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Evaluation of B and Zn Fertilizer Solution Sprays on the Foliage for Management of Blast of Rice Under Natural Epiphytotic Condition

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ABSTRACT

Foliar application of B and Zn fertilizer solutions was evaluated for the management of blast of rice disease under natural condition in the field. Three times fertilizer solutions were sprayed on the foliage of rice plants cv. BRRI dhan49 to examine their influence on the growth parameters, yield parameters, and incidence of blast disease. Characteristics leaf blast symptoms appeared both in control and treated plants at 60 DAT. The blast incidence increased with time and recorded the highest at 120 DAT. Foliar spraying of B and Zn fertilizer significantly increased all growth and yield parameters and reduced disease parameters at all stages of plant growth. All combinations of B and Zn fertilizer solutions sprayed on the foliage slowed down the blast incidence at all growth stages of rice plant. At panicle initiation stage (60 DAT) 71.65% and 75.69 % incidence was reduced in T_5 (Foliar application of Zn fertilizer @5 kg/ha) and T_6 (Foliar application of B and Zn fertilizer @ 2 kg/ha and 4 kg/ha) compared to untreated control. At flowering stage (90 DAT) 83.48 % and 86.65 % reduction in disease incidence was found in T_6 (Foliar application of B and Zn fertilizer @ 2 kg/ha and 4 kg/ha) and T_7 (Foliar application of B and Zn fertilizer @ 3 kg/ha and 5 kg/ha).At 120 DAT, 80.31% and79.94 % reduction was found in T_6 (Foliar application of B and Zn fertilizer @ 2 kg/ha and 4 kg/ha) and T_7 (Foliar application of B and Zn fertilizer @ 3 kg/ha and 5 kg/ha).A significant increase (21.00 % over control) in total no. grain/ panicle was found in T_6. Foliar spraying of B and Zn fertilizer solution is proved to be effective either @ 2 and 4 kg/ha (T_6) or @ 3 and 5 Kg/ha (T_7) on the foliage is effective considering lower blast disease incidence as well as total hill/plot, no. of infected hill/plot, no. of tillers/hill, no. of infected tiller/hill, total panicle/hill, no. of infected panicle/hill and total grain/panicle.

Introduction

Rice is the staple food in Bangladesh. Rice crop is reported to attack by 50 diseases include 6 bacterial, 21 fungal, 4 nemic, 12 viral and 7 miscellaneous diseases and disorders (Hollier *et al*., 1993; Webster and Gunnell, 1992; Jabeen *et al*., 2012). Among 43 diseases of rice 12 diseases were reported as major in Bangladesh (BRRI, 2014). Rice blast is considered as the main constraints for rice production in Bangladesh now-a-days which can cause 80-100% average yield loss (BRRI, 2014). Rice blast caused by *Magnaporthe oryzae* (anamorph: *Pyricularia oryzae*) that can develop symptoms on all parts of the plant, including leaves, leaf collars, necks, panicles, pedicels, and seeds (Zhang *et al*., 2016). Rice blast is prevalent in Bangladesh because the temperature, relative humidity, leaf wetness duration are very much favorable for growing of this pathogen. In Bangladesh the night temperature in Boro season goes below to 25^0C and also relative humidity goes above 95%, those two conditions are very favourable for incidence of rice blast (Bevitori *et al*., 2015). Farmers used to spray chemical fungicides like Nativo (a combination of Tebuconazole and Trifloxystrobin) for controlling this disease. The fungicides are not much effective for blast disease management in the recent years and in some areas “neck blast” caused almost 100% yield loss (Anonymous, 2011).

Balanced nutrition plays vital role in achieving better yield in crop production and also protect the crops from new infection (Agrios, 2005; Narayanasamy, 2002). On the other hand, micronutrients require relatively low quantity but are very essential for proper growth and development of plants. They are not only required for growth and development of plants, but also protect them from diseases and disorders. Copper (Cu) and

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boron (B) are two micronutrients which play great roles in securing rice production but these have been neglected by farmers. Dobermann and Fairhurst (2000) reported that Cu deficiency causing restricted emergence of new leaves in rice reduced tillering and promoted pollen sterility, while deficiency of B in rice also resulted in stunted growth and reduction in the number of panicles. In rice, application of silicon, zinc and boron can control blast of rice (Huber *et al.,* 2012; Marschner, 1986).

