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Organic Management of Brown Spot and Sheath Blight of Rice Cultivar BRRIdhan29 under Field Condition Enhancing Grain Yield

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Abstract

BAU-Biofungicide (Trichoderma based preparation), extracts of garlic (*Allium sativum* L.) and neem (*Azadirachta indica* A. Juss.), Bavistin DF (Carbendazim) (positive control-1) and Potent 250 EC (Propiconazole) (positive control-2) were tested in controlling brown spot and sheath blight diseases of rice cv BRRI dhan29. Significant reduction in mycelial growth of *Bipolaris oryzae* and *Rhizoctonia solani* was observed with BAU-Biofungicide (2%) *In vitro* condition and reduced disease severity of brown spot and sheath blight was noted in the field. BAU-Biofungicide (2%) exhibited grain yield 6325 kg/ha and propiconazole (0.1%) marked the highest (6470 kg/ha) grain yield, while the lowest yield (5120 kg/ha) was attained in control plot. Total cost of production (40851/-) per hectare was obtained in Potent (0.1%) and BAU-Biofungicide (2%) conferred 41260/-as compared to Potent (0.1%). Seed borne pathogen of harvested seeds was greatly diminished due to foliar spray of BAU-Biofungicide and *Trichoderma harzianum* was evidently viable in harvested seeds of sprayed plot with BAU-Biofungicide. BAU-Biofungicide (3%) also resulted in improving maximum vigour index (2284.10) in treated seeds. The results of the study assemble to the further investigation of Trichoderma as an antagonist in improving rice resistance, yield and quality of seed.

Keywords: BAU-Biofungicide; BRRI dhan29; Disease severity; Cost of Production; Management; Yield

Introduction

Rice (*Oryza sativa* L.) is one of the three major food crops in the world. The global demand of rice is increasing day by day. Current average world rice production is 676 million tons, while the global demand will rise to 852 million tons for the year 2035. However, the productivity of rice needs to be increased from 10 to 12.5 t/ha to fulfill the requirement of 176 million tons more rice [1]. The world average yield of rice is 4.59 t/ha and the average yields of rice is 4.50 t/ ha in Bangladesh that is significantly lower compared to 7.73 t/ha in China [2].

Plant pathogens cause crop losses that are also a unique threat to global food security. Rice disease is one of the major constraints of high and sustaining rice productivity. Annual yield loss was recorded from 1% to 10% due to different diseases [3]. Maximum loss in yield was also reported to be 15.60% [4]. Brown spot (*Bipolaris oryzae*) (Breda de Haan) Shoem is one of the most important rice diseases in the world. It affects the quality and the number of grains per panicle, and reduces the kernel weight [5]. The disease becomes more severe under stress conditions; causes seed discoloration, and reduce seedling vigour and the yield loss. The economic losses of brown spot disease have been reported in grain yield up to 90% when the disease was attained epiphytotic as Great Bengal Famine in 1942 [6]. Yield loss of 18.75%-22.50% was reported in brown spot disease in Bangladesh [7]. Sheath blight is known as the most economically important disease and also an important soil-borne fungal disease (*Rhizoctonia solani* Kuhn) [8]. In case of susceptible varieties, the disease becomes severe in closed planting systems [9]. The pathogen survives as sclerotia and mycelia in plant debris and weeds in tropical country [10]. Rice sheath blight (*Rhijoctonia solani*) caused yield losses up to 45% [11].

Total 153 seed-borne pathogens were detected in rice. Among them, 18% were quarantine pathogen, native (65%) and 17% were storage pathogen [12]. The 43 diseases were found in Bangladesh and 14 were of major importance as seed-borne which results loss both in quantity and in quality [13]. Field fungi viz. *Bipolaris*, *Curvularia*, *Fusarium*, *Phoma*, *Pyricularia*, *Rhizoctonia* and *Sarocladium* persists in grains that deter food value and storage quality of grains [14].

