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IMPROVING YIELD OF SALT TOLERANT RICE VARIETIES THROUGH SILICON APPLICATION

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Abstract

Climate change creates hazards like cyclone, sea level rise, and storm surge have been increasing the salinityintrusion problem in many folds of Bangladesh. High level of the salinity affectedin Rabi season therefore, current field experiment was carried out at saline prone area,Sodor, Satkhira under natural salinity condition during Rabi season 2017-2018. The experiment was carried out with two varieties namely, Binadhan-10, BRRIdhan67 and four levels of silicon with control S_0: 0 kg ha^{-1}, S_1: 5 kg ha^{-1}, S_2: 10 kg ha^{-1} and S_3: 15 kg ha^{-1}. The experiment was laid out in a split plot design with three replications. The recommended fertilizer doses applied for the experiment were 80 kg N ha^{-1}, 15 kg P ha^{-1}, 50 kg K ha^{-1} and 20 kg S ha^{-1} and silicon as basal dose. Application of silicon had significant effect on plant height, number of effective tiller m^{-2}, length of panicle, total number of spikelets panicle^{-1}, thousand grain weights, number of filled spikelets panicle^{-1}, grain yield and straw yield.It seems that the crop responded to the application of silicon @ 5-15 kg Si ha^{-1} and best dose was reported @ 15 kg ha^{-1} silicon followed by 10 kg ha^{-1}. Results suggest that an application of silicon along with N, P, K, S, Zn, might be necessary to ensure satisfactory yield of rice in saline prone area under natural salinity condition.

Key words: Salinity, Silicon, Rice yield

Introduction

Silicon is the second most available element in soil despite its recognition as essential element for plant growth. It plays an important role in controlling both abiotic and biotic stresses in plant species (Ma, 2004) and as a nutrient to the rice plant (Takahashi, 1968). Silica deposition in the plant leaf decreased transpiration and therefore decreased salt accumulation (Matoh *et al*., 1986). Ahmad *et al*. (1992) suggested that silicon complexes sodium in the root,therefore decreasing sodium transport to the shoot. Bangladesh is a densely populated agriculture based small country. She has to feed nearly 160 million mouths from an area of 8 million ha of cultivable land (BBS, 2018). Climate change effect in a recentwarming of 4^{o}C temperature could occur as early as 2060s which would lead a sea level rise of 0.5 to 1 m or more (World Bank, 2013). Sea level rise and salinity interruption are likely to be intensified in future affecting crop production seriously in the low-lying coastal area of Bangladesh. More than 80 per cent of the total area of the Khulna,

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Bagerhat and Satkhira districts are already affected by different magnitudes of soil salinity of which about 35 per cent is in the grip of strong salinity (Mainuddin *et al*., 2011). Some report has been observed about the effect of salinity level on growth and yield of rice in saline prone area (Yasmine *et al.,* 2011).

The salinity situation in the coastal area of Bangladesh is going to worsen in the future. About 53% of the coastal areas are affected by salinity. Again, the coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country (Karim and Iqbal, 2001). Agricultural land use in these areas is very poor, which is much lower than country's average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The factors which contribute significantly to the development of saline soil are, tidal flooding during wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November-May). The severity of salinity problem in Bangladesh increases with the desiccation of the soil.It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Soil reaction values (pH) in coastal regions range from 6.0-8.4. The organic matter content of the soils is also pretty low (1.0-1.5%). Nutrient deficiencies of N and P are quite dominant in saline soils. Micronutrients, such as Cu and Zn are widespread (SRDI, 2003). During the wet monsoon the severity of salt injury is reduced due to dilution of the salt in the root-zone of the standing crop. The dominant crop grown in the saline areas is local transplanted aman rice crop with low yields. The cropping patterns followed in the coastal areas are mainly Fallow-Fallow-Transplanted aman rice. Salinity problem received very little attention in the past. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of crops. Thus is necessary to have an appraisal of the present state of land areas affected by salinity.

