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Evaluation of Some Fungicides in Controlling Blast of Rice var. Kalijira in Mymensingh

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Abstract

Bioassay of sixteen chemical fungicide(s) was done against *Pyricularia oryzae* in *in vitro* following poisoned food technique in the Plant Microbe Interaction Lab (PMIL), Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh-2202. Total inhibition (100%) of mycelial growth of *Pyricularia oryzae* was obtained by Tebuconazol 50% + Trifloxistrobin 25% (Nativo 75WG), Trifloxistrobin 25% + Tebuconazol 50% (Blastin), Carbendazim 50% (Autostin 50 WDG), Tebuconazol 25% (Folicur EW 250), Hexaconazol 50% (Contaf 5EC), Mancozeb 80% (Indofil M 45), Zineb 68% + Hexaconazole l4% (Awal 72 WP) and Propiconazol (Proven) containing fungicides at the lowest (0.0125%) concentration. Based on *in vitro* performance and their availability to the farmers, five fungicides (Nativo 75WG, Autostin 50 WDG, Folicur EW 250, Contaf 5EC and Companion) were selected and sprayed in the field onto the foliage of rice plants in two different concentrations (0.1% and 0.2%) to evaluate the efficacy in reducing rice blast incidence and severity and increasing some yield contributing parameters. Among the fungicides used, two times spray (at 45 DAT and 52 DAT) of Nativo 75 WG @ 0.2% concentration showed the best performance in reducing blast incidence (4.31% and 0.00% for leaf and neck blast respectively) and severity (12.4% and 12.6% at 52 and 59 DAT respectively) as well as increasing the yield parameters followed by Autostin 50 WDG @ 0.2% concentration. It is therefore summarized that two times application of Nativo 75 WG or Autostin 50 WDG @ 2g/L of water starting from the late tillering stage will be effective for the control blast disease in field conditions.

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Introduction

Rice (*Oryza sativa* L.) is the main food for half of the population of the world with the second-highest worldwide production after maize, which is also native to Asia, East, and South Asia (Boumas, 1985). Rice is the staple cereal crop of Bangladesh which provides nearly one-sixth of the national income of Bangladesh, accounting for nearly 20 percent of gross domestic production (Khandakar *et al.,* 2013; Sayeed and Yunus, 2018). In 2019 according to the Bangladesh government, 36.2 million tons of rice produced with a seven-million-ton surplus where the domestic needs were 29.1 million tons (AsiaNews.it, 2018). United States Department of Agriculture (USDA) recently forecasted that Bangladesh may produce 36 million metric tons of rice while Indonesia 34.9 million metric tons, India 118 million metric tons, and China 149 million metric tons in 2020/21 period which will make Bangladesh the 3rd highest rice produced country (USDA, 2020). Rice is reported to be attacked by more than 70 different diseases caused by various fungi, bacteria, viruses or nematodes (Zhang *et al*., 2009), wherein Bangladesh rice is subjected to attack by 32 diseases (Kabir *et al.* 2015). Among them, rice blast caused by *Pyricularia oryzae* (anamorph), a fearsome fungal disease in Bangladesh. It's not a new disease in Bangladesh but it has been seriously breakout in the Boro season (winter rice) again in Bangladesh in 2017 and 2018 in the southern, central and northern districts of Bangladesh. Also, after severe damage to crops caused by a flash flood in Haor areas of Bangladesh, the widespread blast attack on Boro paddy may lead to a sharp decline in production in the year 2017. It was around 10-15 percent of the Boro paddy lands have been damaged by the blast fungus in the year

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2017 and 2018 The officials of Bangladesh Rice Research Institute (BRRI) assume that over 5,000 hectares of Boro cropland in southern, mid-northern and northern regions were damaged by the neck blast attack (BRRI, 2019).