Rice disease management strategies through the host plant resistance and chemical pesticides target at preventing the diseases as outbreak. Exactly, the use of chemicals has been found in controlling fungal diseases of plant, but some major problems threaten to limit the continuous use of fungicides. Control of plant disease by biological means instead of using chemicals has drawn special attention all over the world. Botanicals in controlling pathogens against certain fungal pathogens have been reported [15]. Biological control is an innovative, cost effective and ecofriendly approach. The modes of action of Trichoderma are mycoparasitism, antibiosis, and competition and induced resistance. Trichoderma have often been used in the management of diseases of rice in recent years. Trichoderma strains were the most important fungal biocontrol agents in cosmopolitan habits with varied distribution of high biotechnological values [16]. These applications showed their ability to control plant diseases, and to promote plant growth and development [17]. BAU-Biofungicide persists in seeds with the soil from huge number of soil borne and seed borne fungi that can attack the seeds during the germination period [18]. Moreover, the preparation of Trichoderma exerts its antagonistic effect on plant defenses and plant growth development. However, research during the previous two decades has led to the possibility of biological control as an increasingly realistic option for rice disease management. The present experiment has been designed in controlling diseases of rice to increase yield with reduced cost of production by using bio control agent and plant extracts avoiding environmental pollution.

Materials and Methods

Isolation

Bipolaris oryzae was isolated from infected leaf and seeds collected from the field and Rhizoctonia solani from infected sheath of rice plants. Isolation of fungus from seed was done following the ISTA rules [19]. The growth of fungus was observed after 72 hours of incubation under stereoscopic microscope. The single conidium of each fungus in infected leaf piece was transferred to PDA plate for incubation at 25 ± 1 °C for 12 days. The pure culture was kept in PDA with hyphal tip culture method aseptically and preserved in a refrigerator at 4 °C for further study.

Use of BAU-Biofungicide and fungicide

BAU-Biofungicide (Trichoderma based preparation) was used as at 2% and 3%. BAU-Biofungicide is a Trichoderma based preparation [18]. Bavistin DF (Carbendazim) (positive control-1) and Potent 250 EC (Propiconazole) (positive-control-2) were also used at 0.1% and 0.05% concentration.

Preparation of plant extracts

Healthy leaves of neem and garlic cloves were collected, and washed thoroughly with running tap water followed by Sterile Distilled Water (SDW). The extracts were prepared by homogenizing plant parts using a blender and prepared at 1% and 2% solution by dilution with water and stored in conical flasks separately before use.

Bioassay of BAU-Biofungicide, plant extracts, bavistin and potent, on collected fungi

Potato dextrose agar medium was used. After solidification, three 5 mm discs of the medium were scooped from three places maintaining equal distance of 4 cm from the centre with a sterilized disc cutter. One milliliter of each suspension of BAU-Biofungicide, plant extracts, Bavistin DF (positive control-1) and Potent 250 EC (positive control-2) were put into each hole and the plates were stored overnight at room temperature. Next day, the plates were inoculated at the center with 6 mm blocks of 15 days old culture fungus separately and incubated at 24 ± 1 °C. Linear mycelial growth was determined up to 14 days of inoculation and percent inhibition of growth was calculated following the formula of Sundar et al. [20].

Field experiments

The experiments were carried out with rice cv. BRRI dhan29 during two Boro seasons in two successive years 2012 and 2013. The experiments were conducted in the field Laboratory of the Department of Agronomy, Bangladesh Agricultural University (BAU), Mymensingh, using Randomized Complete Block Design (RCBD) having four replications. The field was fertilized as per recommendation of Bangladesh Rice Research Institute, Gazipur [21]. The individual plot size was 10 m^2. Block to block and plot to plot distances were of 2.0 m and 1.5 m, respectively. Thirty-five-day old seedlings of BRRI dhan29 were uprooted from seed bed and three seedlings per hill were transplanted in the field on January 21 in the years of 2012 and 2013. Hill to hill and row to row distances were respectively 15 cm and 20 cm. The spray schedule was started just after appearance of disease symptoms and three sprays were performed at 15 days interval. Disease severity of each plot was estimated following the procedure of Standard Evaluation System for Rice [22].

Seed health test

The harvested seeds of each year were evaluated by blotter method for seed health test to determine seed borne pathogens associated with seed sample [19]. Each seed borne infection was recorded and expressed in percentage [23].

Seed treatment and vigour index

Seeds of rice cv BRRI dhan29 of control plot were treated with BAU-Biofungicide @2% and 3%; each plant extracts of garlic and neem, separately over time (within one hour) by weight basis @1% and 2%, and with Bavistin (positive control-1) and Potent (positive control-2) @0.1% and 0.05% of seed weight. The experiment was tested in the net house (19.81 m × 4.27 m × 3.81 m) of the Seed Pathology Centre, BAU, Mymensingh. Sand was collected from Brahmaputra River, Mymensingh between latitude 23.58° N and longitude 90.55° E, Mymensingh, Bangladesh with latitude 23.6850° N and 90.3563° E. Formalin-sterilized sand was used as substrate for filling plastic trays as described by Dasgupta [24]. The experiment was studied in CRD with three replications. Seeds of each treatment were sown in plastic trays (100 seeds/tray) with equal distances among the seeds at the temperature of highest 31.5 °C and lowest 26.8 °C. Randomly 10 seedlings were raised carefully from each tray and washed thoroughly with running tap water. Data was recorded for each treatment at 14 days after sowing on different parameters. Vigour Index (VI) was assessed following the formula of Baki and Anderson [25].

