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Research Article

Silicon Supplements Potentially Reduce the Sheath Blight Incidence and Severity in Rice (*Oryza sativa* L.)

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Abstract

Sheath Blight (ShB) disease causes up to 50% yield losses of rice depending on severity. Silicon (Si) is a beneficial nutrient for rice having the ability to protect against diseases. So, a pot experiment was carried out at the Bangladesh Institute of Nuclear Agriculture (BINA) Headquarters Farm, Mymensingh from July to November 2021 with artificial inoculation of *Rhizoctonia solani* to study the effect of different Si supplements and their doses on rice ShB incidence and severity. The experiment was laid out in a completely randomized design (CRD) with three replications. The treatments were T_0 (without Si), T_1 (K_2SiO_3 2 mM), T_2 (K_2SiO_3 4 mM), T_3 (K_2SiO_3 6 mM), T_4 ($CaSiO_3$ 2 mM), T_5 ($CaSiO_3$ 4 mM), T_6 ($CaSiO_3$ 6 mM), T_7 ($MgSiO_3$ 2 mM), T_8 ($MgSiO_3$ 4 mM), and T_9 ($MgSiO_3$ 6 mM), respectively. The application of different Si supplements showed a significant positive effect on the growth, yield contributing characters, and yield of rice. The highest yield was found at T_6 treatment. Disease incidence and severity matrix were significantly reduced due to the application of different Si supplements. The minimum disease incidence and severity matrix were found at T_6 treatment. The maximum disease incidence and severity matrix reduction was 35.27% and 54.3% at T_6 treatment over control which was identical to T_3, T_7, and T_8, respectively. The overall disease incidence and severity matrix reduction over control was 24.68% and 35.59%. Again, the highest nutrient concentration was found in different Si supplement treatments over control. Overall, $CaSiO_3$ showed the higher performance than K_2SiO_3 and $MgSiO_3$. So, the application of $CaSiO_3$ 6 mM may be an advisable option for the management of ShB disease of rice.

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world and sustains about two-thirds of the world's population (Rana et al., 2020). The majority of the rice (90%) is being produced in Asian countries. Bangladesh is the 3rd highest rice producer in the world (FAOSTAT 2021). By the year 2100, the world population is expected to increase by 50% (Emerick and Ronald, 2019). So, rice production must increase by at least 25% by 2030 to keep pace with the ever-increasing population (Li et al., 2014). The increased rice production must be achieved using less land, less water, and under more severe environmental stresses due to climate change and disease pressures. One of the major bottlenecks in achieving food security is the diseases caused by various pathogens that account for yield losses of several magnitudes.

Sheath blight caused by the soil-borne fungal pathogen *Rhizoctonia solani* Kuhn AG1-IA, is the second most devastating disease of rice, causing up to 50% yield losses depending upon the severity (Mishra et al., 2020). Breeding for resistance against ShB has not been successful due to a lack of sources of resistant genes (Hashiba and Kobayashi., 1996). Resistance source against the ShB disease of rice is not available in Bangladesh and anywhere (Jalaluddin et al., 2000). Consequently, none of the high-yielding varieties is resistant to ShB neither in Bangladesh nor elsewhere in the world.

The use of chemical fungicides and cultural practices is more common to control the ShB since resistance breeding remains unsuccessful owing to the fact that there is still no resistance resource available in the

