Email: paramita.bhowmik2@gmail.com

blast can be direct or indirect, whereas, in the leaves, it has an indirect effect causing photosynthesis and respiration. Depending on the area, variety affected, and intensity of illness, blast produces 30-80% loss in paddy production (Balgude and Gaikwad, 2019).The extent of damage is determined by determining the disease's occurrence and severity, dependent on elements such as the pathogen's physiological race, cultural practices, rice types used, and the surrounding environment (Obilo *et al*., 2012).There are several factors like high humid condition, moderate temperature, high nitrogen application, and prolonged wetness contribute to disease development (TeBeest *et al.,* 2012). High rainfall and cooler climate are congenial for rice blast development (Ghatak *et al*., 2013).Therefore, the farmers need to be aware of proper use and timing and method of applying appropriate fungicides against this menace through the knowledge of correlation between disease progression and prevailing weather parameters affecting the disease incidence. To enhance productivity and improved rice grain quality by controlling the rice blast this OFT has been implemented by Malda Krishi Vigyan Kendra.

MATERIALS AND METHODS

The study was conducted during two successive *kharif* seasons of 2016 and 2017 at Gopalpur village (25°13'N Latitude and 87°56'E Longitude) of Ratua-I block, Malda, West Bengal utilizing rice variety MTU-1010. Soil texture was clay loam, with a pH of 6.9, a conductivity of 0.3 percent, and an organic carbon content of 0.4 per cent. The experimental plot's available nitrogen, phosphorus, potash, zinc, and boron were 365.85, 85.43, 196.46 kg ha^{-1} and 0.34 and 0.67 mg ha^{-1}, respectively. The weekly average of maximum temperatures, minimum temperatures, average relative humidity, and rainfalls during the experimental period for both years are reflected in Fig. 1. The experiment was set up in RBD with four treatments and seven replications.

There were four treatment combinations *viz.* T_1 (seed treatment one day before sowing with carbendazim 50 WP @ 3 gm kg^{-1} of seed), T_2 (dipping of seedling roots in hexaconazole 5 EC @ 1 ml L^{-1} solution before transplanting for 3 hours), T_3 (T_1 + T_2) and farmers' practice (FP)/control (no seed treatment and seedling root dip treatment, only 2 sprayings of Carbendazim+ Mancozeb @ 1 kg h^{-1} after 25% of disease incidence). Table 1 depicts general demonstration package as well as farmers' practices of *kharif* rice.

Plant heights were measured at 20, 30, 40 and 50 DAS. The percentage of blast-affected plants with above-ground symptoms was used to calculate the leaf blast incidence. At 30, 45, 60, and 75 days following sowing, a plant with any indication of the blast was randomly selected from five 1 m^2 areas of each replication and tallied and recorded as infected. All data regarding yield components and yield were recorded at 115 DAS. The percent yield improvement over control was calculated using the formula below:

$$\text{Per cent yield increase over control} = \frac{\text{Demonstration yield - Control yield}}{\text{Control yield}} \times 100$$

The following formula was used to compute the disease incidence:

$$\text{Disease incidence (\%)} = \frac{\text{No. of plants infected}}{\text{Total no. of plant/ sq.m area}} \times 100$$

The severity of blast disease was determined by visual inspection and grading of infected leaf area by blast disease lesions. A standard evaluation system (0-9) scale was used, as shown in Table 2 (IRRI, 1996), to rate these. Samples of infected plant leaf sections were taken randomly from the experimental site after the trial, using the technology, and infected leaf sections were obtained to determine the responsible organism.

For all treatments, including farmer's practice or control, the Area Under the Disease Progression Curve (AUDPC) was determined as follows (Shaner and Finney, 1976):

$$\text{AUDPC} = \sum_{i=1}^{n-1}\left(\frac{Y_1+Y_{1+1}}{2}\right)\left(t_{i+1}-t_i\right)$$

Where, y_i = disease index expressed as a proportion at the ith observation; t_i = the time (days after planting) at ith observation; n = total number of cases of blast disease that were documented

To determine the extension gap (EG), technology gap (TG), and technology index (TI), the following equations were used (Samui *et al*., 2000):

EG = Yield of demonstrated technology - farmers' yield (control)

TG = Potential yield- demonstration yield

$$\text{TI (\%)} = \frac{\text{Technology gap}}{\text{Potential yield}} \times 100$$

The analysis of variance (ANOVA) technique was used to conduct statistical analysis (Gomez and Gomez, 1984) by using SPSS Statistics 19.0 software. Critical difference (CD) was measured at 5% significance level ($P \leq 0.05$). In addition, meteorological data were collected to determine the relationship between blast disease occurrence and physical factors of the environment in all four treatments from 30 to 75 DAS. Disease incidence with weather parameters was also compared by using a correlation coefficient.