Soil application of boron (B) is reported to be involved in keeping cell wall structure and maintaining membrane function (Marschner, 1995). Cell membrane and wall is strengthened with cross-linked polymer to restrict the invasion of vascular pathogens (Stangoulis and Graham, 2007). Root diseases of tomato caused by *Macrophomina phaseolina*, *Fusarium solani*, and *Rhizoctonia solani* were reduced by increasing soil concentrations of zinc from 0 to 1.6 mg Kg^{-1}(Siddiqui *et al*., 2002). Zinc fertilization increased foliar zinc levels but had only a slight beneficial effect against *Phytophthora infestans* on tomato (Smith, 1951); this result may indicate that the plant incorporated zinc was not bio-available. *Rhizoctonia* root rot of cowpea, caused by *R. solani* and *R. bataticola* was reduced by over 44% by amendment with zinc sulfate at a concentration of 20 µg g^{-1} of soil and root rot of chickpea was reduced by zinc fertilization (Gaur and Vaidya 1983). Zinc levels influence *Mycosphaerella pinodes*, *Phoma medicaginis* var. *pinodeula* and *Peronospora viciae* on pea (Davidson and Ramsey, 2000).

Contrasting to chemical control, blast disease control by fertilizer management will be an eco-friendly, cost-effective and sustainable strategy to ensure better yield. Therefore, the present study was undertaken to know the effect of foliar application of B and Zn fertilizer solution to reduce the incidence of blast disease of rice.

Materials and Methods

The experiment was conducted in the farmer's field, in Krishnanagar, Kaliganj upazilla, in the district of Satkhira which was one of the hotspots for rice blast disease in 2016. The experiment was carried out during Aman season started from July, 2017 and ended in December, 2017. The soil series in the field plots belongs to AEZ-13 (coastal cluster) which is subjected to salinity, mostly because the siltation of coastal mudflats due to continued sedimentation and saline tidal effect having acid sulphate type of soil. This area has been cultivated with rice for many tears, where farmers widely use chemical fertilizers and pesticides. The farmers generally practice rice cultivation considering different rice varieties. The rice variety used in this experiment was BRRI dhan49. Sixty three experimental plots consisting of 10 m^2 in area (2.5 meter wide by 4 meter long) with an additional of 1 meter width planted next to the adjacent plot as buffer zone were lined out in the field and arranged in randomized complete block design (RCBD). Nitrogen (N), phosphorous (P) and potassium (K) fertilizers were applied based on the standard recommended rate in all the treatments. The micronutrients Ravrel Zinc (Chillated zinc) and Solubor plus for Boron were bought from the local market and mixed with water to make fertilizer solution for spraying onto the foliage. Standard rate of Zinc and Boron @ 4 kg and 2 kg per hectare respectively were applied into the soil during final land preparation. For foliar application the standard way of applying micronutrient is 100 g of each micronutrient was mixed with 1 liter of water and then sprayed onto the foliage. Data were collected at different growth stage *viz.* tillering stage, panicle initiation stage, flowering stage and after harvesting. Seven treatment combinations such as T_0 = Control, T_1 = B and Z fertilizer in soil application (2 and 4 kg/ha), T_2 = Foliar application of B (2 kg/ha), T_3 = Foliar application of B (3 kg/ha), T_4 = Foliar application of Zn (4 kg/ha), T_5 = Foliar application of Zn (5 kg/ha), T_6 = Foliar application of B and Zn (2 and 4 kg/ha), T_7 = Foliar application of B and Zn (3 and 5 kg/ha) were considered in the experiments.

Throughout the plants growth period, adequate plant protection measures were taken to avoid yield loss due to weeds and pests. However, there was no fungicide application throughout the experimental period and this was done to provide natural fungal disease infestation. Data were collected on the following parameters: Total hill per plot, No. of infected hill, Tillers per hill, No. of infected tillers per hill, No. of leaves per hill, No. of diseased leaves per hill, Percent leaf area infection. The leaf area infected by disease was monitored and the percentage of leaf area infected was estimated according to the method modified from International Rice Research Institute, IRRI (2002).

Blast incidence was recorded at 60 DAT (leaf blast), 90 DAT (panicle blast) and 120 DAT (Panicle blast) by observing the symptoms in the field. Randomly 10 hills were selected for recording the incidence of blast disease for each replication of all treatments according to scale (IRRI, 2002) for calculation. For proper identification, representative diseased samples were collected and immediately confirmed it by making temporary slides in the laboratory. Where necessary, the infected plant tissues were placed on moistened blotter paper for incubation under alternating cycle of darkness and NUV light (12/12) for 3-4 days and observed it under stereo-binocular microscope. Temporary slides were prepared for observing the conidia of the pathogen.