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present germplasm (Molla et al., 2020). Plant cells contain mineral nutrients and they regulate enzymatic activity which is related to plant metabolism associated with resistance and virulence against pathogens. The balanced nutrition of plants develops disease resistance (Huber and Haneklaus, 2007). Silicon (Si) is a nutritional element that has the ability to prevent pathogen attacks. Many varieties of plants benefit from Si intake from a wide range of pathogens. The mechanisms involved are unknown, but they are thought to be caused by amorphous silica precipitation in plants as a mechanical barrier (Wang et al., 2017). Plant defensive systems, such as lignin phenolic compounds and phytoalexins, are likewise strengthened by Si (Ahanger et al., 2020; Ahammed et al., 2021). When harmful fungi attack the plant, Si either indirectly via sequestering cations or directly by boosting protein activity promotes a rapid and widespread deployment of the plant's natural defenses (Guntzer et al., 2012). In the last few years, it has been proved that Si develops mechanisms in plants against biotic stress (Reynolds et al., 2016). Rice accumulates Si and Si concentrations above 10% of the dry weight of the shoot (Yamamoto et al., 2012). Savant et al. (1997) reported that Si addition to the soil improves soil health and rice yield, particularly in areas where soils are low in plant-available Si. Si amendment has recently been shown to confer significant rice plant resilience to pests, especially ShB (Rodrigues et al., 2003). Sabes et al. (2020) reported that, carbonized rice husk application as a Si source as 1.5 and 3 t ha^{-1} increased Si content in culm by 4% and 9%, respectively any delayed sheath blight disease growth. However, considering the overall conditions, in this study, we evaluate Si amendment to rice plants on the occurrence of rice ShB in Bangladeshi rice Chinigura.

Materials and Methods

Description of the experimental area

Geographically the experimental site was located at 24°75'N Latitude and 90°50'E Longitude at an elevation of 18 m above sea level. The climate of the experimental area was under the sub-tropical climatic zone, which was characterized by moderate to high temperature, heavy rainfall, high humidity, and relatively long day during *kharif* (April to September) and scanty rainfall, low humidity, low temperature and short-day period during *rabi* season (October to March).

Collection and preparation of experimental soil

The soil was collected from 0-15 cm depth of BINA experimental field area. The area under the AEZ-9 and regular cultivation practices. The soil is non-calcareous dark gray floodplain soil. The collected soil was made free from plant residues and other extraneous materials, air-dried, ground, and sieved through a 2 mm sieve. Approximately 500 g of sieved soil was preserved in a polythene bag for physical and chemical analyses. The soil was characterized as silty loam in texture, having bulk density, particle density, and moisture content of 1.26, 2.59 g cm^{-3}, and 27.24%, respectively. Chemical parameters such as pH, organic matter (%), total N (%), P (mg kg^{-1}), K (meq 100 g^{-1}), S (mg kg^{-1}), Zn (mg kg^{-1}), B (mg kg^{-1}), Ca (meq 100 g^{-1}), and Mg (meq 100 g^{-1}) were 5.9, 1.05, 0.06, 3.00, 0.13, 4.00, 1.81, 0.06, 3.32, and 0.78, respectively. About 18 kg of processed soil was taken in each plastic pot having 40 cm height and 35 cm and 30 cm diameter at the top and bottom, respectively. The pot was filled with soil leaving 3 cm from the top and labeled by using a tag.

Treatment details

The following treatments were used in this experiment (Table 1).

Table 1. Treatment symbol and details of this experiment

Treatment symbol	Treatment details
T_0	Control (without Si)
T_1	K_2SiO_3 2 mM
T_2	K_2SiO_3 4 mM
T_3	K_2SiO_3 6 mM
T_4	$CaSiO_3$ 2 mM
T_5	$CaSiO_3$ 4 mM
T_6	$CaSiO_3$ 6 mM
T_7	$MgSiO_3$ 2 mM
T_8	$MgSiO_3$ 4 mM
T_9	$MgSiO_3$ 6 mM

Fertilizer application

The soil was mixed thoroughly with organic (45 g pot^{-1} or 3 t ha^{-1}) and inorganic fertilizers during preparation. Except for Si fertilizer N, P, K, S, Mg, Zn, and B were applied as basal doses at a rate of 120, 25, 85, 18, 10, 5, and 2.1 kg ha^{-1}, respectively (BARC, 2018) from urea, TSP, MoP, gypsum, magnesium sulfate, zinc sulfate heptahydrate and solubor, respectively during final soil preparation for pot filling. Only urea fertilizer was applied in three installments. Silicon supplements were applied as foliar spray from K_2SiO_3, $CaSiO_3$, and $MgSiO_3$ at 25, 35, and 45 days after transplanting (DAT).