RESULTS AND DISCUSSION

Effect on plant height

Table 3 showed the interaction effect between different treatments and plant heights of rice during 2016 and 2017. Results indicated that treatment T_3 had the highest mean plant height of both years at 20, 30, 40 and 50 DAS, followed by treatments T_2, T_1 and control plots. At 20 DAS, *i.e.* during the sprouting stage, the average plant height in T_3 treated plots were 29.0% and 25.9% higher than control plots during 2016 and 2017, respectively. At 30 DAS, *i.e.* during the tillering stage, plant height in T_3 treated plots were recorded 17.8% and 15.5% higher than farmers' practice plots during respective years. During the elongation stage, *i.e.* at 40 DAS, T_3 treated plots showed 13.2% and 12.1% higher than control plots during both the years, respectively. At 50 DAS, *i.e.* during the booting stage, the plant heights in T_3 treated plots were 11.5% and 12.2% higher than control plots during successive years, respectively.

Effect on yield and yield attributes

It was witnessed during respective years that various yield components of rice with the application of T_3 were found significantly higher (Table 4). The average number of effective tillers hill^{-1} for T_3 during 2016 and 2017 were 22.0% and 22.3% more than control, respectively. In the case of average no. of spikelet panicle^{-1}, the same trend was found in T_3 where 17.8% and 16.9% higher spikelet panicle^{-1} were recorded during successive years. While in the case of test weight, 5.7% and 4.9% higher values for T_3 were recorded over control during 2016 and 2017, respectively. T_3 had the best yield metrics in both years, but the test weight of rice across the three treatment plots was at par. The grain and straw yield increase over control were 42.9% and 45.1% and 27.2% & 28.1% in T_3 treated plots during 2016 and 2017, respectively.

Effect on blast disease incidence

The number of diseased leaves was counted to determine the incidence of leaf blast. The shape and colour of blast disease spots depend on environmental conditions and varietal resistance. In both years, T_3 treated plots exhibited slower blast disease progression compared to other plots. Average blast disease incidence in T_1, T_2, T_3 and farmers' plots were 11.1%, 7.5%, 4.4% and 29.3%, respectively during 2016 and 10.0%, 6.9%, 4.0% and 29.4%, respectively in 2017. Average blast disease control over farmers' plots in T_1, T_2 and T_3 treated plots were 64.25%, 75.65% and 85.8%, respectively, for the study period (Table 5). The crops in T_3 treated plots exhibited lower AUDPC value (252% and 198.75%) than T_1 (470.25% and 396%), T_2 (366.75% and 270%) and FP or control (1288.5% and 1294.5%) plots during 2016 and 2017, respectively. Higher AUDPC value showed severe blast disease symptom on foliage of rice plant and lower value showed higher resistance against blast disease. The result on leaf blast incidence at 30, 45, 60 and 75 DAS indicated a significant difference among the treatments. The disease occured at the plots treated with T_1, T_2, T_3 and control at ratings of 6, 5, 5 and 7, respectively. It was also observed that the disease incidence in T_3 treated plots differed significantly from T_1 and T_2 treated plots. Blast disease incidence was not higher than 5.5 on the standard evaluation scale (IRRI, 1996), indicating a high resistance level. Therefore, the plots treated with T_2 and T_3 showed moderately resistance, whereas the plants of T_1 and control plots were susceptible to blast disease.

Correlation co-efficient between blast disease incidence and weather parameters

The occurrence of blast disease has been documented at 30, 45, 60 and 75 DAS and was analyzed in the context of variation of weather parameters. The analytical data on correlation coefficient (at 5% level) between incidence of blast disease with weather parameters (Table 6) indicated that incidence of blast disease exhibited an insignificant positive correlation with average relative humidity during 2016 (r= 0.366, r = 0.377, r= 529 and r= 0.414) and during 2017 (r= 0.781, r= 0.699, r= 719 and r= 0.644) in T_1, T_2, T_3 and farmers' practice plots, respectively; whereas maximum temperature, minimum temperature and rainfall exhibited insignificant negative correlation during 30 DAS to 75 DAS. During 2017, there was also an insignificant positive correlation between rainfall (r = 0.024 in T_1 and r = 0.135 in T_3) and blast disease incidence from 30 DAS to 75 DAS during 2017.