Disease incidence was calculated by following the formula (IRRI, 2002):

Disease incidence: $\frac{n(3) + n(5) + n(7) + n(9)}{tn} \times 100$

where, n(3), n(5), n(7) and n(9) = number of plants showing a reaction in a scale (3), (5) (7), (9), respectively; tn = total number of plants scored (Table 1).

Table 1. Scale of Blast disease of rice (IRRI, 2002)

Scale for leaf blast		Scale for panicle blast	
0	No lesions observed	0	No visible lesion or observed lesions on only a few pedicels
1	Small brown specks of pin-point size or larger brown specks without sporulating center	1	Lesions on several pedicels or secondary branches
2	Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin		
3	Lesion type is the same as in scale 2, but a significant number of lesions are on the upper leaves	3	Lesions on a few primary branches or the middle part of panicle axis
4	Typical susceptible blast lesions 3 mm or longer, infecting less than 4% of the leaf area	5	Lesion partially around the base (node) or the uppermost internode or the lower part of panicle axis near the base
5	Typical blast lesions infecting 4-10% of the leaf area		
6	Typical blast lesions infection 11-25% of the leaf area	7	Lesion completely around panicle base or uppermost internode or panicle axis near base with more than 30% of filled grains
7	Typical blast lesions infection 26-50% of the leaf area		
8	Typical blast lesions infection 51-75% of the leaf area and many leaves are dead	9	Lesion complete around panicle base or uppermost internode or the panicle axis near the base with less than 30% of filled grains.
9	More than 75% leaf area affected		

To record yield contributing characters, ten tillers were randomly sampled within the experimental plot at maturity to determine the yield components, such as the number of spikelets per panicle, the percentage of filled grain and 1,000-grain weight. The rice grain yields were obtained by harvesting all the plants in the experimental plot.

Data collected were subjected to the analyses of variance (ANOVA), performed using the MSTAT-C programme to determine the statistical significance of the effect of the treatments. When the F-values were significant, the Fisher's Least Significant Difference, LSD test was performed for mean comparison (Gomez and Gomez, 1984). The mean was ranked by Duncan's Multiple Range Test (DMRT).

Results

Disease parameters of blast and vegetative parameters of rice at panicle initiation stage (60 DAT)

Effect of Zn and B fertilizer solution spray on various disease parameters of blast and vegetative parameters of rice was monitored at panicle initiation stage (60 DAT) (Table 2). Significant influence was found in all treatment combinations on different disease parameters and vegetative growth parameters of rice except total hill/plot. The maximum number of hill/plot was observed at T_7 (foliar application of B @ 3kg/ha and Zn @ 5kg/ha) followed by T_5 (foliar application of Zn @ 5kg/ha) and T_6 (foliar application of B @ 2kg/ha and Zn @ 4kg/ha). The minimum number of hill/plot was observed at T_0 (control). Variation in no. infected hill/plot, no. of tillers/hill, no. of infected tillers/hill, no. of leaves/hill, no. of infected leaves/hill and % leaf area infected was also significant at 60 DAT for different treatment combinations (Table 1).The highest no. of infected hill/plot (20.67) was recorded in untreated control plot (T_0), while the lowest infected hill/plot (2.66) was recorded in T_2.Statistically similar results were also found in T_5 (4.00) and T_6 (3.33).No. of tillers/hill was recorded highest and identical in T_6 (12.66) and T_7 (12.66). Untreated control yielded the lowest no. of tiller/hill (10.67). Number of infected tiller/hill was found in control treatment (3.66), while the lowest and statistically similar infected tiller/hill (0.67) was found in T_2, T_3, T_4 and T_5. Number of leaves/hill was found highest in T_1 (56.67) followed by T_7 (54.67) and T_6 (53.33). The highest no. of infected leaves/hill was found in control treatment T_0 (2.33). Rest of the treatments showed the lowest and statistically similar no. of infected leaves except T_1 (1.67). The highest % leaf area infected was recorded in control treatment T_0 (1.27), while the lowest and statistically similar results were obtained in T_3 (0.21) and T_2 (0.22).

