

Management of Sheath Blight of Rice Incited by *Rhizoctonia solani* through Different Silicon Sources

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ABSTRACT

Silicon (Si) plays a crucial role in enhancing plant growth, stress tolerance and disease resistance in rice. A field study was conducted to evaluate different silicon sources against sheath blight of rice caused by *Rhizoctonia solani* during summer (February - May) and *kharif* (August - November) 2023. Results revealed that T₂: soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 Days after transplanting showed the least mean disease severity (14.93 and 16.71%) in summer and *kharif* 2023 respectively followed by (T₉), foliar application of potassium silicate 4 g/l @ 30 and 60 DAT (16.14 and 18.19%). T₂ also showed maximum plant height (97.06 and 95.55 cm), number of tillers (19.00, 21.33), panicles per plant (13.80, 11.97) and grain yield (5800 and 5623 kg/ha) in summer and *kharif* 2023 respectively. Positive control (T₁₂) foliar application of 0.2% hexaconazole 5EC @ 30 and 60 DAT was statistically on par with T₂ in all parameters. The highest benefit-cost ratio was recorded in T₂ (2.31 in summer and 2.24 in *kharif*). Treatments without silicon application recorded higher disease severity, lower growth and reduced yields, demonstrating the importance of silicon in plant resilience. These results highlight the synergistic effect of silicon sources and microbial consortia in improving rice productivity and disease resistance, offering a sustainable approach for integrated disease management.

Keywords : Rice, Sheath blight, Calcium silicate, Potassium silicate, Silicon content, Microbial consortia

RICE (*Oryza sativa* L.) is an important cereal crop serving as staple food for more than half of the world's population. Rice accounts for about 80 per cent of the calories consumed by people in Asian countries. Rice alone provides 20 per cent of the world's caloric energy supply, making it the main dietary energy source in many Asian and African nations (Anonymous, 2024a). As the theme 'Rice is Life' reflects, more than one-third of the world's population and more than half of India's population

depend on rice as their primary staple food crop (Maclean, 2002). Rice is cultivated worldwide, with approximately 90 per cent of the global production concentrated in Asia (Haug *et al.*, 2019). India has the largest area of 44 million hectares under rice production worldwide with the annual rice production of 129 million tonnes and productivity of about 3.86 tonnes per hectare (Anonymous, 2024b). In Karnataka it is cultivated in an area of 1.4 million hectares, accounting for about 10 per cent of the state's total

cropped area, with the production of 3.5 million tonnes and productivity of 2.5 tonnes per hectare (Anonymous, 2022).

Rice production faces numerous challenges of biotic and abiotic stresses, with diseases being a primary concern. The pathogens cause various diseases which are responsible for both quantitative as well as qualitative reductions in the crop. These reductions are directly related to loss of price for both crops and its commodities in the world market (Lee and Rush, 2020). Among the fungal diseases, sheath blight caused by *Rhizoctonia solani* Kuhn is one of the most widespread diseases which is responsible for yield loss up to 4-45 per cent depending on the crop stage, time of infection and environmental conditions (Singh *et al.*, 2016, Dey *et al.*, 2019). In terms of seasonal production losses of rice, sheath blight disease is considered the second most severe disease after blast disease (Ou, 1985). It is a major production constraint in profusely tillering and fertilizer responsive high yielding varieties and hybrids under intensive rice production systems (Kumar *et al.*, 2009 and Kumar *et al.*, 2021).

The wide host range of pathogen and persistence of sclerotia on exposure to adverse environmental conditions makes it difficult in managing the sheath blight disease. Most insidiously, the pathogen evolves with time, allowing the sclerotia to overcome the resistance that may have been the hard-won achievement of the farmers and breeders. It is difficult to determine when and how meteorological conditions influence the outbreak of rice sheath blight (Jayashree *et al.*, 2022 and Sindhu *et al.*, 2023). Despite being helpful, fungicides are negatively affecting the people and environment by contaminating soils, water resources and the entire food supply chain. Therefore, it is imperative to find new alternatives, preferably with minimal impact on the environment, to protect crops from *R. solani* while reducing the use of chemical fungicides. One such alternative is use of silicon in managing the disease.

Silicon (Si) is a beneficial element known to enhance plant resistance against pathogens in rice (Frew *et al.*,

2018). Si accumulation in tissues strengthens cell walls and acts as a physical barrier against pathogen invasion (Kim *et al.*, 2002). Additionally, Si has been reported to modulate plant defense mechanisms, including the activation of pathogenesis-related proteins and the production of secondary metabolites (Schurt *et al.*, 2014). The integration of Si into management practices offers a sustainable and environmentally friendly option to enhance resistance and reduce disease impact. As there is no resistant cultivar available till today it is high time to manage the disease in eco-friendly manner. In view of the importance of the crop and wide spread distribution of sheath blight disease an attempt has been made to elucidate the effect of different silicon sources in sheath blight disease management.

MATERIAL AND METHODS

Experimental Details

To explicate the effect of different silicon sources in managing the sheath blight disease, the field experiment was conducted during the summer (February - May) and *kharif* (August - November) 2023 at 'A' Block, College of agriculture, V. C. Farm, Mandya, (12°34' N latitude, 76°50' E longitude and at an altitude of 695.0 m above mean sea level) in Randomized Complete Block Design (RCBD) with 13 treatments and 3 replications. Jyothi variety seedlings were transplanted at spacing of 20 × 10 cm. A distance of 0.5 m between the treatments and 1.0 m between replication was provided. The assessment of disease severity was made by following Standard Evaluation System (SES) scale (Anonymous 2013) given by IRRI at 30, 45, 60, 75 and 90 DAT, as well as the effect of treatment on growth and yield was also recorded. The silicon content in plant was estimated at two different intervals (45 and 100 days after transplanting) and correlated with the disease severity.

