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Biomass yield of rice (*Oryza sativa*) cultivars as affected by applied silicate in an Inceptisol

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ABSTRACT

West Bengal is the largest rice (*Oryza sativa* L) producing state of India. In spite of leading the world in rice production, India lags behind in terms of rice productivity. In view of limited information, a pot experiment was conducted at ICAR-IARI, New Delhi during *kharif*, 2018-19 to evaluate the response of important rice cultivars to applied silicate. The experiment was conducted with four rice cultivars (one indigenous aromatic and rest three HYVs) and three doses of sodium metasilicate (0, 250 and 500 mg/kg) using an alluvial Inceptisol collected from West Bengal. Results indicated that the grain and straw yield was increased up to 40.7 and 18.1%, respectively, due to application of silicate. Rice cultivars, on the basis of grain yield, can be arranged in the order: Khitish (20.8 g/pot)> Satabdi (17.6 g/pot) > IR-36 (15.4 g/pot) >Badshabhog (3.72 g/pot). The highest and the lowest straw yield was recorded with Badshabhog (70.1 g/pot) and IR-36 (14.6 g/pot), respectively. Rice cultivars showed differential responses in terms of yield to applied silicate. It can be concluded that application of sodium metasilicate can be one of the effective options for enhancing rice yield in the alluvial Inceptisol of West Bengal.

Key words: Cultivars, Grain yield, Rice, Silicate, Straw yield

Rice (*Oryza sativa* L.) is cultivated in about 162.9 million ha of land with 494.8 million tonnes of annual production(USDA, 2019). It is a major source of calorie intake for more than three billion people around the world (Datta *et al.* 2017). Besides being the second largest producer as well as consumer, India is the biggest exporter of rice with 30.1% of global share (Statista 2019). West Bengal is the largest producer of rice in India with 5.46 mha land under this crop (India Today 2018). Average productivity of rice in India is 3.86 t/ha, which is 15% less than the global productivity (USDA 2019). Hence, enhancing the productivity of rice constitutes a priority of research.

Silicon (Si) is a beneficial element for paddy. It plays an important role in the mineral nutrition of plants, especially for the high accumulator species, such as rice (Agostinho *et al.* 2017). Although, Si is the second-most abundant element with nearly 29% mean crustal content, its concentration in soil solution remains very low (Sommer *et al.* 2006). Depending on soil mineralogy and other constituents, total soil Si content may range from 5 to 470 g/kg, but the content of available Si varies only from 3 to 450 mg/kg (Cornelis and Delvaux 2016). The problem of lower phyto availability of Si in the form of monosilicic acid is more prominent in tropical and subtropical soils where it inadvertently limits productivity of crop, particularly rice (Haynes 2019).The conventional submerged cultivation of paddy further lowers Si availability, especially if the soil is conducive to leaching. At neutral to near neutral pH (6–7), as prevailed in lowland paddy soils, major aluminosilicate minerals exhibit low solubility owing to polymerization of monosilicic acid into different unavailable forms and also due to its re-adsorption on soil exchange phases (Haynes, 2019). Limited number of studies showed the positive response of rice yield to Si application (Fleck *et al.* 2013; Rao *et al.* 2018). However, there is no such comparative study with different rice cultivars. In the present study, the response of some important rice cultivars to Si application was evaluated.

MATERIALS AND METHODS

One bulk surface (0–15 cm) soil sample was collected

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from Mitrapur village, Haringhata block, Nadia district of West Bengal. The village is located in hot sub humid (moist) to humid (inclusion of per-humid) eco-sub region and falls under Lower Gangetic Plain. The soil belongs to sub-group Typic Haplaquepts. The collected soil sample was and used for greenhouse experiment. Physico-chemical properties of the soil were determined using standard procedures (Jackson 1973; Datta *et al.* 1997), which are presented in Table 1. The soil was heavy textured, slightly acidic in reaction and high in organic carbon content.