Increasing level of salinity in the country is posing serious threatening catastrophe for crop production. Salinity is a year round problem in the coastal agriculture; it varies over the year with the peak salinity occurring during December to April (Fig. 1), and the least during July to September. Therefore, boro rice and other Rabi crops are mostly affected in the coastal area due to salinity stress. For increased crop production in the salinity affected coastal area of Bangladesh selection of a crop species/cultivar is very vital, since significant crop interspecies and inter-varietal variation for salinity tolerance exists. For rice cultivation farmers use some landraces of rice endemic to the coastal region whose yield potentiality is very low compared to that of HYVs of rice. The productivity of coastal area is very low compared to other parts of the country. Very recently Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed salinity tolerant rice cultivars BRRI dhan47, BRRI dhan61, BRRI dhan67, Binadhan-8 and Binadhan-10, respectively, for cultivation during boro season. In addition to the development of salt tolerant cultivars, better understanding of nutritional disorders in the context of plant nutrient uptake and physiological as well as biochemical mechanisms of slat tolerance in rice plants may suggest some strategies for plant breeders and growers for developing salinity tolerant varieties and management practices for cultivation in saline areas. Therefore, the present experiment application of Silicon in context of uptake nutrientas agronomic management practices through which salinity level of a soil can be lowered and/or the stress effects on crops can be mitigatedfor the amelioration of salinity stress effect is the key for improving crop productivity in the salinity affected coastal area of Bangladesh.

Materials and Methods

A field experiment was conducted at saline prone area, Suparishata, Sodor, Sathkira under natural salinity condition during in 2017-18, was carried out with two varieties namely, Binadhan-10(V_1), BRRIdhan67(V_2) and four levels of silicon with control S_0: 0 kg ha^{-1}, S_1: 5 kg ha^{-1}, S_2: 10 kg ha^{-1} and S_3: 15 kg ha^{-1}. The experiment was laid out in a split plot design with three replications. The unit plot size was 3m × 4m. The treatments were randomly distributed to the plots within a block. The bunds around individual plots were sufficiently strong to control water movement between the plots. A drain of 1meter wide provided for watering around the whole experimental plot and between the blocks.

Seedlings were raised in well prepared wet seed bed at the sub-station Satkhira farms. Before sowing, seeds were immersed in water for 24 hours and then they were taken out and kept in jute sacks in dark condition for 48 hours. Seedling nurseries for each variety were prepared by pudding the soil. The sprouted seeds were sown on a well prepared wet nursery bed in 1 January, 2018. No manuring and fertilization was done but water and pest management practices were followed in order to raise healthy seedlings.

The land preparation was started one month prior to transplant of the seedlings. The land was thoroughly prepared with the help of a power tiller. Subsequently the land was sufficiently irrigated and ploughed and cross ploughed three times with country plough followed by laddering to have a good tilth. All kinds of stubble and residues of previous crop were removed from the field. After uniform leveling, the experimental plots were laid out according to the requirement of the treatment.

The plots of Boro rice were fertilized with N, P, K, S, Zn at the recommended by the rate of respectively according to the fertilizer recommendation guide of BARC (2012). The whole amount at triple super phosphate, muriatic of potash silicon, gypsum and zinc sulphate were applied to the soil at the time of final land preparation. Urea was applied in three equal splits. One split of urea was applied with other fertilizers as basal dose and the other two splits were applied 21 and 45 DAT. The seed bed was wet by application of water both in the morning and evening on the previous day before uprooting the seedling. Thirty days old seedlings were uprooted carefully from the seedling nursery for transplanting in the experimental plots. Only selected healthy seedlings were translated in the experimental plots in 1 February 2018 in 20cm apart line maintaining a distance of 15cm from hill to hill with three seedlings hill^{-1} proper care was taken during the growing period of the crop.

Intercultural operating was done in order to ensure and to maintain the normal growth of the plant as and when needed. After one week of transplanting dead seedling were replaced carefully by transplanting fresh seedlings from the same source. The experiment plots were infested with some common weeds which were removed twice by hand weeding.

After transplanting six irrigations were needed to maintain 5-6 cm standing water in each plot. Finally, the field was drained out 7 days before harvest. Observations were regularly made and the field looked nice with normal green plants.

The crops were harvested on 27 April, 2018 with sickle at full maturity. The maturity of crops was determined when some 70% of the seeds became attain their character's color. Grain and straw yields plot were recorded after threshing by a pedal thresher winnowing and drying in the sun properly including the grains and straws of the sample plants. The weight of grains was adjusted to 12% moisture content. Grain and straw yield were them converted to tha^{-1}. From the 10 randomly harvested hills, the following data were recorded, plant height, number of total tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, number of grain $panicle^{-1}$, number of unfilled spikelet's $panicle^{-1}$, 1000 grain weight, Grain yield (tha^{-1}), Straw yield (tha^{-1}) Biological yield (tha^{-1}), harvest index (%).