Treatment details :

- T₁ : Soil application of calcium silicate @ 375 kg/ha
 T₂ : Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT

- T₃ : Soil application of Biochar @ 112.5 kg/ha
- T₄ : Soil application of Biochar @ 112.5 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT
- T₅ : Soil application of Fly ash @ 112.5 kg/ha
- T₆ : Soil application of Fly ash @ 112.5 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT
- T₇ : Soil application of Diatomaceous earth @ 150 kg/ha
- T₈ : Soil application of Diatomaceous earth @ 150 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT
- T₉ : Foliar application of potassium silicate 4 g/l @ 30 and 60 DAT
- T₁₀ : Foliar application of microbial consortia 5g/l @ 30 and 60 DAT
- T₁₁ : Foliar application of 0.2% nano silicon @ 30 and 60 DAT
- T₁₂ : Foliar application of 0.2% hexaconazole @ 30 and 60 DAT
- T₁₃ : Untreated control

Statistical Analysis

The experimental data obtained on various observations were subjected to statistical analysis adopting Fisher's method of 'Analysis of Variance' (ANOVA) as outlined by Gomez and Gomez (1984) and means were separated by Tukey's HSD (Tukey 1965). The data pertaining to percentage were transformed into arc sin transformation, as it is required before statistical analysis.

RESULTS AND DISCUSSION

Effect of Treatments on Rice Sheath Blight Severity

The different silicon sources and their combination with microbial consortia were evaluated for their effect on disease severity of rice sheath blight during summer and *kharif* 2023. In summer 2023, the effect of different treatments on disease severity varied significantly (Table 1), on the basis of mean disease severity and per cent reduction over control, T₂: soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DA was found to be the significantly effective treatment (14.93 and 65.49%) T₉: followed by foliar application of potassium silicate at 4 g/L at 30 and 60 DAT (16.14 and 62.68%) which were statistically on par with the positive control T₁₂: foliar application of

TABLE 1

Effect of silicon treatments on sheath blight severity in rice under field conditions (Summer 2023)

Treatment	35 DAT	50 DAT	65 DAT	80 DAT	95 DAT	Mean disease severity	Per cent reduction over control
T ₁	2.22 (11.08 ^b)	8.89 (17.36 ^{de})	21.48 (27.6 ^{def})	28.81 (32.44 ^{de})	36.29 (37.05 ^{cdef})	19.83	54.15
T ₂	2.22 (8.57 ^c)	3.70 (10.97 ^{gh})	14.07 (21.99 ^{fg})	22.96 (28.62 ^{ef})	31.70 (34.24 ^f)	14.93	65.49
T ₃	4.44 (12.17 ^b)	15.55 (23.24 ^{abc})	34.81 (36.13 ^b)	40.74 (39.68 ^{bc})	46.66 (43.11 ^b)	28.44	34.26
T ₄	3.70 (12.17 ^b)	12.59 (20.73 ^{bcd})	28.88 (32.52 ^{bcd})	36.29 (37.05 ^{bc})	43.70 (41.4 ^{bc})	25.18	41.79
T ₅	4.44 (12.17 ^b)	18.52 (25.49 ^a)	36.29 (37.05 ^b)	42.22 (40.54 ^b)	48.14 (43.96 ^b)	29.92	30.83

Continued....

TABLE 1 Continued....

Treatment	35 DAT	50DAT	65 DAT	80 DAT	95 DAT	Mean disease severity	Per cent reduction over control
T ₆	4.44 (12.17 ^b)	17.03 (24.38 ^{ab})	31.85 (34.36 ^{bc})	39.25 (38.81 ^{bc})	45.18 (42.25 ^b)	27.55	36.31
T ₇	4.44 (14.95 ^a)	12.59 (20.73 ^{bcd})	27.40 (31.57 ^{bcd})	37.77 (37.94 ^{bc})	42.22 (40.54 ^{bcd})	25.33	41.45
T ₈	3.70 (11.09 ^b)	11.11 (19.48 ^{cde})	24.44 (29.64 ^{cde})	34.81 (36.17 ^{cd})	40.74 (39.68 ^{bcd})	22.96	46.93
T ₉	2.22 (8.57 ^c)	5.18 (13.1 ^{fg})	15.55 (23.24 ^{fg})	24.44 (29.64 ^{ef})	33.33 (35.28 ^{ef})	16.14	62.68
T ₁₀	6.66 (12.17 ^b)	17.78 (24.95 ^a)	36.29 (37.03 ^b)	40.74 (39.68 ^{bc})	46.66 (43.11 ^b)	29.18	32.55
T ₁₁	4.44 (11.08 ^b)	7.40 (15.76 ^{ef})	18.52 (25.46 ^{efg})	25.85 (30.56 ^{ef})	34.81 (36.17 ^{def})	18.06	58.26
T ₁₂	2.22 (8.57 ^c)	2.22 (8.57 ^b)	12.59 (20.73 ^e)	20.00 (26.58 ^f)	30.22 (33.35 ^f)	13.45	68.91
T ₁₃	6.66 (14.96 ^a)	19.29 (26.06 ^a)	51.11 (45.66 ^a)	65.92 (54.32 ^a)	73.33 (58.94 ^a)	43.26	0.00
SE m ±	0.266	0.758	1.085	0.839	0.850	1.070	
C.D @5%	0.775	2.213	3.167	2.449	2.481	3.124	