P. oryzae is a seed-borne pathogen and can over-winter within plant debris, rice stubbles and also survive with the alternate host (Hubert *et al.*, 2015, Pak *et al.*, 2017). Disease severity is very much influenced by environmental factors and climatic changes. This blast pathogen might attack any of the growth stages of the rice plant from seedling to the premature stage of the crop. But leaf blast, node blast and neck blast, three different symptoms are observed in the affected organ of the infected rice plant. Leaf blast is characterized by eye-shaped spots on the leaves, neck and node blast are by their certain kind of necrosis. Node infection includes infected nodes appearing black-brown and dry and often occurs in a banded pattern. This kind of infection often causes the culm to break. The neck blast infects the panicle causing failure of the seeds to fill or causing the entire panicle to fall over as it is rotted. Out of three symptoms, neck blast is more destructive (Srinivas *et al.*, 2011). Proper cultural practices, application of chemical fungicides and the use of resistant cultivars are the most important strategies for the management of rice blast till to date (Georgopoulos and Ziogas, 1992; Bekele, 2018; Rao and Kumar, 2018; Rijal and Devkota, 2020). Though production costs, the chance of environmental pollution and health hazards are high in chemical fungicides, chemical control of blast disease has become very much popular all over the world. Both seed treatments and foliar sprays with fungicides had been practiced to minimize the losses due to blast (Chaudhary and Sah, 1998; Chaudhary, 1999; Balgude and Gaikwad, 2019). From the last decade, Trooper and Nativo fungicides belong to Tebuconazole + Trifloxistrobin and Tricyclazole groups were identified as most effeeective against blast but these are expensive fungicides for the growers in Bangladesh. So, keeping this in mind, the effectiveness of some selected fungicides available in the market with their effective dose and spray frequencies has been evaluated both in *in vitro* and field conditions to combat *Pyricularia oryzae*.

Materials and Methods

Two phased experiments named laboratory and field experiment was conducted to evaluate the efficacy of some selected fungicides and their effective doses on controlling rice blast disease incited by *Pyricularia oryzae* in the Plant-Microbe Interaction Laboratory (PMIL), Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh.

Laboratory experiment

Stock culture of an aggressive isolate BD 576 of *P. oryzae* was collected from Plant Pathology Division, Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh. Then the number of pure cultures of *P. oryzae* isolate BD 576 was developed by inoculating the Oat Meal Agar (OMA) plates with the stock culture of BD 576 isolate and the petridishes were incubated in an incubator (model: FOC-215i, VELF Scientifica, Italy) chamber at 25˚C to provide the conditions for the pathogen to grow up to 10 days. Again, the approximately standard amount of fungal materials was transferred from 10 days old culture to the center of fresh PDA plates employing a sterilized block cutter for culture and allow them to grow for 10 days at 25°C temperature in an incubator. Sequential culturing from fungal stock was done for 3-5 times to get a pure culture that was used for screening of some selected fungicide against *P. oryzae*. Sixteen different fungicides with four different concentrations of each were used in the *in vitro* inhibition test (Table 1). OMA plates supplemented with different fungicides were inoculated with a pure culture of *P. oryzae.* After 10 days, the radial mycelial growth of *Pyricularia oryzae* was recorded by measuring the average of two diameters. The growth inhibition percentage was calculated by using the following formula (Al-Burtamani *et al.,* 2005):

$$I = \frac{(C-T)}{C} x100$$

Where, I= Growth inhibition (%), C = Mean mycelial growth (radial) of the pathogen in the control plate, and T = Mean mycelial growth (radial) of the pathogen in fungicide treated plate. This *in vitro* experiment was performed using a completely randomized design (CRD) of three replicates for each treatment. All analyses carried out using SAS (University Edition version 3.71 basic edition) statistical package.

Field experiment

Field trials were conducted in a piece of suitable land belong to Plant Pathology Field Laboratory, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh. The experimental field was well-drained, medium high land with silty-loam textured soil. Kalijira, one of the high yielding traditional aromatic Aman rice (monsoon rice) variety in Bangladesh was used for this field experiment which is susceptible to blast disease. In this experiment, 36 plots were used and each of the plot size was 1.5m × 1.5m. The experimental field was fertilized with chemical fertilizers as per the recommended dose of the Fertilizer Recommendation Guide (BARC, 2012).

Table 1. List of fungicides used in the laboratory experiment along with their active ingredients

Treatments	Active ingredient	Fungicide concentration
T_0 (Control)	Only OMA medium	
T_1 (Nativo 75WG)	Tebuconazol 50% + Trifloxistrobin25%	
T_2 (Blitox 50 WP)	Copper Oxichloride 50%	
T_3 (Blastin)	Trifloxistrobin 25% + Tebuconazol 50%	
T_4 (Companion)	Mancozeb 63% + Carbendazim 12%	
T_5 (Trooper 75 WP)	Tricyclazole 75%	
T_6 (Indofil M 45)	Mancozeb 80%	
T_7 (Awal 72 WP)	Zineb 68% + Hexaconazol 4%	(0.0125%, 0.025%, 0.05% and 0.1%)
T_8 (Fiesta Z-78)	Zinc-Ethylene-bis-di-thio- Carbamate	
T_9 (Autostin 50 WDG)	Carbendazim 50%	
T_{10} (Metaril 72 WP)	Mancozeb 64% + Metalaxyl 8%	
T_{11} (Cabrio Top)	Pyraclostrobin 5% + Metiram 55%	
T_{12} (Bounty 36 WP)	Cymoxanil 6% + Chlorothalonil 30%	
T_{13} (Folicur EW 250)	Tebuconazol 25%	
T_{14} (Contaf 5EC)	Hexaconazol 50%	
T_{15} (Amiscor)	Azoxystrobin 20% + Difenaconazole 12.5%	
T_{16} (Proven)	Propiconazol	

