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Paddy and Silicon Application

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ABSTRACT

The present study has been conducted to evaluate the effects of Potassium silicate, as a silicon source, on the morphological, biochemical, and yield parameters of the two varieties PB-1121 and Karan bhog -521 of rice (*Oryza sativa* L.). For this, thre econcentrations of potassium silicate, i.e. 3g, 5g, and 7g were mixed into 10 kg soil along with basal fertilizers and the results were compared with the control.The effects were observed on no. of effective tillers, spikes, spikelets, grains, the weight of grains, etc. Supplementation of silicon has resulted in an increase of 104.85% in no. of tillers per hill, 135.4% in fertile tillers, 16.22% number of grains per panicle, 172.56% number of grains per hill,8.48% in weight of husk per hill, 18.88% in weight of grains per hill in PB- 1121 and 14.09% no. of spikes per panicle, 147.12% in total spikes per hill, 16.64% in no. of spikelets per panicle, 142.36% in total spikelets per hill 116.13% in no of tillers per hill, 114.36% in fertile tillers per hill, 1.25% in weight of grain per hill Karan bhog-521 variety. Silicon fertilizers being non–corrosive and environmentally friendly can become a suitable fertilizer for increasing the yield of paddy crops in the soil of District Rohtak, Haryana.

Key words: *Potassium silicate, Paddy crop, Haryana, Biochemical and yield parameters*

Introduction

Silicon accumulator crops can take up a substantial amount of silicon, accumulate in various parts, and lead to a reduction in the amount of available silicon in soil. About 20 kg/hm^2 of SiO_2 is being removed from the soil to produce every 100 kg of brown rice (Ma and Takahashi, 2002) and about 210-224 million tons of it is removed from the soil all over the world annually. Simultaneously, there are growing concerns that the amount of Si in agricultural soils may be dwindling. The soil's biogenic Si concentration may also be decreasing as a result of agricultural malpractices that remove plant matter and resulting in making the soil less fertile. Worldwide, lots of literature documents the significant importance of using silicon fertilizer in crops such as rice, wheat, sugarcane, tomatoes, vines, etc. Due to its remarkable importance, in 2014 and 2015, it has been appended as a beneficial substance by the International Plant Nutrition Institute (IPNI) and the Association of American Plant Food Control Officials (AAPFCO)(Majumdar and Prakash, 2017). In the Haryana state, rice farming is considered a by-product of the green revolution, and currently, rice is the second most important crop after wheat. According to the economic survey 2020–21 report, the land under rice cultivation has increased from 14.47 lakh hectares in 2018–19 to 15.59 lakh hectares in 2019-20 (The Pioneer, 2021; Neeraj, 2014). External application of silicon can enhance the productivity of crops and Si fertilizer has been used in many countries to improve rice yield (Tubana *et al*., 2016), but cases of soil fertilization by silicon have not been reported among the farmers of district Rohtak, Haryana, India. By keeping this in mind, the present study has been designed to document the effects of potassium silicate on various growth parameters of rice in natural environmental conditions beyond greenhouse conditions.

Methodology

Description of Study Site: The present experimental work has been performed at the Department of Botany of Baba Mastnath University, Rohtak, Haryana, India, between April – September 2021. This place is located between the latitude of 28°40'30" N and 29°05'35" N and a longitude of 76°13'22"E and 76° 51'20"E. The climate of district Rohtak is arid to semi-arid and the soil is sandy loam to silt clay in nature and falls under the low fertility zone. Various Kharif and rabi crops such as wheat, sugarcane etc. are grown in this area and rice is the most important Kharif crop in this area. The total geographical area of the Rohtak district is 1, 66,847 hectares and the cultivable area is 1, 56,000 hectares with a 163 % cropping intensity (District profile, 2013).

