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Effect of calcium silicate as a silicon source on growth and yield of rice plants

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Abstract

The pot culture experiment was conducted at Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India, to study the effect of calcium silicate as a silicon source on growth and yield of rice plants. The plastic pots were filled with 10 kg soil samples from order Inceptisols and Vertisols. The experiment was laid out in factorial completely randomized design having fourteen treatment combinations replicated thrice. The main treatments were soil types Inceptisols and Vertisols; sub treatments were levels of silicon. The calcium silicate was used as a source of silicon. The soil type Vertisols showed significantly highest growth, yield attributes, grain yield (36.20 g pot^{-1}) and straw yield (39.42 g pot^{-1}) of rice plants over the Inceptisols. The application of general recommended dose of fertilizers along with silicon @ 200 kg ha^{-1} recorded significantly highest growth, yield attributes, grain yield (43.15 g pot^{-1}) and straw yield (46.54 g pot^{-1}) of rice plants over all the levels of silicon.

Keywords: Calcium silicate, silicon, growth, yield, rice plants

Introduction

Rice is deeply engraved in the rich tradition and culture of India. It is the most important human food crop in the world. It is critical to global food security and to the welfare of around 800 million impoverished people around the world. Total area under rice in India is 42.75 million hectares with annual production of 105.24 million tonnes and productivity of 2462 kg ha^{-1}. In Maharashtra state of India rice is cultivated over an area of 1.56 million hectares with an annual production of about 3.06 million tonnes and productivity of 1963 kg ha^{-1} (Anonymous, 2014) [3]. Rice is a silicon (Si) accumulating plant. No other crop requires as much silicon as rice. Silica is required for healthy and productive development of the rice plant (Yoshida, 1975) [14]. Silicon content of monocots is higher than that of dicots. Silicon absorbed by rice from the soil in large amounts that are several fold greater than those of other macronutrients. It is estimated that a rice crop producing a total grain yield of about 5 tonnes ha^{-1} will normally remove 230 to 470 kg Si ha^{-1} (500-1000 SiO_2 kg ha^{-1}) from soil (Amarasiri and Perera, 1975) [2]. Silicon is absorbed by plants as monosilicic acid [$(Si(OH)_4$] (Jones and Handreck, 1967) [5]. Silicon becomes immobilized and accumulates in plant with tissue age and therefore, young rice leaves may have lower Si concentration and are more susceptible to disease. Extensive cultivation of rice in some regions of Asia and Southeast Asian countries has led to depletion of available silicon (Savant *et al*., 1997) [9] and warrants the application of silicate fertilizers for achieving sustainable rice yields. Silicon can be supplied to rice in the form of calcium silicate which is incorporated into the soil before planting. In silicon deficient soil (*Typic haplustept*) the rice yields increased due to the supply of silicon through various silicon sources like rice husk ash, bagasse ash, fly ash and calcium silicate (Aarekar, 2014) [1]. The application of calcium silicate increased the rice yields in Histosols mainly due to the supply of available Si and not due to supply of other nutrients (Snyder *et al*., 1986) [13]. The use of silica fertilizers in the form of either soluble silicates or of calcium silicate slag is still very restricted. An adequate supply of silica is essential, if grasses and cereals are to give a good yield. Even though silicon has not been recognized as an essential element for plant growth, the beneficial effects of silicon have been observed in a wide variety of plants. The beneficial effects of silicon are usually expressed more clearly in silicon accumulating plants under various abiotic and biotic stress conditions. The present study aimed to assess the effect of calcium silicate as a silicon source on growth and yield of rice plants.

Materials and methods

The pot culture experiment was conducted at Department of Soil Science and Agricultural Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The rice plants (*Cv*. Indrayani) were used as a test crop. The soil samples from order Inceptisols (*Vertic Haplustept*) and Vertisols (*Typic Haplustert*) were collected for study. The experimental soil was clay, slightly alkaline, low in available nitrogen, medium in available phosphorus and very high in available potassium. Plastic pots were taken and filled with 10 kg soil. The experiment was laid out in factorial completely randomized design having fourteen treatment combinations replicated thrice. The main treatments were soil types Inceptisols and Vertisols; sub treatments were levels of silicon (Si). The treatment details were T_1: Absolute control, T_2: General recommended dose of fertilizers (GRDF) (100:50:50 kg ha^{-1} $N:P_2O_5:K_2O$ + 5 t ha^{-1} FYM), T_3: GRDF + Si @ 25 kg ha^{-1}, T_4: GRDF + Si @ 50 kg ha^{-1}, T_5: GRDF + Si @ 100 kg ha^{-1}, T_6: GRDF + Si @ 150 kg ha^{-1}, T_7: GRDF + Si @ 200 kg ha^{-1}. The above treatment doses were converted into grams based on 10 kg soil in each pot and doubled before application. The calcium silicate was used as a source of silicon and applied one month before sowing. Two rice seedlings per pot were maintained for growth and yield observations. The data generated from present experiment was statistically analyzed by methods suggested by Panse and Sukhatme (1985) [8].