Effect on economics

For both years, T_3 treated plots had the highest gross and net monetary returns (Table 8). The gross and net economic returns for T_3 treated plots were 38.3% and 208.7% higher, respectively, compared to farmers' practice during 2016, and they were 40.1% and 240.6% higher, respectively, in 2017. Benefit-cost ratios were also highest in T_3 treated plots during 2016 (1.85) and 2017 (1.81). In comparison with farmers' practice, 46.82% and 47.43% higher benefit-cost ratios were

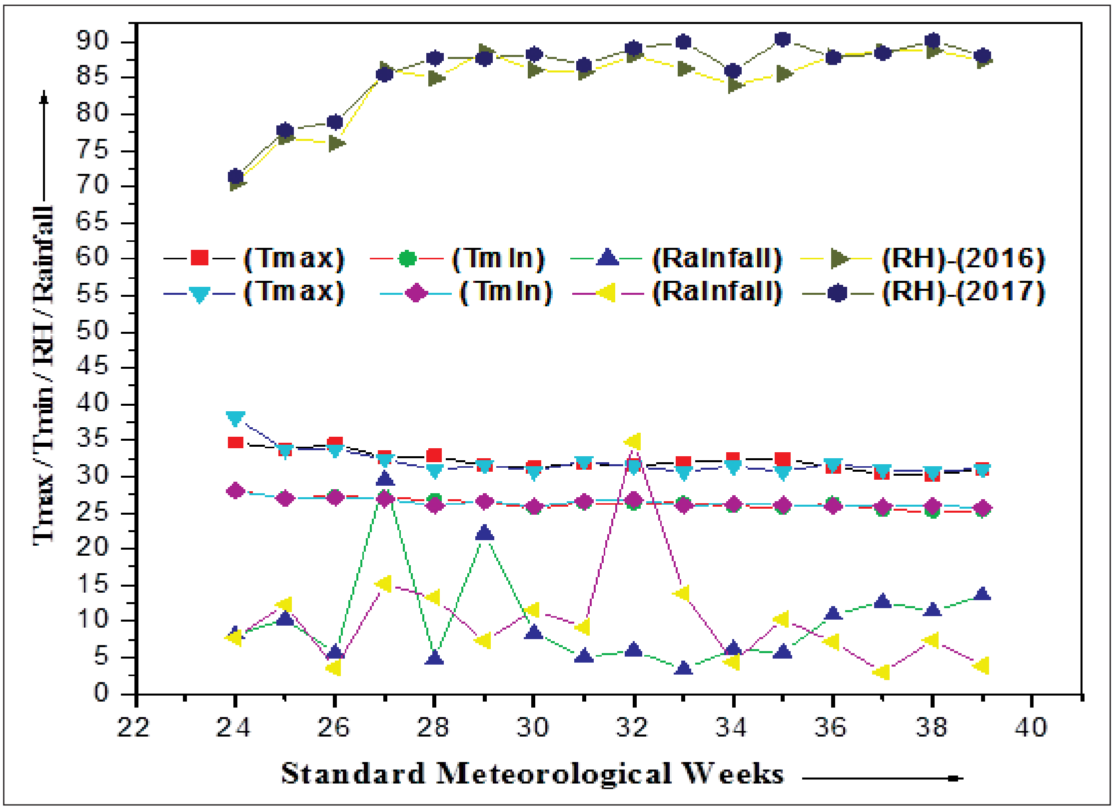


Fig.1: Distribution of weekly average maximum and minimum temperatures (°C), relative humidities (%) and rainfalls (mm) during 16th June – 30thSeptember in 2016 and 2017in the experimental area.

observed for successive years, which confirm the viability of T_3 to enhance the gross income of the farmers.

Extension gap, technology gap and technology index

During the two-year OFT programme, the average extension gap was 1215.0 kg ha^{-1} in T_1 treated plots, 1634.0 kg ha^{-1} in T_2 treated plots, and 2010.5 kg ha^{-1} in T_3 treated plots (Table 9), reversing the trend of huge extension gaps by teaching farmers via various extension techniques such as training and FLD for the adoption of upgraded and innovative technologies for production and protection (Bhowmik *et al*., 2019).