a. Experimental Setup and Treatments

In the present study, the two varieties PB-1121 and Karan bhog -521 of rice (*Oryza sativa* L.) were used. The seeds of these two were obtained from "The Haryana State Seed Certification Agency" in Rohtak, Haryana. The chemical Potassium silicate K_2O_3Si (molecular weight: 154.28 $gmol^{-1}$) was procured from Akshar Chem Private Limited of Mumbai. After thoroughly washing with water, surface sterilizing with sodium hypochlorite solution, and further washing with plain water, the seeds were kept in wet gunny bags for 3–4 days before sowing in soil. Five seedlings of 30 days were transplanted to each pot. Three different concentrations of potassium silicate, i.e. 3g, 5g, and 7g were mixed into 10 kg soil after dissolving in 100 ml. distilled water for thorough mixing in soil. Control was left deprived of potassium silicate. Each treatment and control were replicated thrice. The characteristics of the soil were: pH 8.0, organic matter 42.45 g, total nitrogen 2.50 g, total phosphorus 1.10 g, total potassium 141.36 mg, and silicon 76.6 mg/kg. In each pot, basal fertilizer in the form of Urea 250 kg/hectare, DAP110 kg/hectare, and Potash 25 kg/hectare was used. After the first week of transplantation, a first dose of NPK fertilizer and at panicle initiation, the second dose of NPK fertilizer were added. Potassium silicate, DAP, and potash were applied in a single dose. These pots were kept in under natural conditions of 20.3/35.6^{0}C average day and night temperature and photoperiod of about 16 hours. 4-5 cm of water level was maintained in each pot about to tillering stage and pots were irrigated as per requirements.

Morphological and Biochemical Parameters

The observations on the number of parameters such as no. of saplings surviving in pots, plants length, length of panicle leaf, no. of tillers, no. of effective tillers, spikelets per spike, no. of grains, and grain weight were measured at the age of 10 days (survival of saplings), 65 days (vegetative parameters) and 135 days (reproductive and yield parameters) after transplantation. Leaves extract (from 65 days old plants) was also studied for biochemical parameters by using standard methods: Total carbohydrates (Hedge *et al*., 1962), total protein (Lowery *et al*., 1951), total chlorophyll (Lichlenthaler *et al*., 1987), total antioxidants (Prieto *et al*., 1999) total biomass, MDA content (Heath *et al*., 1962), Relative water content (Barrs *et al*., 1973), total proline (Bates *et al*., 1973), total superoxide dismutase (Beyer *et al*., 1987) and catalase (Cakmak and Marschner, 1992). For statistically analyzing the results, ANOVA in Excel window version 2011 and for comparing means Turkey HSD Test was used at p values of <0.05 and 0.01.

Results and Discussion

Morphological and Yield Parameters

The results have been presented in the form of tables. In each table *denotes percentage stimulation over the control. The values portrayed in different letters in each group denote significant differences at $P<0.01$** and $P < 0.05$*.

Total tillers, fertile tillers per hill, length of panicle leaf, and Spikelet formation are considered as significant parameters for the total yield output (Phommuangkhuk *et al*., 2020). In the present study, all the concentrations of silicon were found effective but the concentration of seven grams was found more promising in comparison to the control. The significant upsurge of 150% number of plant survival per replication, 1.14% in plant height, 41.73% in plant diameter in PB- 1121 and 50.15% number of plants survival/replication, 1.09% in plant height, 32.2% in plant diameter of Karan bhog-521 variety (Table 1) has been documented. Similarly, increase of 104.85% in no. of tillers per hill, 135.4% in effective tillers per hill in PB- 1121, 116.13% in no of tillers per hill, 114.36% in effective tillers per hill in plant of Karan bhog-521 variety (Table 2) has been observed in the plants of silicon treated pots(7g) as comparison to control. The increase of 3.15% in panicle leaf length, 12.38% in panicle leaf area of PB-1121 and increase of 6.32% in panicle leaf length, 8.76% in panicle leaf area of Karan bhog -521 (Table 3), 15.79% no. of spikes per panicle, 169.94% in total spikes per hill, 10.59% in no. of spikelets per panicle, 158.22% in total spikelets per hill of PB-1121 and 14.09% no. of spikes per panicle, 147.12% in total spikes per hill, 16.64% in no. of spikelets per panicle, 142.36% in total spikelets per hill of Karan bhog-521(Table 4 and 5), 16.22% number of grains per panicle, 172.56% number of grains per hill, of PB-1121 variety, 14.95% number of grains per panicle, 145.35% number of grain per hill of Karan bhog-521 (Table 6), 8.48% in weight of husk per hill, 18.88% in weight of grains per hill in plants of PB- 1121 variety, 8.55% in weight of husk per hill of PB- 1121 variety, 19.25% in weight of grain per hill in plants of Si treated than control Karan bhog- 521 variety (Table 7) has been documented in current study. A close relationship has been reported between the nutritional status of parent culm and the number of tillers and a directly proportional relationship between the number of tillers and grain yield (Tanaka, 1972).