Inoculation of pathogen

Ten days after Si foliar application, the rice plants were inoculated with *Rhizoctonia solani.* A virulent isolate of *R. solani*, obtained from symptomatic rice plants and grown on acid potato dextrose agar medium. Plants were inoculated by placing a toothpick colonized by *R. solani* into the lowest inner sheath of the main tiller.

Pathological parameter

Sheath blight incidence, severity, and severity matrix were calculated by using the following equations (Ramathani et al., 2011; Roy et al., 2021). All the data was recorded at 3, 7, 13, 20, and 26 days after inoculation (DAI).

$$\% \text{ Incidence} = \frac{\text{No. of infected plant}}{\text{Total no. of plant}} \times 100 \text{........ (1)}$$

% Severity =

$$\frac{\text{Length of infected portion of the sheath}}{\text{Total length of a sheath}} \times 100 \text{........ (2)}$$

$$\% \text{ Severity matrix} = \frac{\% \text{ Incidence}}{100} \times \frac{\% \text{ Severity}}{100} \times 100 \text{... (3)}$$

Again, the disease reduction over control was calculated by using the following formula.

% Reduction over control =

$$\frac{\% \text{ disease of control} - \% \text{ disease of treatment}}{\% \text{ disease of control}} \times 100 \text{................. (4)}$$

Yield and yield components

Plant height was measured at 30, 60, 90, and 125 DAT. The height of the plant was measured from the ground level to the top of the plant. After harvest panicle length, no. of seeds panicle^{-1}, no. of total panicle pot^{-1}, and weight of thousand seeds (WTS) were recorded. Only grain yield was measured pot^{-1} and expressed in grams.

Preparation of rice leaf extract and determination of Ca, Mg, Na, K, P, S and B

After collection, rice leaf samples were dried in an oven at 65°C up to gaining constant weight and then cooled and ground by a grinding machine. The plant extract was prepared by wet oxidation method using di-acid mixture following the method of Singh et al. (1999). Calcium and Mg concentration was determined by complexometric method of titration using 0.01M Na_2EDTA as a chelating agent (Page et al., 1982). Potassium and sodium of plant samples were determined with the help of flame emission spectrophotometer (Model: JENWAY-PFP7) following Page et al. (1982). Phosphorus was determined spectrophotometrically (Model: TG-60 U) using stannous chloride as a reductant, following the procedure stated by Tandon (2005). Sulfur was determined turbidimetrically with spectrophotometer (Model: TG-60 U) stated by Tandon (2005). Boron in plant samples was determined by Azomethine-H method following the instructions of Page et al. (1982).

Preparation of plant extract and determination of silicon

The plant extract was prepared following the method described by Estefan et al. (2013). Silicon concentration was determined by spectrophotometric method.

Statistical analysis

The recorded data were compiled, tabulated, and subject to statistical analysis. Statistical analysis was performed with the help of a statistics package "Minitab 19". The normality and linearity of data was tasted using Kolmogorov Smirnov and modified Levene's test. The significant difference was determined by using one-way ANOVA test. A pairwise comparison of the means to see where a significant difference lies was performed by using the Tukey Test.

Results

Effects of different silicon supplements on growth, yield attribute, and yield of rice

The plant height was statistically similar at 30 DAT (Table 2). At 60 DAT, a significant ($p<0.05$) difference was observed among the different silicon treatments (Table 2). The T_8 treatment showed the highest plant height which was statistically similar to all other treatments except the T_0. Highly significant ($p<0.005$) variations were found among different treatments at 90, 110, and 125 DAT (Table 2). In all three cases, the highest plant height was found at the T_8 treatment and the lowest was at the T_0.

All the yield-contributing characters were significantly ($p<0.05$) influenced by different treatments (Table 3). The highest panicle length was found in T_6 treatment which was statistically similar to T_3, T_4, T_5, and T_8. The lowest panicle length was found in the T_0. The treatment T_5 showed the highest number of panicle pot^{-1}, but there was no significant difference among other treatments except T_0. The lowest number of panicle pot^{-1} was recorded in T_0. The treatment T_6 showed the maximum number of seeds panicle^{-1} which showed similarity with other treatments except T_1, T_4, and T_0. The maximum number of seed pot^{-1} was recorded in T_6 which was identical with all other treatments except T_1, T_4, and T_0, and the minimum number of seed pot^{-1} was found in T_0. The highest WTS was recorded in T_6. Except T_1, T_4, and T_0, there was no significant variation found among other treatments. The yield pot^{-1} also showed highly significant ($p<0.005$) variations among different treatments where the highest yield pot^{-1} was recorded in T_6 and the lowest in the T_0 treatment but T_1 and T_4 were statistically similar to the T_0. Except T_1, T_4, and T_0, all the treatments were statistically similar among them.