Technology gaps were reflected in Table 9, which confirms superior results in T_3 treated plots. The average two-year OFT technological gap was 1612.5 kg ha^{-1} in T_1treated plots, 1193.5 kg ha^{-1} in T_2treated plots and 817.0 kg ha^{-1} in T_3treated plots. The observed technological gap can be associated with the variations in soil fertility and agricultural production techniques, as well as current weather circumstances of the locality. The feasibility of demonstrated technology can be increased by lowering the index value (Bhowmik *et al*., 2019). The technology index reduced from 2016 to 2017, which exhibited the feasibility of technology demonstrated (Table 9). During the OFT programme, an average technology index of 21.8% was observed in T_1treated plots, 16.1% in T_2treated plots and 11.0% in T_3 treated plots, demonstrating the efficacy of good technical intervention performance. This would hasten the deployment of a proven technological intervention that will improve rice production performance by lowering the incidence of blast disease.

Chemical fungicides are used most frequently to control rice blast disease. The proper dose, time and method of fungicide application depend on the advisory information derived from an appropriate and timely forecasting model of environmental conditions that are congenial for developing rice blast disease incidence. The overuse of fungicides stimulates the development of resistance to blast disease, which leads to resurgence of the disease. Unplanned and repeated use of fungicides also shows phytotoxicity. Rice blast control has relied on seed treatments with systemic fungicides and foliar sprays since the outset (Mohiddin *et al*., 2021). The efficacy of fungicide is higher during seed and seedling treatment when the treatment period is extended (Bagga and Sharma, 2006). Seed dressing is the first line of defense against the disease since it is disseminated through seeds. Seed treatment alone is unlikely to

Table 1: Demonstration packages and farmers practices of *kharif* rice during 2016 and 2017

Particulars	Demonstration practice (T_1, T_2 and T_3)	Farmers' practice (FP)
Variety& Seed rate	MTU-1010 @ 60 kg ha^{-1}	MTU-1010 @ 75 kg ha^{-1}
Soil treatment	Cow dung manure @ 750 kg ha^{-1}, *Trichoderma viride* @ 1.5 kg ha^{-1}and *Pseudomonas fluorescens* @ 1.5 kg ha^{-1}	-
Fertilizer (kg ha^{-1}) as basal	150 kg N:P_2O_5:K_2O(10:26:26)	190 kg N:P:K (10:26:26)
1st top dressing	90 kg urea at 25-26 DAT	110 kg urea at 25-26 DAT
2nd top dressing	60 kg urea and 37.5 kg potash at 45 DAT	75 kg urea and 50 kg potash at 45 DAT
Micronutrient spray	Chelated Zn @ 1 g L^{-1} at 30 DAT and Boron 20% @ 1 g L^{-1} at 35 DAT	-
Weeding	Pretilachlor 6% + Pyrazosulfuron ethyl 0.15% @ 10 kg ha^{-1} at 1-2 DAT and Bispyribac Sodium 10% @ 250 ml ha^{-1} at 30-35 DAT	2 hand weedings
Insect Management	Seedling tip clipping during transplanting and Emamectin benzoate 5 SG @ 225 g ha^{-1} at 30 DAT	Emamectin benzoate 5 SG @ 225 g ha^{-1} at 30 & 40 DAT

DAT = Days after transplanting; T_1: Seed treatment with carbendazim 50WP; T_2: Seedling root dipping in hexaconazole 5EC T_3: T_1+T_2; FP: Farmers' practice/control

Table 2: Scale used to rate blast disease incidence with host behaviour

Scale	Description	Host behaviour
0	No lesion detected	Highly Resistant (HR)
1	Pin point sized brown coloured specks	Resistant (R)
2	Necrotic grey lesions of around 1-2 mm in diameter with a noticeable brown edge can be detected on the lower leaves of the plant	Moderately Resistant (MR)
3	A significant number of same type lesion as in 2 on upper leaves	Moderately Resistant (MR)
4	Less than 4% leaf area infected by susceptible blast lesions (≥3 mm)	Moderately Resistant (MR)
5	4% to 10% leaf area infected by susceptible blast lesions (≥3 mm)	Moderately Resistant (MR)
6	11% to 25% leaf area infected by susceptible blast lesions (≥3 mm)	Susceptible (S)
7	26% to 50% leaf area infected by susceptible blast lesions (≥3 mm)	Susceptible (S)
8	27% to 75% leaf area infected by susceptible blast lesions (≥3 mm); many dead leaves noticed	Highly Susceptible (HS)
9	More than 75% leaf area infected by susceptible blast lesions (≥3 mm)	Highly Susceptible (HS)

** There is a considerable chance that entries with a grade of 4 to 6 with an overall average of 5.5 have good quantitative resistance (Obilo *et al*., 2012).