Biochemical Parameters

The outcomes have been presented in the form of graphs and the simulation percentage over control

Table 1. Effect of Potassium silicate application on number of plant survive per pot, plant height and plant diameter of PB- 1121 and Karan bhog-521 variety of rice (*Oryza sativa* L.) at 65 days after transplantation

Group	No. of plant survive per pot (After 10 days of transplantation)		Plant height (cm)		Plant diameter (cm)	
	PB- 1121	Karan bhog-521	PB- 1121	Karan bhog-521	PB- 1121	Karan bhog-521
Control	2^{b}±0.57	3.33^{a}±1.2019	101.17^{a}±0.5350	101.43a±0.33	4.445^{c}±0.28	4.91^{b}±0.20
3g Si	3.67^{ab}±0.8819	4.33^{a}±0.33	101.58^{a}±0.36	101.382^{a}±0.46	5.26^{b}±0.17	6.06^{a}±0.17
5g Si	5^{a}±0.0	5^{a}±0.0	102.05^{a}±0.39	101.99^{a}±0.34	5.91^{a}±0.12	6.14^{a}±0.11
7g Si	5^{a}±0.0	5^{a}±0.0	102.32^{a}±0.43	102.548^{a}±0.43	6.3^{a}±0.17	6.50^{a}±0.10
	(150%)*	(50.15%)	(1.14%)	(1.09%)	(41.73%) **	(32.2%)**

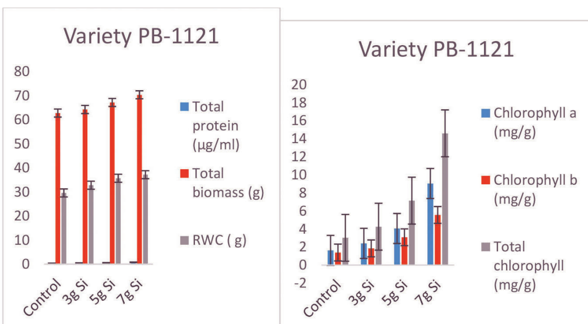
Table 2. Effect of application of potassium silicate on no. of tillers and effective tillers per hill of PB-1121 and Karan bhog- 521 variety of rice (*Oryza sativa* L.) at 65 days after transplantation.

Group	No. of tillers per hill		Effective tillers per hill	
	PB- 1121	Karan bhog- 521	PB- 1121	Karan bhog- 521
Control	5.5^{b}±0.99	5.18^{c}±0.48	4.33^{c}±0.61	4.72^{c}±0.42
3g Si	8.077^{ab}±1.29	7.85^{bc}±0.79	6.46^{bc}±1.02	7.14^{bc}±0.68
5g Si	10.66^{a}±0.82	9.53^{ab}±0.76	8.267^{ab}±0.73	9^{ab}±0.63
7g Si	11.26^{a}±0.72	11.2^{a}±1.13	10.2^{a}±0.62	10.1^{a}±0.94
	(104.85%)**	(116.13%)**	(135.4%)**	(114.36%)**

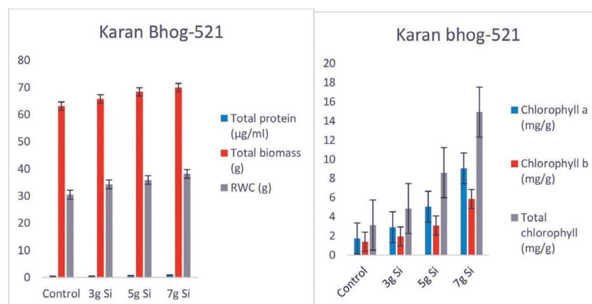
Table 3. Effect of application of potassium silicate on panicle length, panicle leaf length, panicle leaf area of PB-1121 and Karan bhog-521 variety of rice (*Oryza sativa* L.) at 130 days after transplantation.