Table 2. Effects of different silicon supplements on plant height of rice

Treatment	Plant Height (cm)				
	30 DAT	60 DAT	90 DAT	110 DAT	125 DAT
T_0	84.0 a	105.7 b	115.7 c	136.0 c	154.7 d
T_1	83.3 a	109.3 ab	122.3 abc	140.0 bc	158.3 cd
T_2	84.3 a	109.0 ab	125.7 ab	144.3 ab	163.7 ab
T_3	83.7 a	109.7 ab	125.3 ab	144.7 ab	164.0 ab
T_4	85.3 a	108.7 ab	119.0 bc	142.3 abc	161.7 abc
T_5	83.7 a	108.3 ab	119.3 bc	140.3 bc	160.0 bc
T_6	83.7 a	111.3 ab	117.0 bc	145.0 ab	164.7 ab
T_7	87.0 a	113.7 ab	124.3 abc	146.0 ab	165.3 a
T_8	82.7 a	117.3 a	129.7 a	148.3 a	165.7 a
T_9	83.3 a	115.7 a	131.0 a	146.0 ab	159.3 bc
Level of significance	NS	*	**	**	**

Data in a column with the same letter(s) do not differ significantly
NS = Non-significant; * Significant at 5% level of significance; **Significant at both 5% and 1% level of significance.

Table 3. Effects of different silicon supplements on yield and yield attributes of rice

Treatment	Panicle length (cm)	Number of panicles pot^{-1}	Number of seeds panicle^{-1}	Number of seeds pot^{-1}	WTS (g)	Yield pot^{-1} (g)
T_0	32.00 b	44.67 b	202.85 c	9061 c	8.74 b	79.19 c
T_1	31.67 b	50.67 ab	209.31 bc	10606 b	8.79 b	92.17 bc
T_2	31.33 b	49.33 ab	242.21 ab	11948 ab	9.55 ab	114.10 ab
T_3	32.67 ab	50.00 ab	239.71 ab	11986 ab	10.29 ab	123.34 ab
T_4	32.33 ab	47.67 ab	213.27 bc	10167 b	8.81b	89.57 bc
T_5	32.33 ab	53.33 a	278.56 ab	14856 ab	10.41 ab	154.65 ab
T_6	34.33 a	51.00 ab	328.55 a	15756 a	10.92 a	172.06 a
T_7	31.33 b	46.67 ab	285.07 ab	13304 ab	9.50 ab	126.39 ab
T_8	32.67 ab	48.00 ab	313.06 a	15027 ab	10.87 a	163.34 ab
T_9	31.67 b	47.33 ab	295.98 ab	14009 ab	9.84 ab	137.85 ab
Level of significance	*	*	**	**	**	**

Data in a column with same letter(s) do not differ significantly
NS= Non-significant; * Significant at 5% level of significance; Significant both 5% and 1% level of significance.

Effects of different silicon supplements on rice ShB incidence

All the treatments showed a significant effect on the reduction of ShB incidence over control (Table 4). At 7 DAI, the maximum incidence was found in the T_0 treatment and the minimum in the T_3 treatment. Except T_3, other treatments were statistically similar. At 13 DAI, the minimum incidence was found at T_3 treatment which was identical with all other treatments except T_0. Both at 20 and 26 DAI, the minimum incidence was found at T_6 treatment. The results of the T_2, T_3, T_5, T_6, and T_8 treatments were identical among them at 20 DAI, whereas the results of T_2, T_3, T_5, T_6, T_7, T_8, and T_9 were identical among them at 26 DAI.