Data analysis

All recorded data on different parameters were analyzed statistically using MSTAT-C computer program and treatment means were evaluated for significance in Duncan's multiple range test following Gomez and Gomez [26].

Results

Measures of mycelial growth against fungi

Lowest mycelial growth of B. oryzae was recorded with BAU-Biofungicide (2%) followed by Potent 250 EC (0.1%) and the highest mycelial growth was found in untreated control (Figure 1). Minimum mycelial growth in *R. solani* (23.00 mm) was observed with BAU-Biofungicide (3%) preceded by Potent 250 EC (0.1%). Bavistin (0.1%) also showed better result in inhibiting the mycelial growth of *B. oryzae* and *R. solani* compared to control. No significant effect was obtained in the extract of garlic and neem.

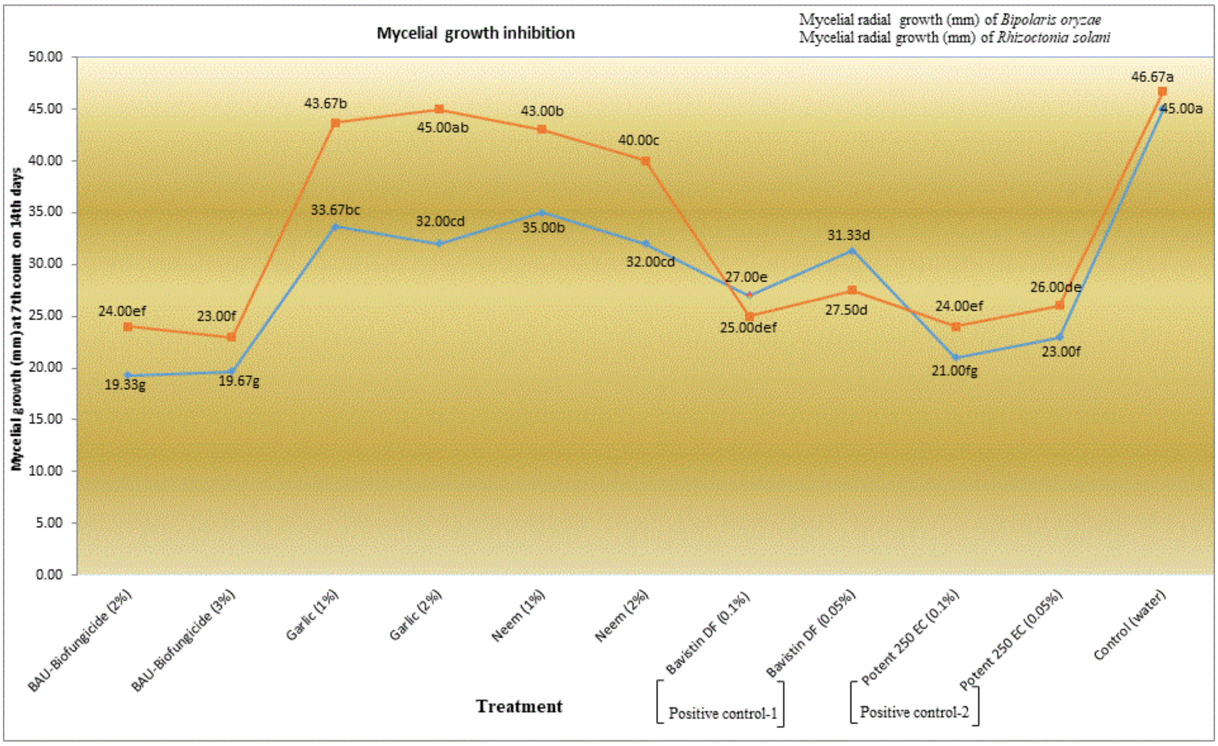

Figure 1: *In vitro* evaluation of BAU-Biofungicide, extracts of garlic and neem, Bavistin and Potent against fungi at seventh count (14th days) of rice cultivar BRRI dhan29.