Table 3: Effect of various treatments on rice plant height in 2016 and 2017

Treatment	Plant height (cm)							
	20 DAS		30 DAS		40 DAS		50 DAS	
	2016	2017	2016	2017	2016	2017	2016	2017
T_1	20.90	21.87	35.84	36.43	51.16	52.72	62.93	63.19
T_2	22.82	24.20	37.59	37.62	52.93	53.66	63.84	63.99
T_3	24.83	25.94	39.91	39.95	54.45	54.60	65.19	66.15
FP	19.25	20.61	33.89	34.60	47.10	47.69	58.47	58.97
SEm(±)	**0.20**	**0.28**	**0.37**	**0.35**	**0.33**	**0.30**	**0.27**	**0.18**
LSD(0.05)	**0.59**	**0.83**	**1.09**	**1.04**	**0.98**	**0.87**	**0.79**	**0.52**

*Significant at 5% level DAS= Days after sowing

Table 4: Effect of various treatments on rice production and yield components in 2016 and 2017

Treatment	No. of effective tillers hill^{-1}		No. of spikelet panicle^{-1}		1000 grain wt. (g)		Yield (kg ha^{-1}) Grain yield		Yield (kg ha^{-1}) Straw yield		YIOC (%)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
T_1	17.37	17.89	138.30	139.74	25.54	25.72	5685	5890	7499.0	7584.0	24.71	28.43
T_2	18.13	18.99	141.24	141.73	25.68	25.78	6184	6229	7956.0	8004.0	35.66	35.83
T_3	19.84	20.53	148.69	148.78	25.83	25.93	6513	6653	8216.0	8344.0	42.86	45.08
FP	16.26	16.79	125.39	126.93	24.43	24.73	4559	4586	6458.0	6510.0	—	—
SEm(±)	**0.14**	**0.15**	**2.41**	**2.25**	**0.11**	**0.12**	**99.81**	**104.42**	**123.64**	**126.11**	**—**	**—**
LSD(0.05)	**0.42**	**0.45**	**6.82**	**6.35**	**0.33**	**0.34**	**281.72**	**294.63**	**348.61**	**355.54**	**—**	**—**

*Significant at 5% level YIOC = Yield increase over control (FP)

Table 5: Performance of various treatments on blast disease incidence during 2016 and 2017

Treatment	Disease incidence (%) 2016				Disease incidence (%) 2017				AUDPC value (%)		Disease control over FP (%)		Rating scale		Host behaviour	
	30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	45 DAS	60 DAS	75 DAS	2016	2017	2016	2017	2016	2017	2016	2017
T_1	8.0	9.7	11.1	15.4	6.7	9.1	11.1	13.1	488.6	451.5	62.3	66.2	6	6	S	S
T_2	4.9	6.3	7.7	11.1	4.6	6.0	7.4	9.4	330.0	306.0	74.4	76.9	5	5	MR	MR
T_3	2.6	3.7	5.1	6.3	2.3	3.1	4.9	5.7	199.3	180.0	84.9	86.7	5	5	MR	MR
FP	13.7	20.3	34.3	48.9	15.1	24.0	30.9	47.7	1287.9	1294.5	-	-	7	7	S	S
SEm(±)	**0.51**	**0.63**	**0.85**	**1.43**	**0.69**	**0.76**	**0.63**	**1.19**	-	-	-	-	-	-	-	-
LSD(0.05)	**1.50**	**1.87**	**2.54**	**4.25**	**2.04**	**2.26**	**1.86**	**3.53**	-	-	-	-	-	-	-	-

*Significant at 5% level, DAS = Days after sowing, FP = Farmers' Practice, MR = Moderately Resistant, S = Susceptible

Table 6: Correlation coefficient between blast disease incidence and weather parameters during 2016 and 2017