* Values in the parenthesis are arc sign transformed values; values in the column followed by common letters are non-significant at $p = 0.05$ as per Tukey's HSD (Tukey, 1965); T₁: Soil application of calcium silicate @ 375 kg/ha, T₂: Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₃: Soil application of Biochar @ 112.5 kg/ha, T₄: Soil application of Biochar @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₅: Soil application of Fly ash @ 112.5 kg/ha, T₆: Soil application of Fly ash @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₇: Soil application of Diatomaceous earth @ 150 kg/ha, T₈: Soil application of Diatomaceous earth @ 150 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₉: Foliar application of potassium silicate 4 ml/ @ 30 and 60 DAT, T₁₀: Foliar application of microbial consortia 5g/L @ 30 and 60 DAT, T₁₁: Foliar application of 0.2 % nano silicon @ 30 and 60 DAT, T₁₂: Foliar application of 0.2 % hexaconazole 5EC @ 30 and 60 DAT, T₁₃: Untreated control

0.2% hexaconazole at 30 and 60 DAT (13.45 and 68.91%). In contrast, T₅: soil application of fly ash at 112.5 kg/ha was found to be least effective treatment (29.92 and 30.83%). This was found statistically on par with T₁₀: foliar application of microbial consortia at 5 g/L at 30 and 60 DAT (29.18 and 32.55%) whereas in T₁₃: control, the mean disease severity was observed to be 43.26 per cent. The remaining treatments recorded mean disease severity values ranging from 18.06 to 28.44 per cent, with reductions over the control varying between 34.26 and 58.26 per cent. The same trend was also observed during *kharif* 2023 (Table 2) where in T₂ was most effective with mean disease severity and

percent reduction over control (16.71 and 63.73%) followed by T₉(18.19 and 60.52%) which were on par to the positive control, T₁₂(15.21 and 66.98%). The least effective treatment was T₅ (30.66 and 33.44%) which was on par with T₁₀ (29.63 and 35.59%), whereas T₁₃: control recorded the mean disease severity of 46.07 per cent. Other treatments exhibited mean disease severity values ranging from 18.06 to 28.44 per cent, with reductions over the control ranging between 34.26 and 58.26 per cent.

Variation in disease severity among treatments is influenced by silicon bioavailability, plant defense activation and microbial interactions. Silicon enhances

TABLE 2
Effect of silicon treatments on sheath blight severity in rice under field conditions (kharif 2023)

Treatment	35 DAT	50 DAT	65 DAT	80 DAT	95 DAT	Mean disease severity	Per cent reduction over control
T ₁	3.70 (8.56 ^c)	11.11 (19.48 ^{cd})	22.96 (28.62 ^{def})	30.22 (33.35 ^{cde})	37.77 (37.89 ^{bcdef})	20.86	54.73
T ₂	2.22 (8.57 ^c)	5.18 (13.11 ^f)	17.04 (24.35 ^{fg})	25.85 (30.56 ^e)	33.25 (35.2 ^{ef})	16.71	63.73
T ₃	4.44 (12.17 ^b)	18.52 (25.49 ^{ab})	31.85 (34.36 ^{bc})	42.22 (40.54 ^b)	48.14 (43.96 ^{bc})	29.03	36.98
T ₄	4.44 (11.09 ^b)	17.04 (24.35 ^b)	27.40 (31.57 ^{bcd})	40.74 (39.68 ^b)	46.66 (43.1 ^{bcd})	27.11	41.16
T ₅	4.44 (12.17 ^b)	20.74 (27.06 ^{ab})	33.33 (35.25 ^b)	45.18 (42.25 ^b)	49.63 (44.81 ^b)	30.66	33.44
T ₆	4.44 (12.17 ^b)	19.26 (26.04 ^{ab})	25.92 (30.6 ^{cde})	42.22 (40.54 ^b)	46.66 (43.1 ^{bcd})	27.70	39.87
T ₇	6.66 (12.16 ^b)	17.77 (24.92 ^{ab})	27.40 (31.56 ^{bcd})	39.25 (38.81 ^{bc})	43.70 (41.4 ^{bcd})	26.51	42.45
T ₈	3.70 (11.09 ^b)	15.55 (23.24 ^{bc})	24.44 (29.64 ^{de})	37.77 (37.92 ^{bcd})	42.22 (40.54 ^{bcdef})	24.74	46.30
T ₉	2.22 (8.57 ^c)	6.67 (14.97 ^{ef})	20.00 (26.58 ^{efg})	27.25 (31.47 ^e)	34.81 (36.17 ^{def})	18.19	60.52
T ₁₀	4.44 (14.96 ^a)	19.26 (26.04 ^{ab})	31.85 (34.36 ^{bc})	42.22 (40.54 ^b)	48.14 (43.96 ^{bc})	29.63	35.69
T ₁₁	3.70 (12.15 ^b)	10.37 (18.77 ^{de})	21.48 (27.6 ^{defg})	28.66 (32.38 ^{de})	36.29 (37.04 ^{cdef})	20.25	56.05
T ₁₂	2.22 (8.57 ^c)	3.70 (10.97 ^f)	15.55 (23.24 ^g)	22.81 (28.46 ^e)	31.77 (34.31 ^f)	15.21	66.98
T ₁₃	6.66 (14.96 ^a)	22.96 (28.62 ^a)	55.55 (48.21 ^a)	70.36 (57.1 ^a)	74.81 (59.92 ^a)	46.07	0.00
SE.m ±	0.272	0.800	0.858	1.094	1.352	1.135	
C.D @5%	0.795	2.336	2.503	3.195	3.946	3.311	