Table 4. Effects of different silicon supplements on rice ShB incidence

Treatment	ShB incidence (%)				
	3 DAI	7 DAI	13 DAI	20 DAI	26 DAI
T_0	0	13.13 a	35.51 a	45.83 a	52.09 a
T_1	0	11.35 ab	27.35 ab	41.80 ab	43.55 b
T_2	0	9.16 ab	25.44 b	36.35 bc	36.35 bc
T_3	0	7.22 b	24.46 b	34.06 bc	35.81 bc
T_4	0	11.79 ab	27.63 ab	41.27 ab	43.36 b
T_5	0	10.72 ab	26.80 b	39.28 bc	41.03 bc
T_6	0	11.53 ab	26.27 b	31.81 c	33.81 c
T_7	0	12.25 ab	24.58 b	37.60 b	34.68 c
T_8	0	11.29 ab	24.51 b	32.68 c	34.64 c
T_9	0	12.78 a	25.56 b	38.33 b	42.33 bc
Level of significance	NS	*	*	**	**

Data in a column with the same letter(s) do not differ significantly
NS = Non-significant; * Significant at 5% level of significance; ** Significant at both 5% and 1% level of significance.

Effects of different silicon supplements on rice ShB severity matrix

Application of different Si supplements showed a significant effect on the ShB disease severity matrix of rice at 7, 13, 20, and 26 DAI (Table 5). At 7 DAI, the lowest value was found in T_3 treatment which was statistically similar to all other treatments except T_9 and T_0. At 13 DAI, the lowest severity matrix was found in T_8 which was identical to all other treatments except T_0, T_1, T_4, and T_5. A highly significant ($p<0.005$) effect was found at 20 and 26 DAI on severity matrix. At 20 DAI, the lowest severity matrix was recorded in T_8 treatment which was statistically identical to T_6 and T_7. Again, the highest severity matrix was found in T_0 which was significantly different from all other treatments. At 26 DAI, the lowest severity matrix was found in T_6 which was similar to T_3, T_8, and T_9. T_0 significantly showed higher severity matrix among the treatments.

Table 5. Effects of different silicon supplements on rice ShB disease severity matrix

Treatment	ShB disease severity matrix (%)				
	3 DAI	7 DAI	13 DAI	20 DAI	26 DAI
T_0	0	2.10 a	9.58 a	14.67 a	18.99 a
T_1	0	1.53 abc	6.92 b	12.29 b	14.69 b
T_2	0	1.24 bc	6.32 bc	10.51 bc	11.45 cd
T_3	0	1.00 c	5.92 bc	9.84 cd	9.32 de
T_4	0	1.73 abc	6.90 b	12.28 b	14.64 b
T_5	0	1.54 abc	6.75 b	11.61 bc	13.24 bc
T_6	0	1.71 abc	4.37 c	7.03 e	7.82 e
T_7	0	1.72 abc	5.12 bc	7.92 de	11.22 cd
T_8	0	1.65 abc	4.20 c	6.43 e	8.86 de
T_9	0	1.88 ab	5.77 bc	9.77 cd	10.26 de
Level of significance	NS	*	*	**	**

Data in a column with the same letter(s) do not differ significantly

NS = Non-significant; * Significant at 5% level of significance; ** Significant at both 5% and 1% level of significance.

Effects of different silicon supplements on rice ShB reduction over control

The application of different Si supplements showed a significant effect ($p<0.05$) on the reduction of ShB incidence and severity matrix over control (Figure 1). Among the treatments, T_6 showed the highest disease incidence reduction (35.27%) over control which was statistically similar to all other treatments except T_1 and T_4. Again, the highest disease severity matrix reduction over control was found in the case of the treatment T_6 which was statistically similar to T_3, T_7, and T_8. The lowest severity matrix reduction was found at T_1 (16.49%) which was identical to T_2 and T_5.