Data recorded for different parameters were subjected to analysis of variance (ANOVA) technique(Gomez and Gomez, 1984) and the mean differences were adjudged with Duncan's Multiple Range Test (DMRT) using the statistical computer package, MSTAT-C (Russell, 1968).

Result and Discussion

Crop yield and silicon fertilization

Application of silicon significantly increased plant height, total tillers $hill^{-1}$, effective tillers $hill^{-1}$, panicle length, filled grain $panicle^{-1}$,1000 grain weight and yield (Table 1). Silicon doses both 10 and 15 kg ha^{-1} was responded positively for yield characteristics. Minimum plant height (96 cm) was noted for control treatment and maximum of that (101 cm) was obtained for 15 kg ha^{-1} silicon application. The most plant height (104.3 cm) had observed at interaction of 15 kg ha^{-1} silicon application in BRRI dhan67 and the least plant height (91.9 cm) was obtained at interaction of control treatment in Binadhan -10. Total tiller number $hill^{-1}$ found highest @ 10 kg ha^{-1}but in interaction highest number of tillers was observed @ 15 kg ha^{-1} silicon application in BRRI dhan67and the leastwas obtained at interaction of control treatment in Binadhan-10. The most effective tiller number $hill^{-1}$(13.1 panicles) was shown with 15 $kgha^{-1}$ silicon and the least number of effective tiller $hill^{-1}$ (10 panicles) was obtained in control treatment. The most effective tiller number $hill^{-1}$ (13.5 panicles) was observed at interaction of 15 kg ha^{-1} silicon application in BRRI dhan67 least number of effective tiller $hill^{-1}$ was obtained at interaction of control treatment in Binadhan10 (9.2 panicle). Maximum panicle length (26.1 cm) was observed with application of silicon 15 kg ha^{-1} and minimum panicle length (23.1 cm) was obtained with control treatment. The most panicle length (26.6 cm) was observed at interaction of 15 kg ha^{-1}silicon application in Binadhan10 and the least panicle length (22.5 cm) was obtained at interaction of control treatment in BRRI dhan67. The maximum filled spikelet percentage $panicle^{-1}$ had obtained with application of 15 kg silicon ha^{-1}(110.3 %), and the least filled spikelet percentage 90.03 %) was observed with application of 0 kg silicon ha^{-1}. The highest filled spikelet percentage per panicle had shown under interaction of 15 kg silicon ha^{-1} for var. BRRI dhan67 and the least filled spikelet percentage (90.3%) had obtained at interaction 0kg silicon ha^{-1} treatment in Binadhan10. The maximum unfilled spikelets per panicle (18.6) had obtained with application of 0 kg silicon ha^{-1} and the least spikelet $panicle^{-1}$ (118) was observed with 15 kg silicon ha^{-1}. The highest unfilled spikelet per panicle (19) had shown under interaction with application of 0 kg silicon ha^{-1} in BRRI dhan67 and the least unfilled spikelet had obtained at interaction with 0 kg silicon ha^{-1} in BRRI dhan67. The beneficial effect of Silicon along with gypsum has been reported on the growth of rice by Khattak *et al.,*(2007). Gong *et al.,* (2003) observed that silicon increased plant height, leaf area and dry mass of rice even under drought. Similarly, Singh *et al.,* (2006) suggested that the increased dry matter and yield in rice. The indirect effects of silicon also cause increase in growth and yield in rice.

There are a statistically significant different in thousand grain weight, grain yield, between rice genotypes (Table 1). The maximum 1000-seed weight (24.7 g) was found with the application of 10 kg silicon ha^{-1} and least 1000-seed wt. (22.8 g) with control treatments. The maximum 1000-seed weight (26 g) interaction with application of 10 kg silicon ha^{-1} for Binadhan-10 followed by15 kg silicon ha^{-1} and least 1000-seed wt. (21.5 g) had obtained at interaction with application of 0 kg silicon ha^{-1} in BRRI dhan67 here is a statistically significant different in grain yield between rice genotypes. The maximum grain yield 7.59 tha^{-1} was recorded with application of 15 kg silicon ha^{-1} and minimum grain yield 5.66 tha^{-1} was recorded with control treatment. The minimum grain yield 7.59 tha^{-1} was obtained at interaction of 15kg silicon ha^{-1} application in Binadhan10 and the least grain yield 5.56 tha^{-1} was obtained at interaction of control treatment in Binadhan10. The maximum straw yield 8.21 tha^{-1} was recorded with 15 kg silicon ha^{-1} and minimum straw yield 6.58 t ha^{-1} was recorded with control treatment. The maximum straw yield 8.24 tha^{-1} was obtained at interaction of 15 kg silicon ha^{-1} application and Binadhan-10 and the minimum straw yield 6.51tha^{-1} was obtained at interaction of 0 kg silicon ha^{-1} and var. BRRI dhan67. In the present study the Silicon levels of 10 and 15 kg/ha had been found positive effects on growth and yield in rice crop. In case of 1000-seed weight and grain yield silicon dose both 10 and 15 kg/ha performed better.