* Values in the parenthesis are arc sign transformed values; values in the column followed by common letters are non-significant at $p = 0.05$ as per Tukey's HSD (Tukey, 1965); T₁: Soil application of calcium silicate @ 375 kg/ha, T₂: Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₃: Soil application of Biochar @ 112.5 kg/ha, T₄: Soil application of Biochar @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₅: Soil application of Fly ash @ 112.5 kg/ha, T₆: Soil application of Fly ash @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₇: Soil application of Diatomaceous earth @ 150 kg/ha, T₈: Soil application of Diatomaceous earth @ 150 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₉: Foliar application of potassium silicate 4 ml/ @ 30 and 60 DAT, T₁₀: Foliar application of microbial consortia 5g/L @ 30 and 60 DAT, T₁₁: Foliar application of 0.2% nano silicon @ 30 and 60 DAT, T₁₂: Foliar application of 0.2% hexaconazole 5EC @ 30 and 60 DAT, T₁₃: Untreated control

plant resistance by strengthening cell walls, forming physical barriers and triggering systemic defense responses, but its effectiveness depends on the

solubility, bioavailability and uptake efficiency of the applied Si source (Kim *et al.*, 2002). Calcium silicate with microbial consortia provided sustained silicon

release and enhanced resistance, while potassium silicate foliar spray ensured rapid uptake and faster defense activation. The results were in confirmation with the findings of Saldares *et al.* (2011) and reported that calcium silicate (1000 kg/ha) exhibited the lowest disease severity and relative lesion height. Jawahar *et al.* (2019) reported that 100% RDF + Silixol granules @ 50 kg/ha considerably reduced the rice blast incidence at tillering and flowering stages when compared to control (75% RDF alone). Setu *et al.*, (2024) who found that the lowest wheat blast (WB) incidence (83.16%), severity matrix (80.20%) in the treatment of CaSiO_3 @ 100 kg/ha at 17 DAI and reduced the WB incidence and severity matrix by 21.10 per cent and 41.73 per cent, respectively at 15 DAI. Kedarnath and Rangaswamy (2016) reported that both silicic acid and orthosilicic acid @ 0.4 per cent reduced the severity of tomato early blight by 52.25 and 50.45 per cent respectively which were on par with the chemical fungicide Mancozeb 75 WP @ 0.3 per cent (53.15).

Effect of Treatments Against Rice Sheath Blight on Plant Height

The significant difference between treatments and plant height was recorded during summer and *kharif*

2023. In summer 2023, all the treatments varied significantly in plant height (Fig. 1), the treatment T_2 : Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT, proved highly effective for plant growth with highest plant height of 97.06 cm with 20.58 per cent increase over the control. This was found statistically on par with the positive control, T_{12} : foliar application of 0.2 % hexaconazole at 30 and 60 DAT (99.19 cm and 23.22%) followed by T_9 : foliar application of potassium silicate @ 4 g/L (94.61 cm 17.52%). T_{10} : foliar application of microbial consortia @ 5 g/L at 30 and 60 DAT was least effective treatment (81.66 cm and 1.45%) whereas, T_{13} : control, recorded a plant height of 80.50 cm. Other treatments produced plant heights ranging from 82.81 to 92.54 cm, corresponding to a percentage increase of 2.87 to 14.96 per cent compared to the control.

During *kharif* 2023, T_2 was significantly effective with plant height of 95.55 cm and 19.48 per cent increase over control which was on par with the positive control T_{12} (97.50 cm and 21.92%) followed by T_9 (92.50 cm and 15.67%). Among all the treatments T_{10} was less effective with least plant height and per cent increase over control (80.81 cm and 1.05%) whereas in control,

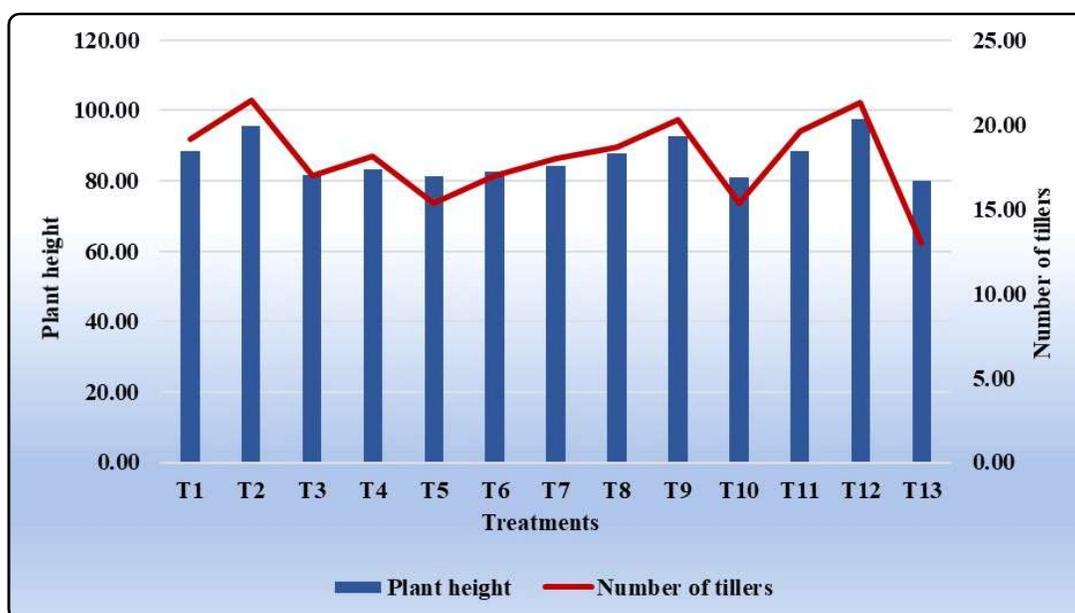


Fig. 1 : Effect of silicon treatments on plant height and number of tillers during summer 2023