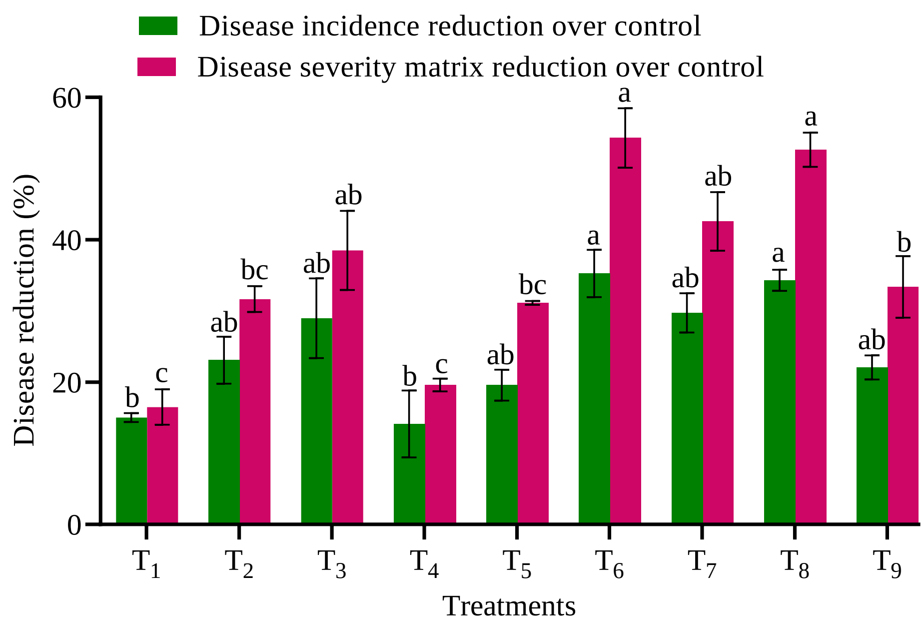

Figure 1. Sheath blight reduction over control at 26 DAI treated with different Si supplements. Bars with the same letter(s) do not differ significantly.

Effects of different silicon supplements on different nutrient concentrations in leaf tissues of rice

A significant ($p<0.05$) effect was observed due to Si application with respect to the different nutrient concentrations of rice leaf sample (Table 6). The T_3 treatment showed the maximum concentration of Ca in the leaf tissues. The minimum concentration was found in the control treatment. Among the treatments, the highest Mg concentration was found at T_6 which was statistically similar with other treatments except T_1 and T_0. The highest K concentration was recorded in T_3 and lowest in T_0, but all the treatments were statistically similar except T_3 and T_0. The highest P concentration was found in T_3 which was similar to other treatments but T_0. The T_3 treatment showed the highest S concentration but minimum in T_0. Boron concentration was highest in T_6 treatment, but there was no significant deviation found among other treatments except T_0 and T_9. Highly significant variation ($p<0.005$) was recorded among the treatments compared to the control with respect to Si concentration. The treatment T_8 showed the highest Si concentration among other treatments which was statistically similar to T_3, T_6, and T_9.

Table 6. Nutrient concentration of flag leaf treated with different silicon supplements

Treatment	Ca (%)	Mg (%)	K (%)	P (%)	S (%)	B (mg kg^{-1})	Si (%)
T_0	0.32 e	0.25 f	0.79 c	0.42 b	0.23 c	14.22 b	1.55 d
T_1	0.40 d	0.31 b	1.29 b	0.44 ab	0.25b c	16.07 ab	2.76 bc
T_2	0.40 d	0.35 ab	1.23 b	0.43 ab	0.32 ab	18.66 ab	3.24 b
T_3	0.56 a	0.37 ab	1.47 a	0.48 a	0.37 a	23.10 a	4.28 ab
T_4	0.40 d	0.39 ab	1.23 b	0.43 ab	0.28 b	19.77 ab	2.28 c
T_5	0.42 c	0.38 ab	1.43 ab	0.43 ab	0.34 ab	16.81 ab	2.84 b
T_6	0.48 b	0.40 a	1.42 ab	0.43 ab	0.36 a	23.84 a	4.52 ab
T_7	0.47 b	0.36 ab	1.38 ab	0.44 ab	0.28 b	23.10 a	3.80 b
T_8	0.48 b	0.39 ab	1.39 ab	0.45 ab	0.36 a	20.88 ab	5.16 a
T_9	0.48 b	0.35 ab	1.33 ab	0.43 ab	0.26 bc	15.70 b	4.76 ab
Level of significance	**	*	**	*	**	*	**

Data in a column with the same letter(s) do not differ significantly

NS = Non-significant; * Significant at 5% level of significance; ** Significant at both 5% and 1% level of significance.

