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Dr. Mini V
Onattukara Regional Agricultural Research Station, Kayamkulam Kerala Agricultural University, Kerala, India

Sree Parvathy P
Onattukara Regional Agricultural Research Station, Kayamkulam Kerala Agricultural University, Kerala, India

Rahanabai H
Onattukara Regional Agricultural Research Station, Kayamkulam Kerala Agricultural University, Kerala, India

Corresponding Author:
Dr. Mini V
Onattukara Regional Agricultural Research Station, Kayamkulam Kerala Agricultural University, Kerala, India

Effect of silicon application on abiotic and biotic stress management in rice in Typic Ustipsamments of Kerala, India

Dr. Mini V, Sree Parvathy P and Rahanabai H

Abstract
Si has been shown to improve the growth and yield of many crops, particularly rice, which accumulates Si. Beyond increasing rice yield, Si treatment has additional benefits such as improving nutrient availability, reducing nutrient toxicity, and reducing biotic and abiotic stress in plants. To determine the impact of Si treatment on rice's ability to tolerate biotic and abiotic stress, a field experiment was conducted in two seasons (Kharif and Rabi) in 2022-2023. Various sources of Si, including potassium silicate, sodium silicate, rice husk ash, and fine silica, were evaluated to standardize the dose and mode of application for rice. A cost-effective method of Si nutrition was developed. The study examined the effect of Si application on the yield of rice grain and straw, and on the management of major biotic (stem borer incidence) and abiotic (iron toxicity) stress. The best treatment for increasing rice yield and managing biotic and abiotic stress in Typic Ustipsamments of Kerala was found to be soil test based NPK+ foliar application of 0.5% potassium silicate at maximum tillering stage and panicle initiation stage.

Keywords: Silicon nutrition, rice, biotic stress, abiotic stress, iron toxicity, stem borer

Introduction
Silicon is considered a beneficial element and has promising impact on yield and quality of Si-loving plants such as rice. Variation in species and outside Si concentrations have an impact on the uptake and transport of silicon in rice (Ma *et al*., 2001) [8]. Rice straw contains 4-20 per cent SiO_2 which indicates the high Si demand of rice. Silicon makes up about 10% of the dry weight of shoots, which is much more than the amounts of important macronutrients like N, P, and K. Rice has a silicon absorption capability of 150 to 300 kg ha^{-1}. (Bazilevich, 2001) [1]. On average, 20 kg of soil-bound SiO2 are removed for every 100 kg of brown rice produced. (Ma and Takahashi,2002) [9].

Positive effects of Si nutrition is detected in plants at the time of stress conditions. Silicon induces changes in the plant resistance mechanisms to combat multiple abiotic and biotic stresses. Silicon application is effective in manging many bacterial and fungal diseases in rice. Silicon reduces water loss through transpiration and alleviate water stress. Because the leaf blades are upright in silicon treated palnts, there is better light absorption, which increases photosynthetic efficiency. Silicon's articulating effects on rice yield, lodging tolerance, and increased reproductive fertility have all been documented (Savant *et al.*, 1997) [13].

It is the only known element that can increase resistance to a variety of stressors. Unfortunately, in Kerala's sandy plains (Typic Ustipsamments), the importance of silicon nutrition in rice development and mitigating abiotic and biotic challenges has not yet been well investigated. Hence the present study has been undertaken at Onattukara Regional Agricultural Research Station, Kayamkulam, Kerala with an objective to assess the effect of silicon application on biotic and abiotic stress management in rice.