Weather parameters	Blast Disease Incidence (%)							
	2016				2017			
	T_1	T_2	T_3	FP	T_1	T_2	T_3	FP
Max. Temp. (^{0}C)	-0.360	-0.366	-0.492	-0.378	-0.821	-0.760	-0.729	-0.729
Min. Temp. (^{0}C)	-0.629	-0.630	-0.699	-0.614	-0.686	-0.679	-0.537	-0.711
Average RH (%)	0.366	0.377	0.529	0.414	0.781	0.699	0.719	0.644
Rainfall (mm)	-0.770	-0.789	-0.851	-0.872	0.024	-0.073	0.135	-0.184

* Correlation coefficient at 5% level, Max. Temp. = Maximum Temperature, Min. Temp. = Minimum Temperature, RH = Relative Humidity

Table 7: Detailed cost of cultivation of rice during 2016 and 2017

Cost of cultivation	2016				2017			
	T_1	T_2	T_3	FP	T_1	T_2	T_3	FP
Seed	2880.0	2880.0	2880.0	2250.0	3000.0	3000.0	3000.0	2250.0
Seed and soil treatment	1250.0	1500.0	1750.0	0	1250.0	1500.0	1750.0	0
Land preparation	15870.0	15870.0	15870.0	15870.0	16220.0	16220.0	16220.0	16220.0
Human labour*	35000.0	35000.0	35000.0	35000.0	36750.0	36750.0	36750.0	36750.0
Weeding	2440.0	2440.0	2440.0	7500.0	2560.0	2560.0	2560.0	7875.0
Fertilizers and manures	10660.0	10660.0	10660.0	10570.0	11500.0	11500.0	11500.0	10690.0
Plant protection	1520.0	1520.0	1520.0	3530.0	1610.0	1610.0	1610.0	3660.0
Irrigation	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0	4500.0
Total cost	74120.0	74370.0	74620.0	79220.0	77390.0	77640.0	77890.0	81945.0

* Human labour used for transplanting, spraying, harvesting, threshing and cleaning

Table 8: Performance of different treatments on the economics of rice cultivation during 2016 and 2017

Treatment	Cost of cultivation (Rs. ha^{-1})		Gross return (Rs. ha^{-1})		Net return (Rs. ha^{-1})		B:C	
	2016	2017	2016	2017	2016	2017	2016	2017
T_1	74120.0	77390.0	121863.0	125423.0	47743.0	48033.0	1.64	1.62
T_2	74370.0	77640.0	131654.0	132567.5	57284.0	54927.5	1.77	1.71
T_3	74620.0	77890.0	137923.5	140669.5	63303.5	62779.5	1.85	1.81
FP	79220.0	81945.0	99725.5	100378.0	20505.5	18433.0	1.26	1.22

*B:C= Benefit Cost Ratio; Gross return = Return from grain and straw; Average price of rice grain = Rs. 15.50 kg^{-1}; Average price of rice straw = Rs. 4.50 kg^{-1}

Table 9: Production performance of rice through different treatments during 2016 and 2017

Treatment	Average grain yield (kg ha^{-1})		Extension gap (kg ha^{-1})		Technology gap (kg ha^{-1})		Technology index (%)	
	2016	2017	2016	2017	2016	2017	2016	2017
T_1	5685.0	5890.0	1126.0	1304.0	1715.0	1510.0	23.18	20.41
T_2	6184.0	6229.0	1625.0	1643.0	1216.0	1171.0	16.43	15.82
T_3	6513.0	6653.0	1954.0	2067.0	887.0	747.0	11.99	10.09
FP	4559.0	4586.0	-	-	-	-	-	-

*Potential yield = 7400.0 kg ha^{-1}

prevent the bakanae (fungal) disease of rice, but when combined with seedling dip and transplanted into improved soils, it prevents the disease effectively (Gupta *et al.,* 2015).

Carbendazim, as a systemic fungicide supposed to be more stable in soil and ensures a continuous supply of fungicide to the above-ground part of the plant.The plant surface converts it to benzimidazole carbamate, which inhibits sensitive fungus nuclear division. A secondary effect of this fungicide is better vigour of the plants during the early stages of growth, perhaps by changing host metabolism or through some change in soil nutrient availability. Tirmali *et al*. (2001) found that carbendazim (0.2%) significantly decreased the severity of neck blast disease in highly vulnerable rice varieties (Chimansal-39). Deepan *et al.* (2018) found that mancozeb + carbendazim WS totally suppressed rice blast disease mycelial development. Seed treatment resulted 80-100% germination of seedling in rice as reported by Naher *et al*. (2016).