Table 2. Fungicides evaluated under field condition against rice blast

Treatments	Fungicides	Chemical group	Concentration
T_0	Control	-	-
T_1	Nativo 75 WG	Tebuconazol 50% + Trifloxistrobin25%	0.1%
T_2	Nativo 75 WG	Tebuconazol 50% + Trifloxistrobin25%	0.2%
T_3	Companion	Mancozeb 63% + Carbendazim 12%	0.1%
T_4	Companion	Mancozeb 63% + Carbendazim 12%	0.2%
T_5	Autostin 50 WDG	Carbendazim 50%	0.1%
T_6	Autostin 50 WDG	Carbendazim 50%	0.2%
T_7	Folicur EW 250	Tebuconazol 25%	0.1%
T_8	Folicur EW 250	Tebuconazol 25%	0.2%
T_9	Contaf 5 EC	Hexaconazol 50%	0.1%
T_{10}	Contaf 5 EC	Hexaconazol 50%	0.2%

After preparation of the plots, thirty (30) days old seedlings were transplanted in the well-prepared puddle field plots. Intercultural operations were done for ensuring and maintaining the normal growth and development of rice plants. Weeding was done three times and plots were irrigated when necessary.

Based on *in vitro* result, the possibility of available fungicides to the farmers and according to some related literatures, five best-performed fungicides (Nativo 75 WG, Companion, Autostin 50 WDG, Folicur EW and Contaf 5 EC) from different chemical groups with two different field effective concentrations (0.1% & 0.2%) were used to know their effect on the disease incidence and severity of rice blast, and different yield contributing parameters of rice. Ten fungicidal treatments and one control were used in this field experiment (Table 2). In this study, fungicide solutions were sprayed in 30 plots twice starting from the late booting stage. The first spray was done at 45 days after transplanting (DAT) at the late tillering stage and the second spray was done at 55 DAT i.e. seven days after the first spray application (at heading stage) Kabir *et al.* (2004). The rest of the six plots were maintained as the control for this experiment.

Each of the plots was investigated for recording the incidence and severity of rice blast diseases. Affected plants from each unit plot were selected for assessing the disease incidence and severity. Data were recorded in 2-time points namely 52 DAT (7 days after the first spray) and 59 DAT (7 days after the second spray) by observing the typical blast symptoms on the leaf and neck region of the infected plant. Percent disease incidence was estimated by using the formula of Rajput and Bartaria, 1995.

$$\text{Disease incidence}(\%) = \frac{\text{No. of infected plants}}{\text{Total no. of plants}} x100$$

Besides, the disease severity of naturally infected rice plants in 36 plots was assessed by a disease severity scale according to Mackill and Bonman, 1992. The disease severity was also measured at 52 and 59 DAT *i.e.* seven days after spray application. The crop was harvested plot-wise on 15 November 2018 when 80-85% of the grains have become straw-colored. Data were collected on different yield contributing parameters namely plant height, number of total tillers per hill, number of effective tillers per hill, number of non-effective tillers per hill, number of infected panicle per hill, number of non-infected panicle per hill and weight of 1000 grains.
The experiment was conducted in RCBD with three replications. The data on different parameters were statistically analyzed using the Analysis of Variance (ANOVA) technique to find out the level of significance.

The treatment means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance. The collected data were analyzed using SAS (University Edition version 3.71 basic edition) statistical package.

Results

Confirmation and Development of a pure culture of Pyricularia oryzae

After transferring the stock culture of *P. oryzae* isolate BD 576 to OMA containing plates, colonies with white color margin along with a blackish center on top and black coloured back appeared. The fungus as *P. oryzae* was confirmed by observing morphological features especially pear-shaped conidia under the microscope (Figure 1). Then slides were prepared from these colonies. An approximately standard amount of fungal material was transferred to the center of a fresh OMA plate using a sterilized block cutter for the re-culture and then grown under optimum incubated conditions for 10 days.