Table 1. Effect of variety and silicon doses and their interaction on grain yield and yield attributes of Boro rice.

	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000 seed wt. (g.)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
	94.7 b	11.8^{ns}	10.8b	25.1a	98.1^{ns}	12.5^{ns}	25.2a	6.51a	7.61a
	102.4 a	12.9	12.1a	24.1b	102.2	11.5	22.4b	6.10b	7.37b
	96d	10.9d	10d	23.1d	90.3d	18.6a	22.8d	5.66d	6.58d
	97.7c	11.9c	10.9c	24.2c	96.7c	14.0b	23.4c	6.21c	7.33c
	99.5b	13.9a	11.9b	25.0b	103.3b	10.6c	24.7a	6.76b	7.63b
	101a	12.9b	13.1a	26.1a	110.3a	6.7d	24.2b	7.51a	8.21a

Table 1. Continued

Treatments	Plant height (cm)	Total tillers $hill^{-1}$ (no.)	Effective tillers $hill^{-1}$ (no.)	Panicle length (cm)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $panicle^{-1}$ (no.)	1000 seed wt. (g.)	Grain yield (t ha^{-1})
Variety×Silicon rate								
V_1S_0	91.9d	10.3e	9.20g	23.6c	90.3d	18.3a	24.1c	5.56d
V_1S_1	93.6cd	11.3d	10.0fg	24.7bc	94.8cd	13.3b	24.9b	6.19c
V_1S_2	95.7cd	12.3c	11.2de	25.7ab	100.6bc	11.0c	25.7a	6.73b
V_1S_3	97.7bc	13.4b	12.7ab	26.6a	106.6ab	7.4de	26.0a	7.59a
V_2S_0	100.2ab	11.4d	10.8ef	22.5d	90.3d	19.0a	21.5e	5.77d
V_2S_1	101.7ab	12.4c	11.7cd	23.8c	98.6bcd	14.6b	22.0e	6.23c
V_2S_2	103.3a	13.5b	12.5bc	24.0c	106.0ab	10.2cd	22.8d	6.8b
V_2S_3	104.3a	14.5a	13.5a	25.6ab	114.0a	6.1e	23.4cd	7.35a

In a column, values with same letter (s) for individual location/ combined means do not differ-significantly at 5% level

It has been found by various workers that silicon has many positive effects on the growth and yield as well as physiology and metabolism of different crops. Ma & Takahashi (1990) concluded that there is a high phosphate uptake in rice with silicon application which directly correlates the increased growth and yield. Mukkram *et al*., (2006)also found that silicon increased growth and yield due to decreased Na^+ uptake in rice under salt stress. Since germination remains un-affected even under usual stress conditions because the seed itself has enough nutrients to germinate. However, it has been found that the initial vigor produced in seeds lasts to the later stages of plant growth thus a remarkable increase in the yield of crop is evident (Rashid *et al*., 2000). The findings of this study showed that when Silicic acid was applied at 0.25-050% level as fertilizer, the rate of germination was increased. While if its levels exceeded the limits it was found harmful resultantly reduced the germination rate and also affected the total crop stand as well as yield. The effects of different levels of Silicon in the form of Silicic acid have been investigated by many investigators. Singh *et al.,* (2006) found that the 180 kg ha^{-1} of Silicon increased nitrogen and phosphate levels in the grain and straw of rice. This suggests that silicon in lesser amounts can be beneficial in increasing grain yield and growth of cereal crops.