Being a systemic fungicide and inhibition ability against the formation of ergosterol (steroid dimethylation inhibitor), hexaconazole reduces the risk of pathogens developing resistance (Prasanna Kumar *et al.,* 2011). The waiting period of hexaconazole 5 EC from the last application to harvest is about 40 days, *i.e*. it persists in rice for about 70 days from sowing. According to Kumar *et al.* (2013), weekly applications of hexaconazole (3%) SC fungicide can successfully suppress rice blast disease.

Seed, soil, and micronutrient treatments generate healthy seedlings. Such techniques are not employed by farmers. As a result, rice seedlings are more susceptible to blast disease. Seed treatment with carbendazim and seedling root dipping in hexaconazole solution produces very healthy seedlings because it inhibits seed borne pathogen. So it is a very effective measure to control blast disease in rice. Seedlings generated from treated seed produce more effective tillers per hill, spikelets per panicle and bold grains. Seed borne pathogen inoculums are reduced by seed treatment (Islam *et al.,* 2000) which decreased disease on rice seedling and ultimately on main field leading to more healthy crop, increased grain number and bold grain. According to Anitha and Savitha (2015) rice seed treatment with carbendazim up to 6 mg is recommended or applicable against fungal disease of rice.

As a result of the current investigation, it can be inferred that seed treatment by carbendazim and seedling root dip treatment by hexaconazole at proper dose and time reduces the risk of pathogen resistance and resurgence as a result of limited fungicide applications to reduce rice blast disease incidence. Hence, the treatment combinations are the key to the trial's improved results in growth and yield attributing traits, boosting farmers' profits. This is also an eco-friendly and environment friendly approach which neither increases the cost of cultivation of rice nor creates environmental pollution because of non-judicious and improper use of fungicides against rice blast disease.

ACKNOWLEDGEMENT

The authors are grateful to the ICAR-ATARI, Kolkata, Zone V, for their support and funding of the On-Farm Trial programme.

REFERENCES

Anonymous. 2019. Agricultural Statistics at a Glance, 2019.Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture Cooperation.

Anitha, S.R. and Savitha, G. 2015. Carbendazim induced alterations in morphological responses, chlorophyll and phenolic contents of rice cultivars. *Int. J. Rec. Sci., Res*, **6** (7): 4978-4982.

Bagga, P.S. and Sharma, V.K. 2006. Evaluation of fungicides as seedling treatment for controlling Bakanae/foot-rot (*Fusarium moniliforme*) disease in Basmati rice. *Indian Phytopathol*., **59**: 305-308.

Balgude, Y.S. and Gaikwad, A.P. 2019. Integrated management of blast of rice .*Int. J. Chem. Stud.*, **7** (1): 1557-1563.

Bhowmik, P., Shajahan, M. and Biswas, P. 2019. Performance of improved Integrated Pest Management (IPM) technology component for enhancing the productivity of *kharif* black gram (*Vigna mungo* L.) under cluster front line demonstration at Malda, West Bengal, India. *Int. J. Curr. Microbiol. Appl. Sci.,* **8**(10) : 987-996.

Deepan, A.B., Manasa, R. and Ramanathan, A. 2018. Combination fungicides offers substantial potential for management of rice blast disease by *Magnaporthe oryzae*. *Int. J. Chem. Stud*., **6** (2): 391-396.

FAO, 2020, *FAOSTAT Database*; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy, 2018. Available online: http://www.fao.org/faostat/en/ (Accessed on 20th December, 2020).

Faivre-Rampant, O., Genies, L., Piffanelli, P. and Tharreau, D. 2013.Transmission of rice blast from seeds to adult plants in a non-systemic way. *Plant Pathol*., **62**: 879-887.

Ghatak, A., Willocquet, L., Savary, S. and Kumar, J. 2013. Variability in aggressiveness of rice blast (*Magnaporthe oryzae*) isolates originating from rice leaves and necks: a case of pathogen specialization. *PloS One*, **8**: 66180.

Gomez, K.A. and Gomez, A. A. 1984. Statistical Procedure for Agricultural Research. John Wiley & Sons, New York.

Gupta, A., Kumar, R. and Maheshwari, V.K. 2015. Integration of seed treatments, seedling dip treatments and soil amendments for the management of bakanae disease in paddy variety Pusa Basmati 1121. *Plant Pathol. J.*, **14** (4): 207-211.