Assessment of disease severity, yield and cost of production

The highest (88.89%) reduction in disease severity of brown spot of rice was observed with foliar application of Potent 250 EC (0.1%) followed by BAU-Biofungicide (2%) in 2012 and 2013 years. Evidently, hundred percent reductions in severity of sheath blight disease was found with Potent (0.1%) and Potent (0.05%) at 110 DAT in 2012 and 2013, respectively followed by Bavistin (0.1% and 0.05%) and BAU-Biofungicide (2% and 3%) as presented in Table 1. Maximum 6470 kg/ha grain yield was noted with Potent 250 EC (0.1%), while BAU-Biofungicide (2%) produced 6325 kg/ha grain yield (Table 2). Total cost of production per hectare in Potent (0.1%) was obtained as 40851/-, and BAU-Biofungicide (2%) exhibited 41260/-which was very close to Potent (0.1%). Benefit-cost ratio (BCR) 2.38:1 was obtained in Potent 250 EC (0.1%) and BAU-Biofungicide (2%) showed 2.30:1.

Treatment (dose)	Disease severity (%)											
	Brown spot						Sheath blight					
	At 80 DAT	At 95 DAT		At 110 DAT		At 80 DAT		At 95 DAT	At 110 DAT			
-	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
BAU-Biofungicide (2%)	5.23bc (-30.9)	5.50c (-27)	5.87d (-55.1)	6.50d (-50)	4.05e (-85)	4.00d (-85)	7.16b (-19)	7.00bc (-30)	6.49b (-35.9)	5.86b (-49.53)	3.69d (-68.2)	3.75d (-69.4)
BAU-Biofungicide (3%)	5.23bc (-30.9)	-	5.93d (-54.6)	-	3.99e (-85)	-	7.00b (-20)	-	6.53b (-35.5)	-	3.63d (-68.7)	-
Garlic (1%)	6.30abc (-16.8)	6.00bc (-20)	8.97bc (-31.4)	9.00bc (-31)	13.17cd (-51)	12.25c (-55)	8.37ab (-4.8)	9.25ab (-7.5)	9.28a (-8.39)	10.00a (-13.86)	7.17b (-38.2)	7.62b (37.80)
Garlic (2%)	5.83abc (-23)	-	8.00c (-38.8)	-	11.53d (-57)	-	8.18ab (-6.9)	-	9.02a (-11)	-	6.68bc (-42.4)	-
Neem (1%)	7.20ab	7.00ab	11.10b	10.00b	16.71b	15.25b	7.92ab	8.50ab	7.36b	7.32b	6.05bc	5.61c

		(-4.89)	(-6.7)	(-15.1)	(-23)	(-38)	(-44)	(-9.9)	(-15)	(-27.3)	(-36.95)	(-47.8)	(-54.2)
Neem (2%)		6.40abc (-15.5)	-	9.37b (-28.3)	-	14.46c (-46)	-	7.22b (-18)	-	6.82b (-32.7)	-	5.76c (-50.3)	-
Bavistin DF (0.1%)	Positive control-1	6.03abc (-20.3)	6.00bc (-20)	8.07c (-38.3)	8.00cd (-38)	11.08d (-59)	10.25c (-62)	5.08c (-42)	5.00cd (-50)	3.00c (-70.4)	2.96c (-74.5)	0.67ef (-94.2)	0.00f (-100)
Bavistin DF (0.05%)		7.23ab (-4.49)	6.50abc (-13)	9.67bc (-26)	9.00bc (-31)	12.67cd (-53)	11.50c (-57)	5.17c (-41)	5.06cd (-49)	3.17c (-68.7)	3.25c (-72.01)	1.40e (-87.9)	2.00e (-83.7)
Potent 250 EC (0.1%)	Positive control-2	5.10c (-32.6)	5.50c (-27)	5.73d (-56.2)	6.00d (-54)	3.97e (-85)	3.00d (-89)	3.50d (-60)	4.00d (-60)	2.00c (-80.3)	2.50c (-78.47)	0.00f (-100)	0.00f (-100)
Potent 250 EC (0.05%)		5.07c (-33)	5.50c (-27)	5.83d (-55.4)	6.50d (-50)	4.03e (-85)	3.50d (-87)	4.00cd (-54)	5.12cd (-49)	2.07c (-79.6)	3.00c (-74.16)	0.00f (-100)	0.00f (-100)
Control (water)		7.57a	7.50a	13.07a	13.00a	26.82a	27.00a	8.79a	10.00a	10.13a	11.61a	11.60a	12.25a

Note: In a column, figures having same letter(s) do not differ significantly at 5% level of significance by Duncan's multiple range tests

DAT: Days after Transplanting

Data represent the means of three replications

Data in parentheses indicate % disease incidence reduction over control

(-) means Not tested in 2013

Table 1: Effect of different treatments on severity of brown spot and sheath blight disease of rice cultivar BRRI dhan29 in 2012 and 2013.