Effect of fungicides on radial mycelial growth of Pyricularia oryzae

The effect of fifteen selected fungicides with four different concentrations was observed on the radial mycelial growth of *P. oryzae* in this study. In the case of 0.0125, 0.025, 0.05 and 0.1% concentrations of fungicides, there was no radial mycelial growth (cm) i.e. 100% mycelial growth inhibition occurred in plates containing Nativo 75 WG, Blastin, Indofil M 45, Awal, Autostin 50 WDG, Folicur EW 250, Contaf 5 EC, Indofil M-45 and Proven fungicides followed by Cabrio Top, Companion, Amiscor, Metaril 72 WP. The maximum radial mycelial growth was recorded in control plates and plates containing Blitox 50 WP, Feyasta Z-78 and Bounty 36WP at 10 DAI (Table 3, Figure 2).

Effect of fungicides on the disease incidence and severity of rice blast

In this field experiment, the effect of five selected fungicides (Nativo 75 WG, Companion, Autostin 50 WDG, Folicur EW 250 and Contaf 5EC) were evaluated for disease incidence and severity for rice blast in the field conditions on the basis of their efficacy in *in vitro* experiment and their availability. Selected fungicides were sprayed at two different concentrations (0.1 & 0.2%) at 45 DAT and 52 DAT and the disease incidence data were recorded at 52 DAT i.e. seven days after first spray application. The different chemical treatments had a significant influence on the percent disease incidence of rice blast at 52 DAT (Table 4). However, in this study, the lowest leaf blast incidence (11.02%) was found in T_1 (Nativo 75 WG @ 0.1%) treated plots in case of 0.1% concentrations followed by T_5 (Autostin 50 WDG @ 0.1%) treated plots and the highest percent leaf blast incidence (41.26%) was observed in control (T_0) plots followed by T_9 (Contaf 5EC @ 0.1%) treated plots at 52 DAT (Table 4). In the case of 0.2% concentrations, the lowest leaf blast incidence (4.31%) was found in T_2 (Nativo 75 WG) treated plots followed by T_6 (Autostin 50 WDG) treated plots and the highest percent leaf blast incidence (41.26%) was observed in control (T_0) plots followed by T_{10} (Contaf 5EC) treated plots at 52 DAT.

On the other hand, the disease severity of rice blast was evaluated against different chemical fungicides in two different time points (@ 45 DAT and 52 DAT). It is visible that the percent disease severity of rice blast (leaf and neck blast) was increased gradually with the advancement of crop growth. In the present research work, the lowest leaf blast severity 12.4% & 12.6% at 52 and 59 DAT respectively were found in T_1 (Nativo 75 WG @ 0.1%) treated plots in case of 0.1% concentrations followed by T_5 (Autostin 50 WDG @ 0.1%) treated plots and the highest percent leaf blast severity i.e. 16.3% and 20.5% were observed in control (T_0) plots at 52 and 59 DAT respectively followed by T_9 (Contaf 5EC @ 0.1%) treated plots (Table 4). In case of 0.2% concentrations, the lowest leaf blast severity 11.53% & 12.00% at 52 and 59 DAT respectively were found in T_2 (Nativo 75 WG @ 0.2%) treated plots followed by T_6 (Autostin 50 WDG @ 0.2%) treated plots and the highest percent leaf blast severity i.e. 16.3% and 20.5% were observed in control (T_0) plots at 52 and 59 DAT respectively followed by T_{10} (Contaf 5EC @ 0.2%) treated plots (Table 4).

The lowest neck blast incidence (0.00%) was recorded in T_2 (Nativo 75 WG @ 0.2%) treated plots followed by T_6 (Autostin 50 WDG @ 0.2%) treated plots at 90 DAT and the highest percent (44.67%) neck blast was observed in control (T_0) plots followed by T_{10} (Contaf 5EC @ 0.2%) treated plots at 90 DAT (Table 4).

Effect of foliar spray of fungicides on the yield contributing parameters of rice

The different yield contributing parameters such as plant height, the number of tiller per hill, the number of effective tiller per hill, number of infected panicles, number of non-infected panicles and thousand-grain weight showed significant differences in treated and control plots in a field experiment (Table 5). The maximum plant height (40.73 cm) was recorded in T_2 (Nativo 75 WG @ 0.2%) treated plots followed by T_1 (Nativo 75 WG @ 0.1%) and T_6 (Autostin 50 WDG @ 0.2%) treated plots (Table 5). On the other hand, the minimum plant height (37.13 cm) was found in control plots followed by T_9 (Contaf 5 EC @ 0.1%) treated plots (Table 5).