Disease parameters of blast and vegetative parameters of rice at flowering stage (90 DAT)

Spraying of Zn and B fertilizer solution in different treatments showed significant variation on disease parameters of blast and yield contributing characters of rice at 90 DAT except total hill/plot (Table 3). The highest no. of hill/plot was found in T_7 (63.33), while the lowest no. of hill/plot was found in T_0 (60.00) and T_4 (60.00). No. of infected hill/plot was found highest in control treatment T_0 (33.00). Statistically similar and lowest no. of infected hill/plot was found in T_6 (12.33) and T_7 (11.67). The highest no. of tillers/hill was found in T_7 (16.67) followed by T_5 (15.33) and T_6 (15.33). No. of infected tillers/hill was highest in T_0 (9.33), while the lowest no. of infected tillers/hill was recorded in T_7 (3.33) followed by T_6 (3.66). Total panicle/hill recorded highest in T_7 (16.33), while rest of the treatments showed similar effect. The highest healthy panicle/hill was found in T_6 (11.67) followed by T_7 (9.00), T_5 (9.00) and T_3 (9.00).The highest infected panicle/hill was found in untreated control (9.33), however, the lowest infected panicle/hill were found in all treatment which were statistically similar.

Table 2. Effect of B and Zn fertilizer solution spray on blast and plant growth parameters of rice at panicle initiation stage (60 DAT)

Treatments	Total hill/plot	No. of infected hill/plot	No. of tillers/hill	No. of infected tillers/hill	No. of leaves/hill	No. of diseased leaves/hill	% Leaf area infection
T_0	60.00	20.67a	10.67 c	3.66 a	49.67 cd	2.33 a	1.27 a
T_1	60.33	14.67 b	12.33 ab	3.00 b	56.67 a	1.67 b	0.72 b
T_2	60.67	2.66 e	11.00 bc	0.67 d	50.00 cd	1.00 c	0.22 d
T_3	61.00	6.00 d	12.00 abc	0.67 d	51.00 c	1.00 c	0.21 d
T_4	60.00	6.00 d	10.67 c	0.67 d	48.67 d	1.00 c	0.33 c
T_5	62.67	4.00 e	11.33 abc	0.67 d	50.00 cd	0.67 c	0.33 c
T_6	62.67	3.33 e	12.67 a	1.67 c	53.33 b	1.00 c	0.78 b
T_7	63.33	9.00 c	12.67 a	1.67 c	54.67 b	0.67 c	0.69 b
$LSD_{0.05}$	3.61	1.65	1.31	0.513	1.77	0.395	0.096
CV (%)	2.44	11.33	6.45	18.52	1.96	19.32	9.10

T_0 = Control, T_1 = B and Z fertilizer in soil application (2 and 4 kg/ha), T_2 = Foliar application of B (2 kg/ha), T_3 = Foliar application of B (3 kg/ha), T_4 = Foliar application of Zn (4 kg/ha), T_5 = Foliar application of Zn (5 kg/ha), T_6 = Foliar application of B and Zn (2 and 4 kg/ha), T_7 = Foliar application of B and Zn (3 and 5 kg/ha). Mean differences were compared by analysis of variance (ANOVA) and compare each other following Duncan's Multiple Range Test (DMRT) at P = 0.05

Table 3. Effect of B and Zn fertilizer solution spray on blast and yield contributing parameters of rice at flowering stage (90 DAT)