A pot experiment was conducted at ICAR-IARI, New Delhi during *kharif*, 2018-19 with four rice cultivars, comprising three dwarf non-aromatic high yielding varieties (HYVs), *viz.* IR-36, Khitish and Satabdi as well as one tall indigenous short-grained aromatic variety Badshabhog. Seeds of these cultivars were obtained from Bidhan Chandra Krishi Viswavidyalaya, Mohanpur. For this purpose, plastic pots of 5 kg capacity were filled with 4 kg of soil. Sodium metasilicate (Na_2SiO_3) was added at the rates of 0 (S_0), 250 (S_1) and 500 (S_2) mg/kg of soil, which were roughly equivalent to field application of 0, 450 and 900 kg Na_2SiO_3 or 0, 103.5 and 207 kg Si per ha, respectively. All 12 treatment combinations were replicated thrice and the experiment was laid out in factorial completely randomised design (FCRD). A uniform basal dose of N: P_2O_5: K_2O @ 40.1: 40.2: 26.8 mg/kg were added in solution form in each pot through urea, diammonium phosphate and muriate of potash, respectively. The soil in each pot was then irrigated and the pots were kept at saturation for a week. After one week, about 8–10 pre-germinated seeds were sown in each pot. At fifteenth day of germination, the plants were thinned to a uniform population of five plants per pot. Water level was maintained 3 cm above the soil surface until harvest. Two top dressings of N, each at the rate of 20.1 mg/kg, were done at 30 and 60 days after sowing (DAS). Three HYVs were harvested at 120 DAS, while Badshabhog was harvested at 150 DAS. The harvesting of paddy was done by cutting the stem close to ground and storing in paper bags separately from each pot. Harvested plants were washed and then dried in hot air oven at 60±5°C. After attaining constant weight, grain and straw yields were separately measured using electronic balance and expressed in g/pot.

Table 1 Initial characteristics of experimental soil

Parameter	Value
$pH_{1:2}$	6.97
$EC_{1:2}$ (dS m^{-1})	0.48
Clay (%)	42.9
Silt (%)	9.3
Sand (%)	47.8
Texture	Sandy clay
Organic carbon (g kg^{-1})	16
Cation exchange capacity [cmol(p^+) kg^{-1}]	27.8

RESULTS AND DISCUSSION

On an average, grain yield of paddy was increased with increasing levels of applied silicate (Table 2). Mean grain yield was increased from 11.8 (in S_0) to 14.9 and 16.6 g/pot under S_1 and S_2, respectively. Significant enhancement in straw yield was also recorded when level of applied silicate was increased from 0 (29.2 g/pot) to 250 mg/kg (34.5 g/pot), but beyond this level such effect of silicate was absent (Table 3).Accumulation of silica in epidermal tissue and its association with cellulose membrane and lignin-carbohydrate complexes strengthen defense mechanism of plants against biotic and abiotic stresses. It plays an important role in the formation of cross-links between lignin and carbohydrates *via* association with phenolic acids or aromatic rings (Savant *et al.* 1996).In these tissues, Si tends to be deposited as a 2.5 μ thick layer in the space immediately beneath the thin (0.1 μ) cuticle layer. It has been proposed that the location and mechanical strength of this cuticle-Si double layer helps to maintainerectness of rice leaves and clumps, thereby facilitating better light interception and increasing the photosynthesis (Meena *et al.* 2014). Silicon nutrition alleviates many abiotic stresses including physical stress like lodging, drought, radiation, high temperature, freezing, UV and chemical stress like salt, metal toxicity, nutrient imbalance and many others (Agostinho *et al.* 2017). Silicon improves availability and assimilation of other nutrients like phosphorus (Bhat *et al.* 2019).

In this experiment, yield was augmented over control by 26.3 and 40.7% at S_1 and S_2, respectively. Similar result was reported earlier by Singh *et al.* (2006).There was increase in straw yield to the tune of 18.8% in the present study, which showed agreement with the result of Fleck *et al.* (2013), although, they used much higher dose of silica. Besides, positive effect of Si application on biomass yield was also evident (Murali *et al.* 2007; Rao *et al.* 2017).