Discussion

Sheath blight is a devastating disease of rice causing moderate to severe yield losses. Silicon-mediated disease reduction is well-established in the literature (Hussain et al., 2019). In this experiment the application of different Si supplements significantly improves growth, yield contributing characters, and yield of rice. Silicon is a beneficial nutrient and imposes a positive effect on plant growth, especially when stress conditions like disease prevail (Frew et al., 2018). Silicon has a positive effect on plant physiological processes like photosynthesis, chlorophyll content, and biomass accumulation of plants (Dorairaj et al., 2017). Generally, the application of Si reduces the disease as well as improves the physiological processes of rice. As a result, higher growth and yield of rice were found in our experiment under different Si treatments, especially at a higher concentration (4 mM and 6 mM). Guntzer et al. (2012) reported that Si significantly increases the dry weight of grain compared to unapplied rice plants. Again, Si significantly increases the panicle number per plant and the percentage of the ripened spikelet of rice reported by Ma (2003).

The disease incidence and severity matrix were significantly reduced due to the application of different Si supplements in this experiment. The 4 mM and 6 mM solution applications showed substantially higher performance than the 2 mM application except $MgSiO_3$. The reduction of performance of $MgSiO_3$ at 6 mM concentration may be due to the insolubility of $MgSiO_3$ at higher concentrations. However, silicon mainly reduced the disease through physical and biochemical interactions in plants. When applied to plants, Si produces a physical or mechanical barrier through the accumulation of plant cell cuticle. This physical barrier helps to prevent the penetration of fungal hyphae or appressorial peg into the plant cell (Wang et al., 2017). Again, Si improves the defense mechanisms of the plant through the rapid production of defense chemical compounds via the primary and secondary metabolic pathways of the plant. The defense compounds include flavonoids, lignin, phenolics, cellulose, phytoalexins, and defense enzymes (Ahanger et al., 2020; Ahammed et al., 2021). In line with our findings, Sathe et al. (2021) reported that the application of carbonized rice husk helps to delay the ShB development of rice. Again, Khaing et al. (2015) reported that granular silica application improves the resistance capacity of rice against ShB disease.

Nutrient concentrations significantly increased through different Si supplement applications. Nutrient uptake by the plant mainly depends on its vigor and metabolisms. Infestation of disease has reduced the vigor of plants by reducing photosynthetic area and hampering metabolisms. The higher nutrient concentration in plant flag leaf may be due to the reduction of disease incidence and severity in rice. The reduction of disease incidence and severity of flag leaf increases the photosynthetic area of rice plant and helps to continue vigorous photosynthesis and metabolism of the plant body. As a result, a higher nutrient is uptaken by the rice plant than control condition. Our results justified the findings of Liu et al. (2017), who found a higher Ca, Mg, and Zn concentration in rice due to the application of exogenous Si. A similar result was reported by Artyszak (2018) in different crops that Si application improves both nutritional and biochemical quality of crops.

Conclusion

The successful management practices of fungal diseases in rice is still insufficient. Again, intensive rice cultivation using fungicides causes environmental threads and the emergence of devastating fungal races. Silicon is an environmentally friendly input that has the ability to manage fungal diseases. In the study, the Si application showed a significant reduction in ShB disease with a yield increase. So, $CaSiO_3$ 6 mM Si as the foliar application could be one of the considerable Si supplements for rice ShB management as well as $MgSiO_3$, particularly as 4 mM Si. K_2SiO_3 also has the potential to show good results regarding ShB. It may be an advisable option to apply K_2SiO_3, $CaSiO_3$, and $MgSiO_3$ for successful crop production which has a pivotal role in sheath blight control. Further studies should be conducted under different agro-climatic conditions and also in the ShB-prone areas with diversified doses for better understanding.

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