Functions	BAU-Biofungicide (2%) (1%)	Garlic clove (1%)	Neem leaf (1%)	Bavistin (0.1%) (Positive control-1)	Potent (0.1%) (Positive control-2)	Control
Seed (Tk.)	750/-	750/-	750/-	750/-	750/-	750/-
Preparation of land (Tk.)	7200/-	7200/-	7200/-	7200/-	7200/-	7200/-
Seed bed preparation (Tk.)	400/-	400/-	400/-	400/-	400/-	400/-
Fertilizer cost (Tk.)	13460/-	13460/-	13460/-	13460/-	13460/-	13460/-
Lay out & Transplantation	5000/-	5000/-	5000/-	5000/-	5000/-	5000/-
Weeding and irrigation (Tk.)	5000/-	5000/-	5000/-	5000/-	5000/-	5000/-
Cost of treatments (Tk.)	3150/-	2496/-	1696/-	3705/-	2741/-	-
Insecticide cost (Tk.)	800/-	800/-	800/-	800/-	800/-	800/-
Harvest cost (Tk.)	3000/-	3000/-	3000/-	3000/-	3000/-	3000/-
Cost of processing (Tk.)	1000/-	1000/-	1000/-	1000/-	1000/-	1000/-
Transportation cost (Tk.)	500/-	500/-	500/-	500/-	500/-	500/-
Others cost (Tk.)	1000/-	1000/-	1000/-	1000/-	1000/-	1000/-
Total cost of cultivation (Tk.)	41260/-	40606/-	39806/-	41815/-	40851/-	38110/-
Yield (kg/ha)	6325	5840	5670	6105	6470	5120
Sell price (Tk/ha)	94875/-	87600/-	85050/-	91575/-	97050/-	76800/-
Profit (Tk/ha)	53240/-	46994/-	45244/-	49760/-	56199/-	38690/-
(%) return over control	37.61	21.46	16.94	28.61	45.25	-

Benefit-Cost ratio	2.30:1	2.16:1	2.14:1	2.19:1	2.38:1	2.02:1
Note: Legends for costs: Labour: Tk.200/labour; Seed: Tk.30/kg; ploughing: Tk.2400/ha (one time); BAU Biofungicide: Tk.50/kg; garlic clove: Tk.64/kg; neem leaf: Tk. 40/kg; Bavistin: Tk.2500/kg; Potent: Tk.1850/litre; Urea: Tk.20/kg, TSP: Tk.24/kg, MP: Tk.17/kg, Zypsum:Tk.10/kg,, Zinc:Tk.220/kg, and rice sell price: Tk.15/kg.						

Table 2: Benefit-Cost Ratio (BCR) analysis of different treatments in controlling diseases of rice cultivar BRRI dhan29.

Treatment effect of seed borne pathogen

The seeds with different seed borne fungi were found to be observed, viz., *Alternaria padwickii*, *Alternaria tenuis*, *Aspergillus niger*, *B. oryzae*, *Nigrospora oryzae* and *Trichoderma harzianum* (Table 3). Harvested seeds showed 100% reduction of seed borne infections of A. padwickii both in BAU-Biofungicide (2%) and Potent (0.1%). Maximum reduction (70.37%) of Alternaria tenuis was recorded with BAU-Biofungicide (2% and 3%) followed by Bavistin (0.1%). Hundred per cent reduction of A. niger was found with BAU-Biofungicide (2 and 3%), Bavistin (0.1% and 0.05%) and Potent (0.1%) over untreated control. The highest reduction of seed borne infection of *B. oryzae* (76.47%) was observed in BAU-Biofungicide (3%) over control followed by BAU-Biofungicide (2%) and Potent 250 EC (0.1%). Seed borne infection of *N. oryzae* was not found with BAU-Biofungicide (2% and 3%).