Among the cultivars, on average, the highest grain yield was obtained with Khitish (20.8 g/pot), followed by Satabdi (17.6 g/pot), IR-36 (15.4 g/pot) and Badshabhog (3.72 g/pot) (Table 2).Effect of silicate application on grain yield of rice was significantly modified by cultivars. For example, Khitish showed concomitant increase in grain

Table 2 Effect of sodium metasilicate (Na_2SiO_3) addition on grain yield of different rice cultivars

Rice cultivar	Grain yield (g/pot)			
	Silicon treatment			Mean
	S_0	S_1	S_2	
IR-36	13.5^{e}	15.4^{de}	17.4^{cd}	15.4^{C}
Khitish	15.9^{de}	21.1^{b}	25.4^{a}	20.8^{A}
Satabdi	15.7^{de}	19.4^{bc}	17.6^{cd}	17.6^{B}
Badshabhog	1.88^{g}	3.54^{fg}	4.82^{f}	3.72^{D}
Mean	11.8^{C}	14.9^{B}	16.6^{A}	

Values followed by common letters are not significantly different at $P \leq 0.05$

Table 3 Effect of sodium metasilicate (Na_2SiO_3) addition on straw yield of different rice cultivars

Rice cultivar	Straw yield (g/pot)			
	Silicon treatment			Mean
	S_0	S_1	S_2	
IR-36	13.1	15.2	15.6	14.6^C
Khitish	20.0	26.6	23.7	23.4^B
Satabdi	18.4	22.8	18.5	19.9^{BC}
Badshabhog	65.2	73.3	71.8	70.1^A
Mean	29.2^B	34.5^A	32.4^A	

Values followed by common letters are not significantly different at $P \leq 0.05$; interactive effects are non-significant

Table 4 Simple correlation coefficient between applied level of silicate and yield of rice cultivars

Simple correlation coefficient (r)			
Cultivars			
IR-36	Khitish	Satabdi	Badshabhog
Grain yield			
0.84**	0.96**	0.39	0.72*
Straw yield			
0.37	-0.78*	-0.62	0.4

* and ** indicate that value of r is significant at 5 and 1% probability levels, respectively

yield with the increasing silicate levels, unlike Satabdi, for which significant improvement in yield was recorded only between S_0 and S_1, and S_0 and S_2 but not between S_1 and S_2. Satabdi is the only variety which showed reduced yield at S_2, as compared to S_1. Badshabhog was the lowest yielder but it showed the highest per cent increase in yield over control both at S_1 (88.2%) and S_2 (156%). The highest straw yield was obtained with Badshabhog (70.1 g/pot), followed by Khitish (23.4 g/pot), Satabdi (19.9 g/pot) and IR-36 (14.6 g/pot) (Table 3). Unlike grain yield, interactive effect of rice cultivars and rates of silicate addition on yield was non-significant. It is noticeable that in Badshabhog, grain yield was conspicuously lower (4.14 to 5.38 times) and straw yield was recorded to be much higher (2.99 to 4.8 times) than other three HYVs.

Further, an attempt has been made to assess the impact of applied Si on straw yield of rice cultivars through simple correlation (Table 4). In case of grain yield, IR-36 (r=0.84), Khitish (r=0.96) and Badshabhog (r=0.72) had significant positive relationship with applied Si. However, Satabdi did not show significant relationship with applied Si. For straw yield, all the cultivars except Khitish showed non-significant correlation with applied Si. This is attributed to the fact that there was no consistent increase in straw yield with the increasing level of applied Si. Rather, straw yield was reduced at 500 mg/kg applied Si over that obtained at 250 mg Si/kg in case of all the cultivars, except IR-36.

Results, therefore, revealed that practically realizable doses of sodium metasilicate had significant positive effect on the grain as well as straw yield of paddy. Grain yield was concurrently augmented by 26.3 and 40.7% when sodium metasilicate was applied at the rates of 250 and 500 mg/kg, unlike straw yield which increased 18.1% under S_1 and showed no further significant response at S_2.Putting it into perspective, it seems that the higher (500 mg/kg) dose of Si had more pronounced effect on grain yield as compared to the straw yield. It can be concluded that there is considerable variation in response to applied Si among different rice cultivars. Such positive and differential responses of rice cultivars should be exploited to enhance the productivity of rice, particularly in the alluvial Inceptisol of West Bengal.

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