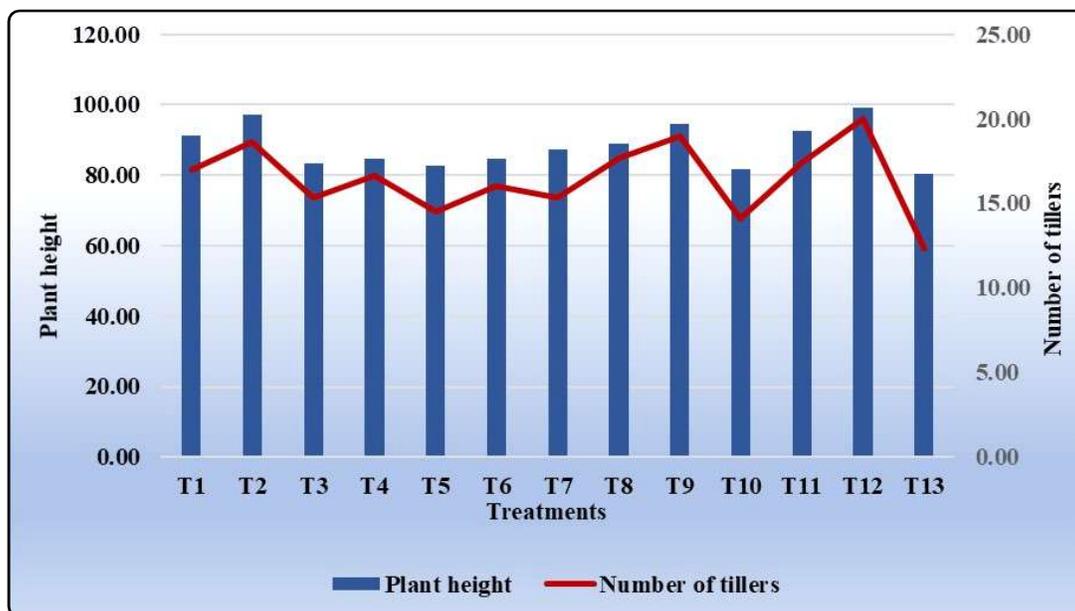


Fig. 2. Effect of silicon treatments on plant height and number of tillers during *kharif* 2023

the plant height of 79.97cm was recorded. The remaining treatments recorded the plant heights in the range of 81.40 to 88.40 cm and 1.79 to 10.63 per cent increase over control (Fig. 2).

Differences in plant height are influenced by silicon bioavailability, disease suppression, microbial interaction and growth enhancement. Soluble silicon sources promote quick uptake, promoting early growth, while less soluble forms provide gradual benefits. Microbial consortia enhance silicon solubilization, improving plant health (Frew *et al.*, 2018). Effective disease control directs energy toward growth, whereas low silicon availability or weak disease protection results in shorter plants.

Effect of Treatments against Rice Sheath Blight on Number of Tillers

A significant variation in number of tillers per plant was observed among the treatments during summer and *kharif* 2024. The significant variation among the treatments in number of tillers was observed in summer 2023 (Fig. 1) wherein, T₂: Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT, recorded the maximum tillers per plant of 19.00

reflecting 54.10 per cent increase over the control. This result was statistically on par with the positive control, T₁₂: foliar application of 0.2% hexaconazole at 30 and 60 DAT (20.00 and 62.21%) followed by T₉: foliar application of potassium silicate @ 4 g/L (18.67 and 51.42). In contrast, T₁₀: foliar application of microbial consortia (5 g/L) at 30 and 60 DAT was least effective (14.10 and 14.36%) whereas, T₁₃: control, recorded the tillers of 12.33. Other treatments produced tillers per plant in the range of 14.50 to 17.43, corresponding to a percentage increase of 17.57 to 41.39 per cent compared to the control.

In *kharif* 2023, the same trend was observed wherein, T₂ recorded the highest number of tillers per plant with maximum per cent increase over control (21.33 and 64.10%) which was on par with positive control T₁₂ (21.46, 65.10%) followed by T₉ (20.26 and 55.87%). Among the treatments, least number of tillers per plant was recorded in T₁₀ (15.33 and 17.92%) wherein, T₁₃ control has recorded the minimum number of tillers per plant (13.00). Other treatments produced tillers in the range of 15.35 to 19.63 with 17.93 to 51.03 per cent increase over control (Fig. 2).

Variations in tillers per plant are also influenced by silicon availability, disease suppression, nutrient uptake and microbial interactions. Silicon strengthens plant structure, enhances photosynthesis and reduces lodging, promoting better tillering. Highly soluble silicon sources support early tiller development, while less soluble forms provide sustained benefits. Microbial consortia improve silicon solubilization and nutrient absorption, further boosting tiller production (Frew *et al.*, 2018). Additionally, effective disease control allows plants to allocate more energy to tiller formation, whereas low silicon availability or weak disease resistance leads to fewer tillers per plant.