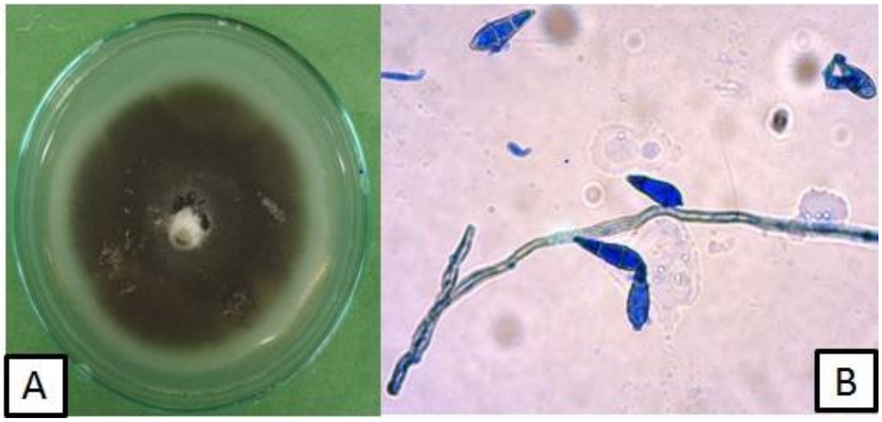

Figure 1. Pure culture of *Pyricularia oryzae* (10 days old) and different structures of *Pyricularia oryzae*

Table 3. Radial mycelial growth (RMG) and percent mycelial growth Inhibition (% MGI) of *Pyricularia oryzae* on OMA plates supplemented with different fungicide(s)

Concentrations (%)	0.0125		0.025		0.05		0.1	
	RMG	(% MGI)	RMG	(% MGI)	RMG	(% MGI)	RMG	(% MGI)
T_0 (Control)	6.20 a	0	6.20 a	0	6.20 a	0	6.20 a	0
T_1 (Nativo 75 WG)	0.00 i	100	0.00 h	100	0.00 g	100	0.00 e	100
T_2 (Blitox 50 WP)	5.00 b	19.35	4.73 b	23.65	3.57 b	42.47	2.33 c	62.36
T_3 (Blastin)	0.00i	100	0.00 h	100	0.00 g	100	0.00 e	100
T_4 (Companion)	1.13fg	81.72	1.27ef	79.56	1.13 e	81.72	0.30 e	95.26
T_5 (Trooper 75 WP)	2.60 d	58.06	1.73 de	72.04	0.57 f	90.86	0.00 e	100
T_6 (Indofil M 45)	0.00i	100	0.00 h	100	0.00 g	100	0.00 e	100
T_7 (Awal 72 WP)	0.00i	100	0.00 h	100	0.00 g	100	0.00 e	100
T_8 (Fiesta Z-78)	3.87 c	37.63	3.40 c	45.16	3.00 c	51.61	2.73 b	55.91
T_9 (Autostin 50 WDG)	0.00 i	100	0.00 h	100	0.00 g	100	0.00 e	100
T_{10} (Metaril 72 WP)	1.37 f	77.95	1.73 de	72.04	1.10 e	82.25	1.10 d	82.25
T_{11} (Cabrio Top)	0.73gh	88.17	0.63 g	89.78	0.33fg	94.62	0.30 e	95.16
T_{12} (Bounty 36 WP)	2.13 e	65.59	1.87 d	69.89	1.50 d	75.8	1.30 d	79.03
T_{13} (Folicur EW 250)	0.00i	100	0.00 h	100	0.00 g	100	0.00 e	100
T_{14} (Contaf 5EC)	0.00i	100	0.00 h	100	0.00 g	100	0.00 e	100
T_{15} (Amiscor)	1.17fg	81.18	1.07fg	82.79	1.30 de	79.03	1.10 d	82.25
T_{16} (Proven)	0.00i	100	0.00 h	100	0.00 g	100	0.00 e	100
LSD (0.05)*	0.437		0.538		0.313		0.313	

*LSD (0.05): Least Significant Difference. In a column, means followed by the same letter(s) are statistically similar at 5% level by DMRT , *DAI=Days after inoculation