Materials and Methods
Various sources of silicon *viz.*, potassium silicate, sodium silicate, rice husk ash and fine silica were evaluated for standardizing the dose and method of application for rice and a cost-effective method of silicon nutrition was developed. Field experiment was conducted in two seasons during during *Kharif* and *Rabi* seasons of 2022-23. The field experiment used a randomized block design with eight treatments that were duplicated three times each and were T_1 (Recommended dose of NPK (K.A.U,2016) [7], T_2 (Soil test based NPK), T_3 (Soil test

based NPK+ Foliar application of 0.1% potassium silicate), T_4 (Soil test based NPK+ Foliar application of 0.1% sodium silicate), T_5 (Soil test based NPK+ Foliar application of 0.5% potassium silicate), T6(Soil test based NPK+ Foliar application of 0.5% sodium silicate), T_7 (Soil test based NPK+ soil application of fine silica @ 100 kg/ha) and T_8 (Soil test based NPK+ soil application of rice husk ash @ 500 kg/ha).

Rice variety Bhagya was used for the experiment. Soil and plant samples were collected for various analysis after the experiment. Observations on biometric and yield and yield attributing characters were also recorded. Scoring on iron toxicity was done using the standard evaluation system for rice (IRRI, 2000) [6] and percentage incidence of stem borer was also recorded at panicle initiation stage. Spraying of potassium and sodium silicate was carried out twice, once at the maximum tillering and once at the panicle initiation stage.

Results and Discussion

Impact of silicon application on rice grain and straw yield and major biotic (incidence of stem borer) and abiotic (iron toxicity) stress management were investigated.

Effect of silicon application on grain and straw yield of rice

Yields of grain and straw were considerably increased by the application of silicon. The maximum yield was obtained with the soil test-based NPK+ foliar application of 0.5% potassium silicate (T_5), which was significantly better than all other treatments (Table 1). The improvement in rice's growth and yield characteristics as well as the stimulating effects of Si in lowering biotic and abiotic stress may be responsible for the rise in grain and straw yields. The results showed that Si addition aided plant growth, which may be attributable to increased photosynthetic efficiency after Si addition. This effect was manifested through an increase in the number of productive tillers, length of panicles, percentage of filled grains, weights of 1000 grains, and a decrease in pest and disease infestation, which ultimately led to an increase in yield. This supported the conclusions made by Buck *et al.* (2008) [2], Prakash *et al.* (2011) [12], and Gholami and Falah (2013). [4] Si is already known to be a useful nutrient for many crops, including rice and sugarcane, and it is crucial for the growth and development of plants. Si treatment has the ability to increase the optimal nitrogen (N) rate due to the synergistic effect, increasing rice productivity (Hodson *et al.*, 2005) [5].

Table 1: Impact of silicon on grain and straw yield of rice

Treatment		Kharif		Rabi	
		Grain (t ha^{-1})	Straw (t ha^{-1})	Grain (t ha^{-1})	Straw (t ha^{-1})
T_1:	Recommended dose of NPK	1.85	4.16	1.76	4.17
T_2:	Soil test-based NPK (STB-NPK)	2.51	5.31	2.36	5.38
T3:	STB-NPK + foliar spray of 0.1% potassium silicate	2.63	5.77	2.53	6.13
T_4:	STB-NPK + foliar spray of 0.1% sodium silicate	2.52	5.52	2.40	5.92
T_5:	STB-NPK + foliar spray of 0.5% potassium silicate	3.28	5.93	3.16	6.21
T_6:	STB-NPK + foliar spray of 0.5% sodium silicate	2.61	5.38	2.50	5.24
T_7:	STB-NPK + soil application of fine silica @ 100kg/ha	2.42	5.43	2.31	5.54
T_8:	STB-NPK + soil application of rice husk ash @ 500 kg/ha	2.62	5.48	2.51	5.63
CD (0.05)		0.123	0.157	0.071	0.418

3.2 Effect of silicon application on biotic and abiotic stress management in rice

Incidence of stem borer was the least in T5 (soil test based NPK+ foliar application of 0.5% potassium silicate) and was significantly superior to all the treatments in both the seasons (Table 2). Application of silicon results in increased resistance to destructive pests such the brown plant hopper, green leaf hopper, stem borer, mites, and stem maggots. A mechanical barrier is set up against chewing and probing by insects by the Si deposition in the plant tissues. Two main resistance mechanisms by which silicon application imparts resistance to insects are physical and chemical defenses. Si is mostly found as opaline phytoliths in plants, which increases the hardness and abrasiveness of plant tissues, serves as a form of physical protection, and decreases digestibility. (Ma, 2004) [10].