Group	Panicle leaf length (cm)		Panicle leaf area (cm)	
	PB- 1121	Karan bhog- 521	PB- 1121	Karan bhog- 521
Control	7.71^{c}±0.04	7.38^{b}±0.10	1.31^{d}±0.03	1.33^{b}±0.04
3g Si	7.83^{bc}±0.02	7.75^{a}±0.05	1.34^{cd}±0.02	1.35^{ab}±0.02
5g Si	7.93^{a}±0.02	7.86^{a}±0.04	1.38^{bcd}±0.02	1.40^{ab}±0.02
7g Si	7.96^{a}±0.02	7.88^{a}±0.03	1.48^{a}±0.02	1.45^{a}±0.02
	(3.15%)**	(6.32%)**	(12.38%)**	(8.76%)*

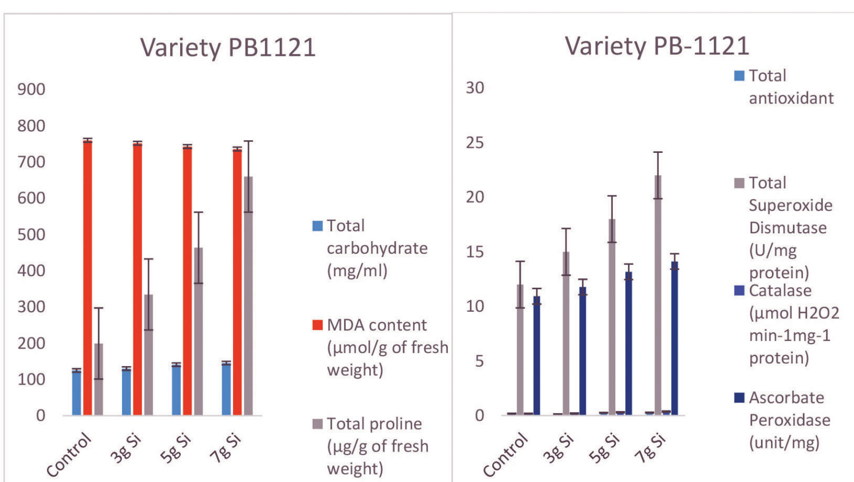
has been provided at 7g concentration. In the present work, increase in total carbohydrates (16.37%, 16.72%), total protein (128.57%, 120.51%), total proline (231.51%, 224.09%), and total chlorophyll (382.65%, 376.35%) has been recorded in PB -1121 (Figure 1 & 2) and Karan Bhog-521 respectively (Figure 5 & 6), which may be a contributory factor in enhancing the tillers no., number of spikes, spikelets and finally the total yield. The antioxidant enzymes work as a defense system for plant and their concentration get increased under stressful conditions (Asada, 1999). The combined activity of superoxide dismutase (SOD) and Catalase convert the free radicals to molecular oxygen and water (Malhotra *et al*., 2017) In our findings, an increase in the concentration of proline (231.51%, 224.09%), total antioxidants (45.45%, 46.49%), SOD (83.83%, 61.54%), Ascorbate Peroxidase (40.98%) and Catalase (1117.65%, 84.21%) of PB-1121(Figure 3 and 4) and Karan Bhog-521 (Figure 7 and 8) respectively have been observed which might work as scavenging mechanism under harsh conditions. MDA content is considered as a reliable marker to measure oxidative stress(Oracaz *et al*.,2007) Its concentration was found to be 3.16% and 2.51% less in silicon-treated plants as compared to control in PB-1121 and Karan Bhog-521 respectively. The silicon supplementation was also able to maintain relative water content and thus indicating the healthy metabolic activity of cells or tissues (Figures 3 and 4). Similar findings have been dictated in alfalfa (Wang, 2009). The findings concluded by other researchers on efficacy of the application of silicon at tillering, anthesis stage, grain



Figs. 1 and 2. Effect of Potassium silicate application on Total protein, Total biomass, RWC, Chlorophyll a, b, and total chlorophyll of PB- 1121 variety of rice (*Oryza sativa* L.) at 65 days after transplantation.