Treatment (dose)		*Alternaria padwickii*		*Alternaria tenuis*		*Aspergillus niger*		*Bipolaris oryzae*		*Nigrospora oryzae*		*Trichoderma harzianum*	
		2012	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
BAU-Biofungicide (2%)		0.00e (-100.0)	0.0d (-100.0)	2.00d (-70.37)	2.00d (-66.67)	0.00e (-100.0)	1.00d (-66.67)	2.50e (-70.59)	2.00e (-66.67)	0.00f (-100.00)	1.00d (-78.95)	8.50a	0.0b
BAU-Biofungicide (3%)		1.00d (-66.67)	-	2.00d (-70.37)	-	0.00e (-100.0)	-	2.00e (-76.47)	-	0.00f (-100.0)	-	8.50a	0.0b
Garlic (1%)		1.75c (-41.67)	2.00a (-33.33)	6.50a (-3.70)	4.50bc (-25.00)	2.00c (-42.86)	2.00b (-33.33)	6.50b (-23.53)	4.25bc (-29.17)	1.50de (-25.00)	1.50cd (-68.42)	0.00c	0.0b
Garlic (2%)		1.00d (-66.67)	-	6.50a (-3.70)	-	0.00e (-100.0)	-	5.50c (-35.29)	-	2.00d (-0.00)	-	0.00c	0.0b
Neem (1%)		0.00e (-100.0)	1.00c (-33.33)	7.00a (-3.70)	5.50ab (-8.33)	3.00b (-14.29)	2.00b (-33.33	4.00d (-52.94)	3.50cd (-41.67)	7.50b (+275.0)	4.50a (-5.26)	0.00c	0.0b
Neem (2%)		2.00b (-33.33)	-	4.50bc (-33.33)	-	1.00d (-71.43)	-	4.00d (-52.94)	-	8.50a (+325.0)	-	4.50b	5.50a
Bavistin DF (0.1%)	Positive control-1	1.00d (-66.67)	1.00c (-33.33)	4.00c (-40.74)	3.00cd (-50.00)	0.00e (-100.0)	0.0e (-100.0)	8.50a (-0.00)	4.75b (-20.83)	1.00e (-50.00)	1.0d (-78.95)	0.00c	0.0b
Bavistin DF (0.05%)		2.00b (-33.33)	1.00c (-33.33)	4.25bc (-37.04)	3.50cd (-41.67)	0.00e (-100.0)	0.0e (-100.0)	8.50a (-0.00)	5.00ab (-16.67)	2.00d (-0.00)	2.50b (-47.37)	0.00c	0.0b
Potent 250 EC (0.1%)	Positive control-2	0.00e (-100.0)	0.00d (-100.0)	5.00b (-25.93)	3.75c (-37.50)	0.00e (-100.0)	1.0c (-66.67)	3.50d (-58.82)	2.25e (-62.50)	2.00d (-0.00)	1.0d (-78.95)	0.00c	0.0b
Potent 250 EC (0.05%)		2.00b (-33.33)	1.00c (-33.33)	6.25a (-7.41)	4.25c (-29.17)	2.00c (-42.86)	1.50c (-50.0)	5.00c (-41.18)	3.00de (-50.00)	2.00d (-0.00)	2.0bc (57.89)	0.00c	0.0b
Control (water)		3.00a	1.50b	6.75a	6.00a	8.50a	6.00a	8.50a	6.00a	3.50a	3.00a	0.00c	0.0b

Note: In a column, figures having same letter(s) do not differ significantly at 5% level of significance by DMRT

Data represent the means of four replications

Data in parentheses indicate % increased (+) and % decreased (-) over control

(-) means Not tested in 2013

Table 3: Effect of different treatments on seed borne fungi f rice cultivar BRRI dhan29 (blotter method) during Boro season in 2012 and 2013.

Test of quality seed

Maximum seed germination (97.00%) was noticed in treated with BAU-Biofungicide (3%), while BAU-Biofungicide (3%) resulted the highest (2284.10) vigour index. BAU-Biofungicide (2%) also signified the highest shoot weight (42.00 mg) and root weight (41.33 mg). The highest normal seedling (90.33%) and the lowest (3.00%) of diseased seedling were found to observe with BAU-Biofungicide (3%) as shown in Table 4.