Hubert, J., Mabagala, R.B., and Mamiro, D.P. 2015. Efficacy of selected plant extracts against *Pyricularia grisea*, causal agent of rice blast disease. *American J. Pl. Sci*., **6**: 602-611.

IRRI, 1996.The standard evaluation system for rice.4th ed. International Rice Research Institute, Manila, Philippines.

IRRI, 2014.Standard Evaluation system for Rice (SES). Los Banos, Philippine: International Rice Research Institute.

Islam, M.S., Jahan, Q.S.A., Bunnarith ,K., Viangkum, S., and Merca, S.D. 2000. Evaluation of seed health of some rice varieties under different conditions.*Bot. Bull. Aca.Sin.*, **41**: 293-297.

Kumar, M.K.P., Gowda, D.K.S., Moudgal, R., Kumar, N.K., Gowda, K.T.P. and Biswanath, K. 2013. Impact of fungicides on rice production in India.*In*: Nita M. Fungicides: Showcases of Integrated Plant Disease management from Around the World. *InTech*, 77-98.

Mohiddin, F.A., Bhat, N.A., Wani, S.H., Bhat, A.H., Ahanger, M.A., Shikari, A.B., Soû, N.R., Parveen, S., Khan, G.H., Bashir, Z., Vachova, P., Hassan, S. and Sabagh, A.EL. 2021. Combination of strobilurin and triazole chemicals for the management of blast disease in Mushk Budji -aromatic rice. *J. Fungi*, **7**: 1060.

Naher, L., Ali, M.A. and Sheheli, S. 2016. Effect of seed treatment on seed borne fungi of rice. *Progressive Agric.*, **27** (1): 48-56.

Nasruddin, A. and Amin, N. 2013. Effects of cultivar, planting period and fungicide usage on rice blast infection levels and crop yield. *J. Agril. Sci*., **5** (1), 160-167.

Obilo, O.P., Daniel, A.E., Ihejirika, G.O., Ofor, M.O. and Adikuru, N.C. 2012.Control of rice blast (*Magnaporthe grisea*) disease using various organic manures. *J. Agril. Ext. Rur. Dev.*, **15**: 1198–05.

Prasanna Kumar, M.K., Siddegowda, D.K., AtheekurRehaman, H.M., PandurangeGowda, K.T. and Sudarshan, G.K. 2011.New strobilurin group fungicide in rice disease management. *Pestology*, **35** (9): 34-39.

Samui, S.K., Maitra, S., Roy, D.K., Mandal, A.K. and Saha, D. 2000. Evaluation of frontline demonstration on groundnut. *J. Ind. Soc. Costal Agril. Res.*, **18** (2): 180-83.

Seebold, D.J., Correa-Victoria, K. and Snyder, G. 2004. Effects of silicon and fungicides on the control of leaf and neck blast in upland rice. *Plant Dis.*, **88**: 253-58.

Shaner G. and Finney R.E. 1976. Weather and epidemics of Septoria leaf blotch of wheat. *Phytopathol*.,**66**: 781-785.

Spence, C., Alff, E., Johnson, C., Ramos, C., Donofrio, N. and Sundaresan, V. 2014. Natural rice rhizospheric microbes suppress rice blast infections. *BMC Plant Biol.*, **14** (130).

TeBeest, D.O., Guerber, C. and Ditmore, M. 2012. Rice blast.*Plant Health Instructor*, Vol. 1, 10.1094/PHI-I-2007-0313-07.

Tekrony, D.M. and Egli, D.B. 1991. Relationship of seed vigour to crop yield: A review. *Crop Sci.*, **31**: 816-22.

Tirmali, A.M., Latake, S.B. and Bendre, N.J. 2001. Integrated management of blast disease of rice under rainfed conditions. *J. Maharashtra Agril. Univ*., **26** (2): 192-193.

USDA, 2021.United States Department of Agriculture-Economic Research Service.https://www.ers.usda.gov/topics/crops/rice/ (Accessedon 22nd July, 2021).

Wang, J.C., Correll, J.C. and Jia, Y. 2015. Characterization of rice blast resistance genes in rice germplasm with monogenic lines and pathogenicity assays. *Crop Protec.*, **72**: 132–38.

Wang, X.Y., Lee, S.H., Wang, J.C., Ma, J.B., Bianco, T. and Jia, Y.L. 2014. Current advances on genetic resistance to rice blast disease. In: Rice: Germplasm, Genetics and Improvement. *In Tech.*, pp. 195-217.