Effect of Treatments against Sheath Blight Disease on Yield Parameters

Data pertaining to yield parameters of rice *viz.*, number of panicles per plant, test weight (gm) and grain chaffiness influenced by different treatments were recorded and depicted in Table 3 and 4. All treatments significantly influenced the yield parameters during summer and *kharif* 2023.

In summer 2023, the data pertaining to yield parameters varied significantly among all the treatments (Table 3) wherein, T₂: Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT, recorded the highest number of panicles of 13.80 representing 72.46 per cent increase over control with highest test weight of 24.56 g recording 49.58 per cent increase over control and least grain chaffiness of 9.17 per cent and 51.04 per cent reduction over control. The results were statistically on par with the positive control, T₁₂: Foliar application of 0.2% hexaconazole at 30 and 60 DAT in panicles per plant (14.33 and 79.17%), test weight (26.54 g and 61.53%) and grain chaffiness (8.33 and 55.53%). In contrast T₁₀: foliar application of microbial consortia @ 5 g/L at 30 and 60 DAT recorded a smaller number of panicles per plant (8.27 and 3.14%), test weight (17.12 g and 4.20 %) and highest grain chaffiness and per cent reduction over control (15.67 and 18.47%) whereas, T₁₃: control, recorded 8.00 panicles per plant, with test weight of 16.43 g and maximum grain chaffiness of 18.73 per cent.

TABLE 3
Effect of silicon treatments against rice sheath blight on yield parameters (Summer 2023)

Treatment	No. of panicles/ plant	Per cent increase over control	Test weight (g)	Per cent increase over control	Per cent chaffiness	Per cent reduction over control
T ₁	11.56 ^{de}	47.46	20.14 ^{bcde}	22.58	11.56 ^{cde}	38.28
T ₂	9.17 ^f	72.46	24.56 ^{ab}	49.48	9.17 ^{de}	51.04
T ₃	14.28 ^{bc}	13.83	19.16 ^{cde}	16.62	14.28 ^{bc}	23.75
T ₄	12.67 ^{cd}	25.00	19.50 ^{cde}	18.69	12.67 ^{bcd}	32.35
T ₅	16.23 ^b	9.08	17.50 ^{de}	6.51	16.23 ^{ab}	13.35
T ₆	15.27 ^b	14.58	17.95 ^{de}	9.25	15.27 ^{ab}	19.11
T ₇	15.67 ^b	20.88	18.50 ^{cde}	12.60	15.67 ^{ab}	16.34
T ₈	14.19 ^{bc}	35.42	19.13 ^{cde}	16.43	14.19 ^{bc}	24.26
T ₉	9.33 ^{ef}	61.63	23.15 ^{abc}	40.90	9.33 ^{de}	50.19
T ₁₀	15.15 ^b	3.41	17.12 ^e	4.20	15.15 ^{abc}	18.47
T ₁₁	10.28 ^{ef}	52.08	21.86 ^{abcd}	33.05	10.28 ^{de}	45.11
T ₁₂	8.33 ^f	79.17	26.54 ^a	61.53	8.33 ^e	55.53
T ₁₃	18.73 ^a	0.00	16.43 ^e	0.00	18.73 ^a	0.00
SE m ±	0.677		0.906		0.707	
C.D @5%	1.976		4.183		2.065	

TABLE 4
Effect of silicon treatments against rice sheath blight on yield parameters (*kharif* 2023)

Treatment	No. of panicles/ plant	Per cent increase over control	Test weight (g)	Per cent increase over control	Per cent chaffiness	Per cent reduction over control
T ₁	10.5 ^{bcde}	43.84	18.93 ^{bcde}	21.98	11.83 ^{cd}	41.38
T ₂	11.97 ^{ab}	63.93	22.93 ^{ab}	47.76	10.90 ^d	45.99
T ₃	8.20 ^{ef}	12.33	17.87 ^{cde}	15.15	15.10 ^b	25.17
T ₄	8.60 ^{def}	17.81	18.23 ^{cde}	17.47	14.63 ^{bc}	27.50
T ₅	7.90 ^{ef}	8.22	16.45 ^{de}	6.02	16.17 ^b	15.91
T ₆	8.10 ^{ef}	10.96	16.83 ^{de}	8.48	14.27 ^{bc}	29.29
T ₇	8.57 ^{def}	17.35	17.20 ^{cde}	10.83	16.97 ^{ab}	15.91
T ₈	9.67 ^{cde}	32.47	18.00 ^{cde}	15.99	15.10 ^b	25.17
T ₉	11.5 ^{abc}	57.53	21.56 ^{abc}	38.93	10.90 ^d	45.99
T ₁₀	7.53 ^{ef}	3.20	16.00 ^{de}	3.11	16.97 ^{ab}	19.87
T ₁₁	10.9 ^{bc}	49.32	20.52 ^{bcd}	32.22	11.37 ^{cd}	43.66
T ₁₂	13.00 ^a	78.08	24.82 ^a	59.94	9.17 ^d	54.56
T ₁₃	7.30 ^f	0.00	15.52 ^e	0.00	20.18 ^a	0.00
SE m ±	0.449		0.906		0.630	
C.D @5%	1.311		2.645		1.839	