Treatment (dose)		Germination (%)	Normal seedling (%)	Abnormal seedling (%)	Diseased seedling (%)	Germin. failure (%)	Shoot length (cm)	Root length (cm)	Shoot weight (mg)	Root weight (mg)	Vigour Index
BAU-Biofungicide (2%)		96.67ab (+15.08)	89.33a (+32.67)	4.00e (-42.86)	3.33f (-65.56)	2.33f (-74.11)	10.83a (+25.35)	12.67ab (+26.70)	42.00a (+27.27)	41.33a (+53.07)	2272.87a (+44.76)
BAU-Biofungicide (3%)		97.00a (+15.48)	90.33a (+34.16)	3.67e (-47.57)	3.00f (-68.98)	2.00f (-77.77)	10.78a (+24.77)	12.76a (+27.60)	41.67a (+26.27)	40.00ab (+48.15)	2284.10a (+45.47)
Garlic (1%)		90.67abc (+7.94)	79.33abc (+17.82)	6.33bc (-9.57)	5.00e (-48.29)	6.00bcd (-33.33)	8.99bcd (+4.05)	11.15cd (+11.50)	38.00ab (+15.15)	30.50de (+12.96)	1831.96bcd (+16.68)
Garlic (2%)		92.33abc (+9.92)	81.33ab (+20.79)	6.00bcd (-14.29)	5.00e (-48.29)	5.00de (-44.44)	9.59abc (+11.00)	11.38bcd (+13.80)	39.33ab (+19.18)	34.00cd (+25.93)	1932.974bc (+23.11)
Neem (1%)		88.00c (+4.76)	75.00bcd (+11.39)	6.67b (-4.71)	6.33cd (-34.54)	7.00b (-22.22)	9.13bcd (+5.67)	10.84cd (+8.40)	36.67bcd (+11.12)	31.00de (+14.81)	1756.48cde (+11.87)
Neem (2%)		90.33abc (+7.54)	78.67abc (+16.84)	5.67bcd (-19.00)	6.00cde (-37.95)	6.00bcd (-33.33)	9.53abc (+10.30)	11.00cd (+10.00)	37.67ab (+14.15)	34.33bc (+27.15)	1853.33bcd (+18.04)
Bavistin (0.1 %)	Positive control-1	90.33abc (+7.54)	78.67abc (+16.84)	4.67de (-33.29)	7.00c (-27.61)	5.67cd (-37.00)	10.30ab (+19.21)	12.08abc (+20.80)	38.67ab (+17.18)	38.00abc (+40.74)	2020.35b (+28.68)
Bavistin (0.05%)		88.33bc (+5.15)	75.00bcd (+11.39)	5.00cde (-28.57)	8.33b (-13.86)	6.67bc (-25.89)	9.67abc (+11.92)	11.23cd (+12.30)	37.00bc (+12.12)	37.00bc (+37.04)	1845.83bcd (+17.56)
Potent 250 EC (0.1%)	Positive control-2	89.67abc (+6.75)	65.33d (-2.97)	15.00a (+114.29)	9.33ab (-3.52)	4.33e (-51.89)	8.05d (-6.83)	10.48de (+4.80)	32.50d (-1.52)	34.50cd (+27.78)	1663.69de (+5.96)
Potent 250 EC (0.05%)		92.50abc (+10.12)	69.50bcd (-3.22)	14.67a (+109.57)	8.00ab (-17.27)	2.50f (-72.22)	7.93d (-8.22)	9.35e (-6.50)	32.50d (-1.52)	29.50e (+9.26)	1598.47de (+1.81)
Control (water)		84.00c	67.33cd	7.00cd	9.67a	9.00a	8.64cd	10.00de	33.00cd	27.00e	1570.11e

Note: In a column, figures having same letter(s) do not differ significantly at 5% level of significance by DMRT

Data represent the means of three replications

Data in parentheses indicate % increased (+) and % decreased (-) over control

DAS: Days after Sowing

Table 4: Effect of seed treatments with BAU-Biofungicide, extracts of garlic and neem, Bavistin and Potent on germination (%) and vigour index at 14 days after sowing of seeds of rice cultivar BRRI dhan29 following tray method.

Discussion

Determination of mycelial growth inhibition

Hassan et al. reported that Trichoderma species showed 100% reduction of radial growth of *B. oryzae in vitro* condition [27]. Similar findings were consisted with Khalili et al. [28]. The researchers as Parmar et al. and Dildey et al. reported that mycelial growth of *B. oryzae* was controlled by degrading the cell wall due to release of hydrolytic enzymes (chitinase and glucanase) [29,30]. Complete reduction of *B. oryzae* was observed in propiconazole (0.1%and 0.2%) at poisoned food technique method as reported by Naik et al. [31]. Similar findings were reported by Mahmud and Hossain [32]. Naik et al. also reported that Carbedazim 50% WP showed 46.81% and 51.70% inhibition of *B. oryzae* at 0.1%and 0.2% concentration, respectively [31]. Kumar et al. reported that propiconazole and carbendazim at 1000 ppm reduced complete mycelial growth of *R. solani* [33]. Naeimi et al. reported that Trichoderma species were found to be ubiquitous fungi having antagonistic activity against *R. solani* and found growth inhibition [34]. The Trichoderma spp. showed as the potential biocontrol agents and reduced *R. solani* through mycoparasitic or antibiosis as well as induced plant defense as reported by Abbas et al. [35].