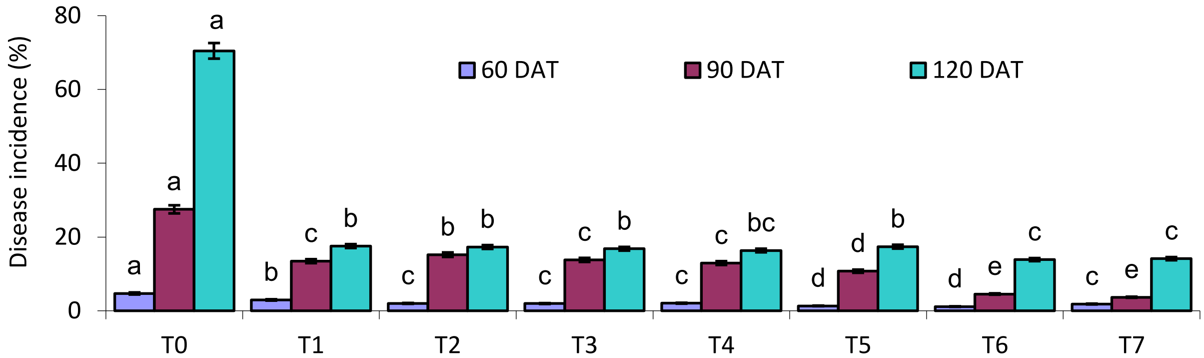
Treatments	Total hill/plot	No. of infected hill/plot	No. of tillers/hill	No. of infected tillers/hill	Total panicle/hill	Healthy panicle/hill	Infected panicle/hill
T_0	60.00	33.00 a	13.67 c	9.33 a	12.33 b	4.00 c	9.33 a
T_1	60.33	23.33 b	14.33 bc	5.66 b	13.33 b	8.66 b	4.66 b
T_2	60.67	23.33 b	13.67 c	5.33 bc	13.33 b	8.00 b	4.33 b
T_3	61.00	22.00 b	15.00 bc	5.66 b	13.33 b	9.00 b	4.33 b
T_4	60.00	26.67 b	14.67 bc	5.00 bcd	12.67 b	8.66 b	4.16 b
T_5	62.67	26.33 b	15.33 ab	5.33 bc	13.67 b	9.00 b	4.66 b
T_6	62.67	12.33 c	15.33 ab	3.66 cd	14.00 b	11.67 a	4.66 b
T_7	63.33	11.67 c	16.67 a	3.33 d	16.33 a	9.00 b	4.66 b
$LSD_{0.05}$	2.61	5.40	1.41	1.59	1.53	1.12	1.30
CV (%)	2.44	13.80	5.43	16.79	6.41	7.54	14.52

T_0 = Control, T_1 = B and Z fertilizer in soil application (2 and 4 kg/ha), T_2 = Foliar application of B (2 kg/ha), T_3 = Foliar application of B (3 kg/ha), T_4 = Foliar application of Zn (4 kg/ha), T_5 = Foliar application of Zn (5 kg/ha), T_6 = Foliar application of B and Zn (2 and 4 kg/ha), T_7 = Foliar application of B and Zn (3 and 5 kg/ha). Mean differences were compared by analysis of variance (ANOVA) and compare each other following Duncan's Multiple Range Test (DMRT) at P = 0.05

Table 4. Effect of B and Zn fertilizer solution spray on blast and yield contributing parameters of rice at flowering stage (120 DAT)

Treatments	Total panicle/hill	Length of panicle (cm)	Healthy panicle/hill	Infected panicle/hill	Healthy looking grain/panicle	Total grain/panicle
T_0	12.33 b	26.63 c	4.00 c	9.33 a	41.33 e	140.00 d
T_1	13.33 b	26.97 c	8.66 b	4.66 b	116.00 d	140.70 d
T_2	13.33 b	27.93 bc	8.00 b	4.33 b	118.00 d	142.70 d
T_3	13.33 b	26.87 c	9.00 b	4.33 b	125.30 cd	150.70 c
T_4	12.67 b	27.20 bc	8.66 b	4.16 b	129.70 bc	155.00 bc
T_5	13.67 b	30.50 ab	9.00 b	4.66 b	128.30 c	155.30 abc
T_6	14.00 b	33.70 a	11.67 a	4.66 b	138.70 b	161.00 a
T_7	16.33 a	32.53 a	9.00 b	4.66 b	149.00 a	158.00 ab
$LSD_{0.05}$	1.53	3.26	1.12	1.30	9.10	5.51
CV (%)	6.41	6.41	7.54	14.52	4.39	2.09

T_0 = Control, T_1 = B and Z fertilizer in soil application (2 and 4 kg/ha), T_2 = Foliar application of B (2 kg/ha), T_3 = Foliar application of B (3 kg/ha), T_4 = Foliar application of Zn (4 kg/ha), T_5 = Foliar application of Zn (5 kg/ha), T_6 = Foliar application of B and Zn (2 and 4 kg/ha), T_7 = Foliar application of B and Zn (3 and 5 kg/ha). Mean differences were compared by analysis of variance (ANOVA) and compare each other following Duncan's Multiple Range Test (DMRT) at P = 0.05