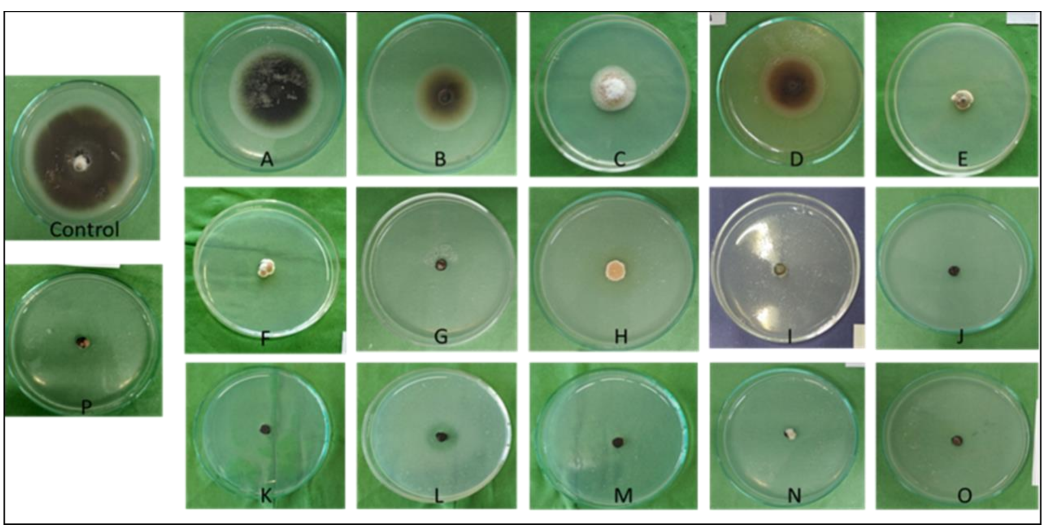

Figure 2. Radial mycelial growth status of *Pyricularia oryzae* on OMA plates containing 0.0125% of different fungicide(s) separately over control at 10 DAI (Days After Inoculation). Here, A) Blitox 50 WP, B) Fiesta Z-78, C) Trooper, D)Bounty E) Metaril, F)Amiscor, G) Autostin H) Companion, I) Cabrio Top, J)Nativo, K) Contaf, L)Folicur, M)Proven, N)Blastin, O) Indofil and P) Awal.

Table 4. Effect of fungicides on disease incidence and severity of rice blast

Treatments	% Disease Incidence (leaf blast) (52 DAT)	% Disease severity (leaf blast)		% Disease Incidence (Neck blast) (90 DAT)
		After 1st spray (52 DAT)	After 2nd spray (59 DAT)	
T_0 = Control	41.26 a	16.3 a	20.5a	44.67 a
T_1 = Nativo 0.1%	11.02fg	12.4fg	12.6h	10.64 f
T_2 = Nativo 0.2%	4.31i	11.53g	12.00i	0 .00h
T_3 = Companion 0.1%	14.53 d	14.8bc	14.67e	17.65 d
T_4 = Companion 0.2%	13.2 e	13.6 de	16.00d	14.35e
T_5 = Autostin 0.1%	11.67 f	13.3def	13.9fg	11.09 f
T_6 = Autostin 0.2%	5.82 h	13.00ef	13.5g	5.71 g
T_7 = Folicur 0.1%	19.15 c	14.00cde	14.38ef	17.54 d
T_8 = Folicur0.2%	10.59 g	14.2 cd	16.3d	11.14 f
T_9 = Contaf 0.1%	21.63 b	15.5 ab	18.4b	22.38 b
T_{10} = Contaf 0.2%	19.1 c	15.1bc	17.3c	18.6 c
LSD (0.05)	0.7261	1.0831	0.5557	0.8929

*LSD (0.05): Least Significant Difference. In a column, means followed by the same letter(s) are statistically similar at 5% level by DMRT, *DAI=Days after inoculation

Table 5. Effect of different fungicides on yield contributing parameters of rice CV Kalizira