Analysis and evaluation of disease severity, yield and cost of production

Tuli et al. reported that the lowest disease severity of brown spot was observed both in Tilt 250 EC 0.2% and Proud 25 EC 0.1% (propiconazole) and found the highest grain yield [36]. Spraying of *T. harzianum* in controlling brown spot disease significantly increased the grain yield (15.63%) over control as reported [37]. These findings were in accordance with the observation of Gomathinayagam et al. and Mahmud and Hossain [32,38]. França et al. reported that *Trichoderma asperellum* reduced disease severity of sheath blight and increased yield 41% under field condition when *Trichoderma* was applied as foliar spray [11]. Similar findings were supported by Costa et al. [39]. Uppala and Zhou reported that propiconazole was also more effective in reducing sheath blight disease in the field [40]. Muthukumar et al. reported that spraying of Carbendazim 50% WP @250-500 g/ha was found to have significant effect in controlling sheath blight disease caused by *Rhizoctoniasolani* and increased grain yield [41]. Mahmud and Hossain observed benefit cost ratios by 2.41:1 and 2.58:1 with application of BAU-Biofungicide (2%) and Potent (0.1%), respectively [32]. Total cost of production Tk 37,490 was obtained for 6020 kg/ha rice in BAU-Biofungicide (2%) and Potent (0.1%) conferred 6380 kg/ha with Tk 37,081 as also reported by Mahmud and Hossain [32]. BAU-Biofungicide (2%) was found to show lower cost of production as an alternative potential option in avoiding chemical fungicides that caused environmental pollution.

Infection of seed borne pathogen estimation

Talapatra et al. reported that Trichodermaviride was tested against *Alternaria sp* and *Trichoderma* showed the maximum inhibitory effect [42]. Mahmud and Hossain also observed antagonistic activity of *T. harzianum* on A. padwikii which is in agreement with our study [43]. The species of *Trichoderma* was evaluated against *Alternaria tenuissima* and exhibited the highly antagonistic activity as reported by Ambuse et al. [44]. *T. asperellum* caused a significant reduction 66.6% as well as antagonistic effect over A. niger strains as defined by Lima et al. [45]. Similar findings were supported by Romero-Cortes et al. [46]. Prajapati et al. reported that propiconazole 1000 ppm and bavistin 25% completely inhibited the mycelial growth of A. niger [47]. The compliance with the observation of Sarkar et al. who evaluated the efficacy of *T. harzianum* against *B. oryzae* and recorded inhibited growth of rice brown spot pathogen [48]. Naik et al. also reported that the growth of *B. oryzae* was reduced by propiconazole [31]. The *Trichoderma* isolates had a greater inhibition in mycelial growth of *N. oryzae* in dual cultures as studied of Ali et al. [49].

Evaluation of seed quality

Doni et al. reported that *Trichoderma*spp was found to increase seed germination rate, seedling growth and vigour index in *Trichoderma* treated rice seeds [50]. Similar findings were also reported by Mahmud and Hossain [43]. They reported that the highest shoot weight, maximum root weight and highest reduction of diseased seedling were observed with BAU-Biofungicide (3%). The results showed consensus with the reports of other researchers viz., Doni et al. and Hossain et al. [50,15]. Notably, *Trichoderma* marked significant higher germination and plant growth, less disease infection, and enhancement of yield and quality through seed invigoration of rice [18,50,32]. Nevertheless, BAU-Biofungicide (2%) was found to be more effective in reducing disease severity as well as reduced cost of production with BCR in the filed as foliar spray and protecting seed borne pathogens as of propiconazole 250 EC (0.1% and 0.05%).

Conclusion

Evidently, BAU-Biofungicide showed significant effect in increasing seedling growth and vigor index in treated seeds, and enhanced grain yield with BAU-Biofungicide sprayed plot among the treatments. Consecutively, the effect of Trichoderma encodes its attributed antagonistic potentiality in increasing grain yield and plant growth development.

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