*Values in the column followed by common letters are non-significant at $p = 0.05$ as per Tukey's HSD (Tukey, 1965); T₁: Soil application of calcium silicate @ 375 kg/ha, T₂: Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₃: Soil application of Biochar @ 112.5 kg/ha, T₄: Soil application of Biochar @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₅: Soil application of Fly ash @ 112.5 kg/ha, T₆: Soil application of Fly ash @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₇: Soil application of Diatomaceous earth @ 150 kg/ha, T₈: Soil application of Diatomaceous earth @ 150 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₉: Foliar application of potassium silicate 4 ml/ @ 30 and 60 DAT, T₁₀: Foliar application of microbial consortia 5g/L @ 30 and 60 DAT, T₁₁: Foliar application of 0.2 % nano silicon @ 30 and 60 DAT, T₁₂: Foliar application of 0.2 % hexaconazole 5EC @ 30 and 60 DAT, T₁₃: Untreated control

During *kharif* 2023, the same trend in yield parameters were observed among the treatments. T₂ was found to be effective treatment in all yield parameters with 11.97 panicles per plant and 63.93 per cent increase over control with test weight of 22.93 g with 47.76 per cent increase over control and least chaffiness of 10.90 per cent with 45.99 per cent reduction over control. This result was on par with positive control T₁₂ which recorded panicles per plant (13.00 and 78.08%), test weight (24.82 g and 59.94%) and grain chaffiness (9.17 and 54.56%). In contrast T₁₀ recorded a smaller number of panicles per plant (7.53 and 3.20%), test weight (16.00 gm and 3.11%) and highest grain chaffiness (16.17 and 19.87%) whereas, T₁₃ recorded least panicles per plant (7.30), test weight (15.52 g) and maximum chaffiness (20.18%) (Table 4).

Variations in yield parameters are influenced by disease suppression, nutrient efficiency and silicon availability. Silicon strengthens plants, improves grain filling and reduces sterility, leading to more panicles with higher test weight and lower chaffiness. Effective disease management ensures better resource allocation for grain development. Soluble silicon supports quick uptake, while microbial consortia enhance absorption, boosting yield. Poor silicon availability or weak disease resistance results in fewer panicles, lower test weight and higher chaffiness, reducing productivity.

Effect of Treatments against Sheath Blight Disease on Grain Yield and Straw Yield

A significant variation in grain and straw yield was observed among the treatments during summer 2023

TABLE 5

Effect of silicon treatments against sheath blight disease on grain and straw yield during summer 2023

Treatment	Mean disease severity	Grain yield (Kg/ha)	Per cent increase	Straw yield (Kg/ha)	Per cent increase	B:C ratio
T ₁	19.83	5227 ^{abcd}	32.99	9683 ^a	27.97	2.11
T ₂	14.93	5710 ^{ab}	47.58	9807 ^a	30.79	2.31
T ₃	28.44	4723 ^{cdef}	20.17	9283 ^a	22.69	1.97
T ₄	25.18	4899 ^{cde}	24.66	9467 ^a	25.11	2.03
T ₅	29.92	4350 ^{ef}	10.05	9080 ^a	15.63	1.82
T ₆	27.55	4450 ^{def}	13.23	9273 ^a	22.56	1.86
T ₇	25.33	4507 ^{def}	14.69	9270 ^a	22.51	1.86
T ₈	22.96	4920 ^{bcde}	25.19	9397 ^a	24.19	2.00
T ₉	16.14	5403 ^{abc}	37.49	9587 ^a	26.70	2.24
T ₁₀	29.18	4363 ^{ef}	11.03	8850 ^{ab}	20.00	1.83
T ₁₁	18.06	5353 ^{abc}	36.22	9497 ^a	25.51	2.14
T ₁₂	13.45	5870 ^a	49.36	9927 ^a	31.19	2.40
T ₁₃	43.26	3930 ^f	0.00	7567 ^b	0.00	1.66
SE m ±		156.555		266.005		
C.D @5%		456.951		776.413		

and *kharif* 2023, as presented in the Table 5 and 6. In summer 2023, the treatment T₂: Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/l @ 30 and 60 DAT, recorded the maximum grain and straw yield of 5800 and 9897 kg/ha reflecting 47.58 and 30.79 per cent increase over

control respectively. This result was statistically on par with the positive control, T₁₂: foliar application of 0.2% hexaconazole at 30 and 60 DAT showing the grain yield (5870kg/ha and 49.36%) and straw yield (9927 kg/ha and 31.19%), followed by T₉: foliar application of potassium silicate (4 g/l), recording the

TABLE 6

Effect of silicon treatments against sheath blight disease on grain and straw yield during *kharif* 2023

Treatment	Mean disease severity	Grain yield (Kg/ha)	Per cent increase	Straw yield (Kg/ha)	Per cent increase	B:C ratio
T ₁	20.86	5160 ^{abc}	32.63	9517 ^a	25.94	2.08
T ₂	16.71	5623 ^a	44.53	9690 ^a	28.23	2.24
T ₃	29.03	4529 ^{cde}	16.40	9200 ^a	21.75	1.90
T ₄	27.11	4827 ^{bcd}	24.06	9410 ^a	24.53	2.00
T ₅	30.66	4149 ^{de}	6.65	8967 ^a	12.26	1.75
T ₆	27.70	4320 ^{de}	11.03	9073 ^a	20.07	1.81
T ₇	26.51	4404 ^{de}	13.19	9160 ^a	21.22	1.82
T ₈	24.74	4810 ^{bcd}	23.63	9327 ^a	23.42	1.96
T ₉	18.19	5290 ^{ab}	35.97	9490 ^a	25.58	2.19
T ₁₀	29.63	4274 ^{de}	9.85	8483 ^{ab}	18.66	1.80

Continued....

TABLE 6 Continued....