Figs. 5 and 6. Effect of Potassium silicate application on Total protein, Total biomass , RWC, Chlorophyll a, b, and total chlorophyll of Karan Bhog-521 variety of rice (*Oryza sativa* L.) at 65 days after transplantation



Figs. 3 and 4. Effect of Potassium silicate application on Total carbohydrates, MDA content, Total proline , Total antioxidants, SOD, Catalase and Ascorbate peroxidase of PB- 1121 variety of rice (*Oryza sativa* L.) at 65 days after transplantation output, spikes number, number of tillers and number of grains/spike, the mass of 1000 grains in wheat and rice, number of grains/ cob in maize, number of fruits in tomato indicates towards the benefits of using silicon (White *et al*., 2017; Gerami *et al*., 2012; Amin *et al*., 2016; Malhotra *et al*., 2018) The increase in yield may also be due to the deposition of silica in the epidermis of the leaf and shoot which worked as a barrier to protect the plant from abiotic and biotic stresses (Silva *et al*., 2015).

Conclusion

Rice, wheat, and other monocotyledons crop being silicon accumulator accumulate lot percentage of silicon in various organs. Usually, straws and husks

Table 4. Effect of application of potassium silicate on number of spikes per panicle and total spikes in hill of PB- 1121 and Karan bhog-521 variety of rice (*Oryza sativa* L.) at 130 days after transplantation.

Group	Number of spikes per panicle		Total spikes in hill	
	PB- 1121	Karan bhog- 521	PB- 1121	Karan bhog- 521
Control	$6.33^{b}\pm0.21$	6.54±0.15	$27.8^{c}\pm4.6$	30.7±2.78
3g Si	$6.76^{ab}\pm0.20$	7.14±0.17	$44.9^{bc}\pm8.03$	51.6±5.3
5g Si	$7.06^{ab}\pm0.18$	7.26±0.15	$57.86^{ab}\pm5.01$	65.4±4.8
7g Si	$7.33^{a}\pm0.15$	7.46±0.13	$75.1^{a}\pm5.2$	75.9±7.2
	(15.79%)*	(14.09%)**	(169.94%)**	(147.12%)**

Table 5. Effect of application of potassium silicate on number of spikelets per panicle and total spikelets per hill of PB-1121 and Karan bhog-521 variety of rice (*Oryza sativa* L.) at 130 days after transplantation.

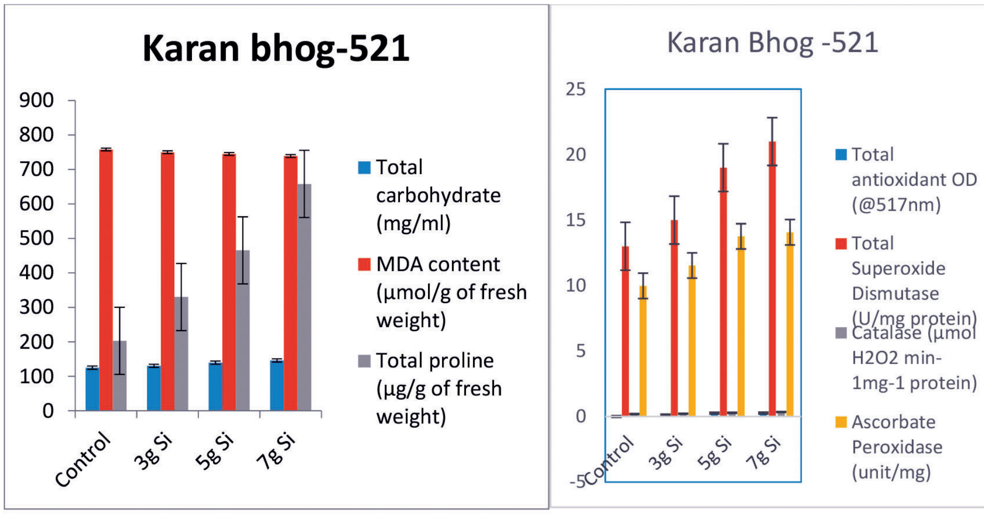
Group	Number of spikelets per panicle		Total spikelets per hill	
	PB- 1121	Karan bhog- 521	PB- 1121	Karan bhog- 521
Control	$42.5^{c}\pm0.42$	40.18±0.29	$185.1^{c}\pm27.9$	$195.9^{c}\pm18.4$
3g Si	$43.69^{bc}\pm0.80$	43.3±0.6	$278.6^{bc}\pm42.8$	$315.4^{bc}\pm33.2$
5g Si	$45.8^{a}\pm0.26$	46.2±0.32	$379.06^{b}\pm34.5$	$417.5^{ab}\pm29.5$
7g Si	$47^{a}\pm0.32$	46.8±0.3	$478.1^{a}\pm28.0$	$474.8^{a}\pm44.2$
	(10.59%)**	(16.64%)**	(158.22%)**	(142.36%)**