T_0 = Control, T_1 = B and Z fertilizer in soil application (2 and 4 kg/ha), T_2 = Foliar application of B (2 kg/ha), T_3 = Foliar application of B (3 kg/ha), T_4 = Foliar application of Zn (4 kg/ha), T_5 = Foliar application of Zn (5 kg/ha), T_6 = Foliar application of B and Zn (2 and 4 kg/ha), T_7 = Foliar application of B and Zn (3 and 5 kg/ha)

Figure1. Effect of different treatments on blast incidence of panicle initiation (60 DAT), flowering stage (90 DAT) and harvesting stage (120 DAT). Mean differences were compared by analysis of variance (ANOVA) and compare each other following Duncan's Multiple Range Test (DMRT) at P = 0.05

Disease parameters of blast and vegetative parameters of rice at mature stage (120 DAT)

At 120 DAT, disease parameters and yield contributing characters showed significant variation due to Zn and B fertilizer solution spray on the foliage (Table 4). Total panicle/hill was significantly higher in T_7 (16.33) than other treatments including control treatment. The lowest panicle/hill was recorded in control treatment (12.33). Significantly higher length of panicle was recorded in T_5 (30.5), T_6 (33.7) and T_7 (32.53). The highest panicle length was found in T6 (33.7), while the lowest panicle length was recorded in T_0 (26.63). Healthy panicle/hill was significantly higher in T_6 (11.67), while the least healthy panicle/hill was found in untreated control (4.00). All the treatment combinations showed significant variation in infected panicle/hill compared untreated control. Healthy looking grain/panicle was significantly higher in T_7 (149.00) followed by T_6 (138.7). Total grain/panicle significantly varied in different treatment combination. Statistically similar and higher total grain/panicle was found in T_6 (161.00), T_7 (158.00) and T_5 (155.3). The lowest total grain/panicle was found in T_0 (140.00).

Incidence of blast of rice at different growth stages

At 60 DAT incidence of blast was the highest in untreated control which was below 5% and gradually increase at 90 and 120 DAT, while the lowest and statistically similar incidence was found in T_6 and T_5 (Fig. 1). Incidence of blast at 90 DAT was the highest (27.50) in control plot whereas statistically similar and lowest incidence was found in T_7 (3.67 %) and T_6 (4.45 %). Among all the treatments, blast incidence was the highest at 120 DAT (70.47 %) and the lowest disease incidence was recorded in T_6 (13.87 %) and T_7(14.13 %).

Discussion

Foliar application of fertilizer solution is not the alternative of soil application. But, many researchers found greater absorption of nutrient when spray on the foliage and induce rapid physiological alternation to develop defense against pathogens (Kaya and Higgs,2001; Mishra and Singh, 2017). The foliar applications of micronutrients promote plant growth with good effects on yield and crop production. Foliar application of silicon was found most effective in rice cultivation @ 20-80 mg Si/L (Agostinho *et al*., 2017).

Boron and zinc are two important micronutrients that are required for optimum growth and development of plants as well as necessary to defend the pathogenic invasion. Zn is poorly available to the plants in soil solution. Generally, most of the fertilizers are applied into the soil for better uptake and utilization. On the other hand, Boron promotes stability and rigidity of the cell wall structure and therefore supports the shape and strength of the plant cell (Brown *et al*., 2002). In the present study, both Zn and B fertilizer solution spraying on the foliage showed significant influences on disease parameters and different parameters of plant growth and yield. Up to 60 DAT, the disease appeared only on the foliage and the incidence is not high. Incidence of blast gradually increased with time and the highest incidence was recorded at 120 DAT. At 60 DAT, no. of hill/plot did not vary for different treatment combinations. These findings are similar to the observation of Joshi *et al*. (2007) who evaluated the efficacy of silicon and boron on vegetative growth of rice. They observed that there is no significant difference among the number of hill/plot on silicon and boron sprays at different rate.