Treatment	Mean disease severity	Grain yield (Kg/ha)	Per cent increase	Straw yield (Kg/ha)	Per cent increase	B:C ratio
T ₁₁	20.25	5150 ^{abc}	32.37	9320 ^a	23.33	2.06
T ₁₂	15.21	5770 ^a	48.30	9830 ^a	30.08	2.36
T ₁₃	46.07	3891 ^c	0.00	7557 ^b	0.00	1.64
SE m ±		156.555		266.005		
C.D @5%		456.951		776.413		

*Values in the column followed by common letters are non-significant at $p = 0.05$ as per Tukey's HSD (Tukey, 1965); T₁: Soil application of calcium silicate @ 375 kg/ha, T₂: Soil application of calcium silicate @ 375 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₃: Soil application of Biochar @ 112.5 kg/ha, T₄: Soil application of Biochar @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₅: Soil application of Fly ash @ 112.5 kg/ha, T₆: Soil application of Fly ash @ 112.5 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₇: Soil application of Diatomaceous earth @ 150 kg/ha, T₈: Soil application of Diatomaceous earth @ 150 kg/ha + foliar spray of microbial consortia 5g/L @ 30 and 60 DAT, T₉: Foliar application of potassium silicate 4 ml/ @ 30 and 60 DAT, T₁₀: Foliar application of microbial consortia 5g/L @ 30 and 60 DAT, T₁₁: Foliar application of 0.2 % nano silicon @ 30 and 60 DAT, T₁₂: Foliar application of 0.2 % hexaconazole 5EC @ 30 and 60 DAT, T₁₃: Untreated control

grain yield (5403 kg/ha and 37.49%) and straw yield (9927 kg/ha and 31.19%). In contrast, T₅: soil application of fly ash at 112.5 kg/ha was found to be least effective treatment with less grain and straw yield of 4325 and 8750 kg/ha with 10.05 and 15.63 per cent increase over control followed by T₁₀: foliar application of microbial consortia (5 g/l) at 30 and 60 DAT with grain yield (4363 kg/ha and 11.03%) and straw yield (9080 kg/ha and 20.00%) whereas, T₁₃: control, recorded the least grain yield (3930 kg/ha) and straw yield (7567 kg/ha). Other treatments recorded the grain yield in the range of 4450 to 5353 kg/ha, corresponding to a percentage increase of 133.23 to 36.22 per cent compared to the control and straw yield ranging from 9270 to 9497 kg/ha with 22.51 to 25.51 per cent increase over control. Among all the treatments T₂ was found to be the best treatment with highest benefit cost ratio of 2.31 when compared to control (1.66) followed by T₉ with B:C ratio of 2.24. T₅ was found to be the least effective treatment in managing the disease with lowest benefit cost ratio of 1.82 (Table 5).

In *kharif* 2023, the treatments exhibited the same trend as previous season where, T₂ recorded the highest grain and straw yield of 5623 and 9690 kg/ha reflecting 44.53 and 28.23 per cent increase over

control respectively, which was on par with the positive control T₁₂ with grain yield (5770 kg/h and 48.30%) and straw yield (9830 kg/ha and 30.08%) followed by T₉: foliar application of potassium silicate @ 4 g/L, recording the grain yield (5290 kg/ha and 35.97%) and straw yield (9490 kg/ha and 25.58%). In contrast, T₅ recorded less grain and straw yield of 4149 and 8483 kg/ha with least increase of 6.65 and 12.26 per cent increase over control respectively followed by T₁₀ with grain yield (4274 kg/ha and 9.85%) and straw yield (8967 kg/ha and 18.66 %) whereas, T₁₃: control, recorded the grain yield of 3891 kg/ha and straw yield of 7557 kg/ha. Other treatments recorded the grain yield in the range of 4320 to 5150 kg/ha, corresponding to a percentage increase of 11.03 to 32.37 per cent compared to the control and straw yield ranged from 9073 to 9320 kg/ha corresponding per cent increase of 20.07 to 23.33 per cent. By considering the benefit to cost ratio, T₂ was found to be the best treatment among all the treatments with highest benefit cost ratio of 2.24 when compared to control (1.64) followed by T₉ with B:C ratio of 2.19 whereas, T₅ was found to be the least effective treatment in managing the disease with lowest benefit cost ratio of 1.75 (Table 6).

Grain and straw yield variations are influenced by all factors like disease control, growth and development of plants, silicon availability and nutrient uptake of plants. Soluble silicon sources enhance growth, photosynthesis and grain filling thereby leading to higher yields. Microbial consortia improve nutrient absorption, while effective disease management allows better energy allocation for productivity (Schurt *et al.*, 2014). Treatments with low silicon bioavailability or weak disease resistance showed reduced yields, emphasizing the role of proper silicon application. The results were in confirmation with the findings of Santos *et al.* (2011) who observed that calcium silicate effectively reduced the brown spot and the panicle blast, which resulted in an increased rice yield. Mahmud-Toher *et al.* (2022) reported that the soil amendment with Si compound significantly improved the rice yield-related components and yield as compared to the control (Si-free treatment). At 100 days after planting (harvest stage), the grain yield per experimental pot (MR219 and MR253 rice varieties) treated with rice husk ash (with and without Mn) showed no significant difference to the plants treated with CaSiO_3 (with and without Mn). Setu *et al.*, (2024) reported that most of the yield indicators were significantly improved by the Si fertilizers, except for grain per spike quantity, weight and thousand grain weight (g). The maximum yield was achieved by CaSiO_3 at 100 kg/ha.

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