Table 6. Effect of application of potassium silicate on number of grains per panicle and number of grains per hill of PB- 1121 and Karan bhog- 521 variety of rice (*Oryza sativa* L.) at 130 days after transplantation.

Group	Number of grains per panicle		Number of grains per hill	
	PB- 1121	Karan bhog- 521	PB- 1121	Karan bhog- 521
Control	$38.8^{c}\pm0.3$	$39.0^{c}\pm0.5$	$168.5^{d}\pm24.3$	$185.1^{c}\pm17.7$
3g Si	$40.15^{bc}\pm0.3$	$39.9^{bc}\pm0.4$	$258.6^{cd}\pm40.1$	$286.2^{bc}\pm28.7$
5g Si	$41.6^{b}\pm0.46$	$43.6^{a}\pm0.7$	$335.2^{bc}\pm29.8$	$392.4^{ab}\pm30.7$
7g Si	$45.1^{a}\pm0.7$	$44.9^{a}\pm0.7$	$459.2^{a}\pm28.0$	$454.3^{a}\pm41.4$
	(16.22%)**	(14.95%)**	(172.56%)**	(145.35%)**

Table 7. Effect of application of potassium silicate on number weight of husk per hill and weight of grain per hill of PB-1121 and Karan bhog-521 variety of rice (*Oryza sativa* L.) at 130 days after transplantation.

Group	Weight of husk per hill		Weight of grain per hill	
	PB- 1121	Karan bhog- 521	PB- 1121	Karan bhog- 521
Control	$110.03^{d}\pm0.33$	$109.8^{d}\pm0.21$	$24.57^{d}\pm0.2$	$24.879^{d}\pm0.22$
3g Si	$111.23^{cd}\pm0.32$	$111.6^{c}\pm0.26$	$26.06^{c}\pm0.2$	$26.356^{c}\pm0.18$
5g Si	$114.79^{b}\pm0.31$	$114.92^{b}\pm0.30$	$27.71^{b}\pm0.2$	$27.855^{b}\pm0.15$
7g Si	$119.36^{a}\pm0.31$	$119.28^{a}\pm0.28$	$29.20^{a}\pm0.28$	$29.669^{a}\pm0.19$
	(8.48%)**	(8.55%)**	(18.88%)**	(19.25%)**



Figs 7 and 8. Effect of Potassium silicate application onTotal carbohydrates, MDA content, Total proline , Total antioxidants, SOD, Catalase and Ascorbate peroxidase of Karan Bhog-521 variety of rice (*Oryza sativa* L.) at 65 days after transplantation

of wheat and paddy are also removed from the field. This may be leading to hampering of silicon cycle and resulting in the deficiency of plant-available silicon in soil. The studies also reveal that insufficiency of plant-available silicon can become the major reason for the decrease in the yield of wheat and rice. In the current study, the exogenous application of silicon has been found to promote the reproductive parameters and ultimately resulted in the rise in the final yield output of the paddy crop. Even for small and marginal farmers, silicon fertilizers are effective, environmentally safe, and economical when compared to other chemical or synthetic fertilizers. To enhance plant development and resistance to stress, silicon can be utilized as a growth enhancer. So it can be concluded that silicon can be used by farmers in the soil of Haryana, India in paddy crops for better results. There is a further need to provide awareness among farmers about the importance of silicon nutrients and to provide them the cheap and locally available sources of silicon, which can be added to enhance the productivity of soil and crop.

Financial Disclosure/Conflict of Interest

The authors state that they received no funding for this research and have no conflicts of interest related to it.

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