Fungicide	Plant Height	No. of total tiller /Hill	No. of effective tiller /Hill	No. of Non-infected panicle	No. of infected panicle	Thousand-grain weight
T_0 = Control	37.13 d	12.20 a	11.36 a	6.03 a	5.30 a	9.42 d
T_1 = Nativo 0.1%	40.47 ab	14.87 a	14.33 a	11.00 b	1.27 bc	13.16 abc
T_2 = Nativo 0.2%	40.73 a	15.33 a	14.40 a	13.67 b	0.00 c	13.75 a
T_3 = Companion 0.1%	38.53 abcd	14.13 a	13.80 a	10.93 b	1.53 bc	12.55 abc
T_4 = Companion 0.2%	39.67 abc	12.67 a	12.07 a	11.06 b	1.33 bc	12.61 abc
T_5 = Autostin 0.1%	40.37 ab	14.27 a	13.93 a	11.13 b	1.00 bc	12.89 abc
T_6 = Autostin 0.2%	39.73 abc	14.60 a	14.00 a	12.40 b	0.80 bc	13.38 ab
T_7 = Folicur 0.1%	39.00 abc	12.27 a	11.80 a	9.40 ab	2.07 bc	12.00 bc
T_8 = Folicur0.2%	38.40 bcd	12.07 a	11.40 a	10.00 b	1.27 bc	12.25 bc
T_9 = Contaf 0.1%	37.80 cd	12.27 a	11.93 a	8.87 ab	2.67 b	11.81 c
T_{10} = Contaf 0.2%	39.47 abc	13.60 a	13.60 a	10.53 b	2.53 b	12.42 abc
LSD (0.05)	2.2123	4.2296	4.6593	3.8432	2.3894	1.4432

*LSD (0.05): Least Significant Difference. In a column, means followed by the same letter(s) are statistically similar at 5% level by DMRT

The maximum number of total tillers (15.33), effective tillers (14.40), non-infected panicle (13.67) and infected panicle (0.00) per hill were recorded for the T_2 (Nativo 75 WG @ 0.2%) treated plots followed by T_1 (Nativo 75 WG @ 0.1%) and T_6 Autostin 50 WDG @ 0.2%) treated plots (Table 5), whereas the minimum total tillers (12.20), effective tillers (11.36), non-infected panicle (6.03) and infected panicle (5.30) per hill were recorded for the Control plots (T_0) followed byT_9 (Contaf 5 EC @ 0.1%) treated plots. To determine the effect of five selected fungicides on the weight of 1000 seeds (gm) of rice were also evaluated in this study and this parameter showed significant differences under different treatments. However, the weight ranged from 9.42 to 13.75g. In the case of weight of thousand seed, T_2 (Nativo 75 WG @ 0.2%) treated plants showed maximum weight (13.75g) followed by T_1 (Nativo 75 WG @ 0.1%) and T_6 (Autostin 50 WDG 0.2%) treated plants while the lowest (9.42g) weight of thousand seeds was observed belong to the control plots.

Discussion

According to the results of *in vitro* study, Trifloxistrobin 25% + Tebuconazol 50%, Tebuconazol, Hexaconazol, Mancozeb, Zineb 68%+ Hexaconazole l4% and Carbendazim containing fungicides were more effective in controlling *P. oryzae* compared to Tricyclazole, Metalaxyl, Zineb, Pyraclostrobin, Metiram, Copper oxychloride containing fungicides. These findings are in agreement with the findings of Surapu *et al.* (2017) who stated that in *in vitro* conditions two fungicides namely Carbendazim showed complete inhibition (100% inhibition) of mycelial growth of *P. oryzae* at 1000 and 1200 ppm concentrations, in case of Tricyclazole complete inhibitions was recorded at 800 ppm and maximum growth inhibition was at 600 ppm. Chander *et al.* (2013) screened some fungicides under *in vitro* conditions each at a concentration of 0.1, 1, 10, 25, 50 and 100 ppm. Among tested fungicides, Tilt, Amistar top, Score and Folicur were found significantly effective over other treatments. Tilt exhibited 100% growth inhibition at 10 ppm while Folicur, Amistar top and Score exhibited 100% growth inhibition at 25 ppm. These studies revealed that Tilt followed by Amistar top, Score and Folicur are the most promising fungicides. Kunova *et al.* (2013) found in an *in vitro* study that the mycelium growth of *Magnaporthe oryzae* was inhibited to low concentrations of azoxystrobin and relatively high concentrations of tricyclazole. In the present study, the high concentration (0.1 & 0.2%) of tricyclazole (Tropper) showed better growth inhibition compared to low concentration (0.05%) in *in vitro*.