Table 2: Impact of silicon on rice stem borer incidence management

Treatment		Stemborer attack (%)	
		Kharif	Rabi
T_1:	Recommended dose of NPK	13.8	14.89
T_2:	Soil test-based NPK (STB-NPK)	11.8	12.73
T3:	STB-NPK + foliar spray of 0.1% potassium silicate	9.5	10.21
T_4:	STB-NPK + foliar spray of 0.1% sodium silicate	11.2	12.01
T_5:	STB-NPK + foliar spray of 0.5% potassium silicate	4.2	4.45
T_6:	STB-NPK + foliar spray of 0.5% sodium silicate	9.8	10.57
T_7:	STB-NPK + soil application of fine silica @ 100kg/ha	16.2	17.41
T_8:	STB-NPK + soil application of rice husk ash @ 500 kg/ha	14.2	15.25
CD (0.05)		3.353	4.628

The treatment T_5 (soil test based NPK+ foliar application of 0.5% potassium silicate) in both seasons received the lowest score for the iron toxicity symptom. (Table 3). Si treatment increases the activity of antioxidant enzymes such ascorbate peroxidase, catalase, and soluble peroxidase under conditions of moderate iron toxicity. (Chalmardi *et al*., 2014) [3]. Decreased lipid peroxidation and increased hydrogen peroxide detoxification result from such an increase in antioxidant enzyme levels. Therefore, lowering the content of Fe in plants with Si fertilization can mitigate the negative consequences of Fe toxicity. In Kerala's laterite soils, foliar application of Si and B was found to lower the amount of Fe in rice soils that was readily available. Application of silicon promotes air flow from the leaves to the stem and then to the roots, increasing the rice roots' ability to oxidize. The toxicity of iron in soil is decreased by oxidizing it from ferrous iron to ferric iron. (Nagula *et al*.,2016) [11].

Table 3: Impact of silicon on iron toxicity management in rice

Treatment		Scoring for iron toxicity	
		Kharif	Rabi
T_1:	Recommended dose of NPK	2.33	3.00
T_2:	Soil test-based NPK (STB-NPK)	1.67	2.33
T3:	STB-NPK + foliar spray of 0.1% potassium silicate	1.00	2.00
T_4:	STB-NPK + foliar spray of 0.1% sodium silicate	1.33	2.33
T_5:	STB-NPK + foliar spray of 0.5% potassium silicate	0.33	1.00
T_6:	STB-NPK + foliar spray of 0.5% sodium silicate	1.33	2.00
T_7:	STB-NPK + soil application of fine silica @ 100kg/ha	2.00	2.67
T_8:	STB-NPK + soil application of rice husk ash @ 500 kg/ha	1.00	2.00
CD (0.05)		0.615	0.604

Conclusion

Si nutrition and its control can be extremely important in reducing biotic and abiotic stress because rice is a Si accumulator. Silicon largely promotes secondary metabolite synthesis, photosynthetic machinery defense, ion homeostasis, antioxidant machinery, and metal chelation. Application of soil test based NPK + foliar application of 0.5% potassium silicate at maximum tillering stage and panicle initiation stage (T_5) recorded the highest yield and was significantly superior to all other treatments. Incidence of stem borer was the least in T_5 and the least score for iron toxicity symptom was also obtained in treatment T_5. Soil test based NPK+ foliar application of 0.5% potassium silicate at maximum tillering stage and panicle initiation stage was found to be the best treatment for increasing the rice yield and managing the biotic and abiotic stress in rice in Typic Ustipsamments of Kerala. The addition of silicon will aid in overcoming the negative impacts of biotic and abiotic stresses and enhance plants' ability to adapt to harsh conditions.

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