Other vegetative and disease parameters were significantly influenced by foliar application of Zn and B fertilizer solutions. In a recent study by Sharma and Shukla (2020) reported that trace elements i.e. Zinc (Zn), Boron (B), Magnesium (Mg) and Copper (Cu) affect the growth and sporulation of *Pyricularia oryzae.* They found that Zinc, Boron and Copper are most effective and promote growth and sporulation at 2 ppm concentration but increasing the concentration of these elements in the medium, growth and sporulation decreased. The maximum sporulation was recorded at 2 ppm concentration of Boron. With the increasing concentration of Boron hyphal growth and sporulation both decrease. High concentration i.e. 20 ppm has a more adverse effect of growth and sporulation. They further reported that Zn was required in very minute quantity i.e. 2 ppm for the optimum growth of the fungus and keeps an adverse effect on growth when provided in more than 2 ppm. It is clear that both Boron and Zinc fertilizer has direct growth suppressive effect against *M. oryzae* which is relevant with the findings of present research where foliar spraying of Zinc and Boron fertilizer reduced the blast disease incidence which might be due to suppression of *M. oryzae* on the foliage and panicle. Micronutrients can significantly influence the disease parameters. No. of diseased leaves/hill of rice BRRI dhan49 significantly varied in different treatments. The highest no. of diseased leaves/hill was recorded in T_0 (control) and the lowest no. of diseased leaves/hill were founded in T_5 (foliar application of Zn @ 5kg/ha). The application of Zinc reduces the infection in the leaves because it synthesizes protein and starch which protect against oxidative damage through detoxification of superoxide radicals and it inhibits the pathogenic attack. Manandhar *et al*. (1998) evaluated the efficacy of foliar application of micronutrients zinc and silicon against blast of rice. They found that silicon and zinc has some role against the pathogen of blast disease. Silicon accumulates flavonoid and diterpenoid phytoalexins which destroy the fungal cell walls and zinc has adverse effects on the pathogen directly.

In this experiment the highest percent of incidence was found at control plot at 60, 90 and 120 DAT where no micronutrient was applied. The lowest percent incidence was found in T_5 (foliar application of Zn @ 5 kg/ha) and T_6 (foliar application of B @ 2 kg/ha and Zn @ 4 kg/ha) at 60 DAT and T_6 (foliar application of B @ 2 kg/ha and Zn @ 4 kg/ha) and T_7 (foliar application of B @ 3 kg/ha and Zn @ 5 kg/ha) at 90 and 120 DAT. So, from these findings we can conclude that T_6 (foliar application of B @ 2 kg/ha and Zn @ 4 kg/ha) and T_7 (foliar application of B @ 3 kg/ha and Zn @ 5 kg/ha) are the best treatments for lowering the blast incidence. In T_6 Boron and Zinc were applied combined at the rate of 2 kg/ha for boron and 4 kg/ha for zinc. In T_7 boron and zinc were also applied in combination at the rate of 3 and 5 kg/ha. So, this rate of application (T_6 and T_7) is more effective in reducing the incidence of rice blast.

Application of micronutrients can reduce the incidence and severity of the rice blast and some other foliar diseases. Hooda and Srivastava (1998) also found that low silicon, zinc and boron uptake has been proved to increase the susceptibility of rice to diseases such as rice blast, leaf blight of rice, brown spot, stem rot and grain discoloration. He suggested that silicon and zinc application at the rate of 3kg/ha is effective for reducing rice blast disease. Hooda and Srivastava (1998) further mentioned that application of Silicon in the rice plants results accumulation of antifungal compounds which can degrade fungal and bacterial cell walls and Zinc breaks amino acids and reducing sugars which inhibit fungal attraction to the plants. Galbieri and Urashima (2008) found that, Zinc was found to have a number of different effects as in some cases it decreased, in others increased, and in others had no effect on plant susceptibility to disease.

Galbieri and Urashima (2008) found that, in most cases, the application of Zn reduced disease severity, which could be because of the toxic effect of Zn on the pathogen directly and not through the plant's metabolism. Brown *et al*. (2002) found that, B has a direct function in cell wall structure and stability and has a beneficial effect on reducing disease severity. Boron strengthens the cell membrane permeability, stability or function. It also integrates plasma membrane and has metabolism of phenolics or lignin which suppress the pathogenic attack.

Conclusion

Application of B and Zn fertilizer solution on the foliage shows promising response in promoting different growth parameters and reducing disease incidence of rice cv. BRRI Dhan 49. In the present experiments, it is found that treatments T_6 [Foliar application of B and Zn fertilizer (2 and 4 kg/ha)] and T_7 [foliar application of B and Zn fertilizer (3 and 5 kg/ha)] showed better performance for management of rice blast compared to untreated control in the field condition. This experiment emphasizes the necessity to conduct similar experiments considering other popular rice cultivars at different agro-climatic zones to have comprehensive recommendations for the farmers. Moreover, experiments under artificial inoculated condition with the similar treatments may also validate the outcomes of field experiments.

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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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