In saline condition, excessive concentration of sodium and chloride ion accumulates in their leaves and reduces the growth of rice seedling. Ratio of potassium and sodium (K/Na) ion concentration for root and shoot were measured (Table 2) and compared with control (0 kg silicon ha^{-1}) condition. Result showed thation concentration ratio for shoot and root was higher in control condition for both varieties but this ratio was decreased with the increase of silicon dose. Gong *et. al.*, (2006) was observed silicon decreases transpirational bypass flow and ion concentration.A significant higher efficiency in reclamation of clay saline soil was obtained in terms of reducing Na^+ and EC when Silicon was applied and water was added in comparison to non-treated soil. The highest number of filled spikelet $panicle^{-1}$, grain and straw yields were obtained when rice plants were grown on soil treated with silicon compared to soil with no silicon. Plant uptake this nutrient which improved soil properties and which effect rice growth and its productivity. This might be due to the valuable nutrient source of silicon, which mitigated the toxicity caused by salts in saline soils. Silicon can also be considered as an effective application for clay saline soil in Satkhira regions of Bangladesh.From above discussion it is revealed that effect of silicon had positive trend for both varieties studied here andconsidering the dose ofsilicon almost all of the agronomic traits performed better@ 15 kgha^{-1} followed by 10 kg ha^{-1} (Table1 and 2).

Table 2. Shoot ion concentration and Root ion concentration of Binadhan-10 and BRRI dhan67 along with different doses of silicon application

Treatments	Shoot ion concentration ratio (K/Na) (μ mol g^{-1}DW)		Root ion concentration (K/Na) (μ mol g^{-1}DW)	
Variety	Binadhan-10	BRRI dhan67	Binadhan-10	BRRI dhan67
Silicon rate				
0 kg silicon ha^{-1} (S_0)	0.41d	0.45d	0.30d	0.38c
5 kg silicon ha^{-1} (S_1)	0.75c	0.70c	0.32c	0.42b
10 kg silicon ha^{-1} (S_2)	0.96b	0.85b	0.37b	0.40b
15 kg silicon ha^{-1} (S_3)	1.20a	1.32a	0.41a	0.53a

In a column, values with same letter (s) for individual location/combined means do not differ-significantly at 5% level

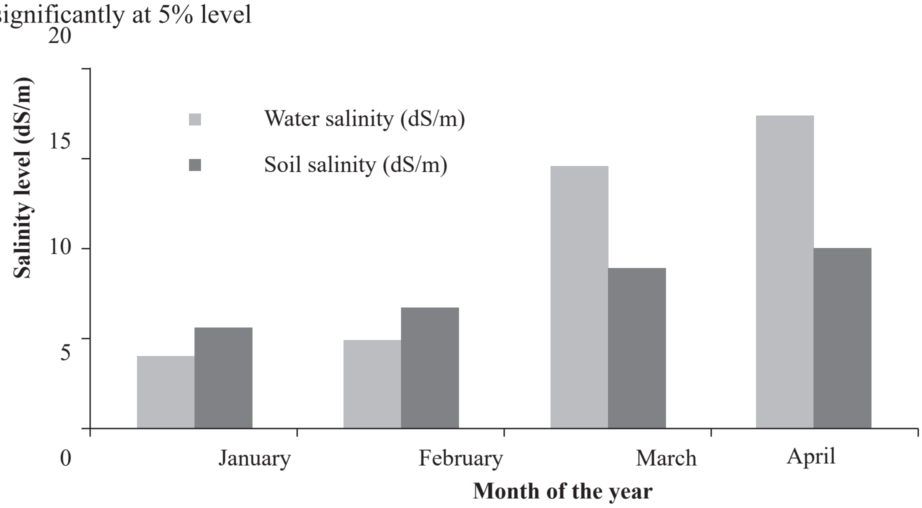

Fig. 1: Level of salinity during crop growing season

Conclusions

Silicon application significantly increased Si of the clay saline soilwhich reduces ion concentration at shoot and root zone and enhance rice productivity grown on saline prone area. The improvement of soil chemical properties in terms of removal Na^+ salt and reducing EC that caused a significant reduction in soil salinity obtained from silicon. A significant improvement in growth and increase in yield of rice were obtained from @ 15 kg ha^{-1} followed by 10 kg ha^{-1} when silicon was applied into clay saline soil. Therefore, silicon is considered as effective treatments to leach the soluble salts for reclamation of clay saline soil and better plant growth, and yield of rice genotypes. Further study is needed to optimize the silicon dose based on soil property for more clarification.

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