In the field experiment, the lowest leaf blast incidence (4.31%) was found in T_2 (Nativo 75 WG @ 0.2%) treated plots followed by T_6 (Autostin 50 WDG @ 0.2%) treated plots compared to other treatments used in this experiment (Table 4). In addition, the lowest neck blast incidence (0.00%) was recorded in T_2 (Nativo 75 @ 0.2%) treated plots followed by T_6 (Autostin 50 WDG @ 0.2%) treated plots at 90 DAT compared to controlled (T_0) plots. On the other hand, the lowest disease severity 11.53% & 12.00% at 52 and 59 DAT respectively were found in T_2 (Nativo 75 WG @ 0.2%) treated plots followed by T_1 (Nativo 75 WG @ 0.1%) and T_6 (Autostin 50 WDG @ 0.2%) treated plots compared to other treatments were used in this study. However, these findings are in concurrence with the findings reported by other researchers. Pal (2014) studied six fungicides like Kresoxim methyl, Azoxystrobin, Propiconiazole, Trifloxystrobin+Tebuconazole (Nativo), Difeconazole, and Tricyclazole to control the leaf blast of rice. Among them, Trifloxystrobin + Tebuconazole (Nativo) was found to be highly effective for the control of rice blast. Roumen (1993) tested the efficacy of newly evolved fungicides viz; Trifloxystrobin 25% + Tebuconazole 50% (Nativo 75 WG), Kresoxim methyl (Ergon 44.3 SC), Thifluzamide 24 SC, Metaminostrobin 20 SC, Azoxystrobin 25 SC (Amistar), Tricyclazole 75 WP (Beam), Carbendazim 50WP (Bavistin), Propiconiazole 25EC (Tilt) against leaf blast of rice under natural conditions. Among them, Azoxystrobin and Tricyclazole (Nativo) showed better results compared to other fungicidal treatments. Magar *et al.* (2015) reported that combined use of Tricyclazole 22 % + Hexaconazole 3% SC thrice showed the highest disease control (87.03 % and 79.62 % in leaf and neck blast respectively) and highest grain yield (4.23t/ha). Biswas (2017) found that to enhance defense mechanisms within the rice plant mixture, Nativo (tebuconazol + trifloxystrobin) is a better option.

Moreover, plots sprayed with Nativo 75 WG @ 0.2% (T_2) showed the best performance for yield contributing parameters like plant height (40.73cm), the number of tiller per hill (15.33), the number of effective tiller per hill (14.40), No. of infected panicle (0.00), number of non-infected panicles (13.67) and thousand-grain weight (13.75) showed significant differences in treated and control plots followed by Autostin 50 WDG @ 0.2% (T_6), whereas control plots showed the lowest value for all yield contributing parameters. Researchers from around the world also found similar results while testing the various fungicides, like Varma and Santhakumari (2012) found that the highest increase in grain and straw yield over the control was also recorded with isoprothiolane (22.5 and 28.3%), followed by carpropamid (20.5% and 25.7%). Qudsia (2017) studied that Amistar Top 325 SC (Azoxytrobin + Difenconazonle) performed best to control the rice blast incidence (11%) and contributed to high yield (4.68 t/ha) compared to Nativo 75 WG (Tebuconazole + Trifloxystrobin), Dora 10 WG (Difenoconazole), Dorazole 50 EC (Difenconazole + Propiconazole), Score 250 EC (Difenoconazole) and Kocide 3000 52.4 WG (Copper hydroxide). Singh *et al.* (2019) evaluated that Tebuconazole 50 % + Trifloxystrobin 25 % (WG) treated plants showed minimum disease intensity (11.46 %) and highest grain yield (4102.11 kg/ha).

Conclusions

This research work was conducted to find out the efficacy of some selected fungicides against rice blast disease control in *in vitro* and field conditions. Based on the findings of the present study it may be concluded that some fungicides were more effective to inhibit *Pyricularia oryzae* at a very low concentration in *in vitro* condition as it inhibited radial mycelial growth up to 100% at only 0.0125% concentrations. On the other hand, Nativo 75 WG (Trifloxistrobin 25% + Tebuconazol 50%) @ 0.2% was found most effective for controlling blast of rice (leaf and neck), as the lowest percentage of leaf blast incidence (4.31%), lowest neck blast incidence (0.00%) and the lowest leaf blast severity 11.53% & 12.00% at 52 and 59 DAT respectively were found in Nativo 75 WG (@ 0.2%) treated plots followed by Autostin 50 WDG @ 0.2%. Plots sprayed with Nativo 75 WG @ 0.2% showed the best performance for yield contributing parameters like plant height (40.73cm), the number of tiller per hill (15.33), the number of effective tiller per hill (14.40), No. of infected panicle (0.00), number of non-infected panicles (13.67) and thousand-grain weights (13.75) showed significant differences in treated and control plots followed by Autostin 50 WDG @ 0.2%. However, two times the application of Nativo 75 WG or Autostin 50 WDG @ 2g/L of water starting from just panicle initiation will be effective for the control blast disease in field conditions.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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