Results and discussion

Growth attributes of rice plants under pot culture

Plant height

The plant height was significantly influenced by soil types, levels of silicon and their interactions (Table 1). Vertisols showed significantly highest plant height (76.48 cm) over the Inceptisols (74.57 cm). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest plant height (80 cm) over all the levels of silicon. However, it was at par with GRDF + Si @ 150 kg ha^{-1} (79.33 cm). The interaction effect of Vertisols with GRDF + Si @ 200 kg ha^{-1} recorded significantly highest plant height (80.33 cm) over all the interactions. However, it was at par with Inceptisols with GRDF + Si @ 200 kg ha^{-1} (79.67 cm), Vertisols with GRDF + Si @ 100 kg ha^{-1} (79.00 cm) and Vertisols with GRDF + Si @ 150 kg ha^{-1} (80.00 cm). There was significant increase in plant height with increased levels of silicon. This might be due to dissolution of silicon from calcium silicate as well as from soil and become available to plant. The silicon gets deposition in the plant tissues causing erectness of leaves and stem. These results corroborate those obtained by Singh *et al*. (2005) [10].

Number of tillers hill^{-1}

The numbers of tillers hill^{-1} were significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 1). Vertisols recorded significantly highest number of tillers hill^{-1} (10.81) over the Inceptisols (9.67). The application of treatments GRDF + Si @ 100 kg ha^{-1}, GRDF + Si @ 150 kg $ha^{-1}$and GRDF + Si @ 200 kg ha^{-1} recorded significantly highest number of tillers hill^{-1} (11.17) over all the levels of silicon. However, it was at par with GRDF + Si @ 50 kg ha^{-1} (10.50). The increase in number of tillers hill^{-1} with increased levels of silicon can be accounted for the improvement in photosynthetic activity. As silicon gets deposited in plant, makes leaves more erect and expose its maximum area to the sunlight. Tillering is the production of expanding auxiliary bud which is clearly associated with nutritional condition of mother clump. The nutrients become available to plant because silicon has synergistic effect with other nutrients. These results are in conformity with the findings of Mukherjee and Sen (2005) [6].

Panicle length

The panicle length was significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 1). Vertisols recorded significantly highest panicle length (17.45 cm) over the Inceptisols (17.10 cm). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest panicle length (18.40 cm) over all the levels of silicon. However, it was at par with GRDF + Si @ 150 kg ha^{-1} (18.15 cm). There was increase in the panicle length with increased levels of silicon. This might be due to deposition of silicon at cellular level makes plant parts more elongated and erect. These results were similar to that of Singh *et al*. (2007) [12].

Dry matter hill^{-1}

The dry matter hill^{-1} was significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 1). Vertisols showed significantly highest dry matter hill^{-1} (21.08 g) over the Inceptisols (20.48 g). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest dry matter hill^{-1} (22.61 g) over all the levels of silicon. There was significant increase in the dry matter hill^{-1}with increased levels of silicon. This might be due to efficient utilization of sun light by making plant leaves more erect. Such ideal crop stand enhanced photosynthetic activity and translocation of assimilated product from source to sink. This ultimately resulted in higher dry matter accumulation hill^{-1}. Similar results were also reported by Singh *et al*. (2005) [10] and Singh *et al*. (2006) [11].

Table 1: Effect of soil types, levels of silicon and their interactions on growth attributes of rice plants under pot culture

	Plant height (cm)	No. of tillers hill^{-1}	Panicle length (cm)	Dry matter hill^{-1} (g)
A. Soil types (S)				
S_1: Inceptisols	74.57	9.67	17.10	20.48
S_2: Vertisols	76.48	10.81	17.45	21.08
SE (m) ±	0.208	0.139	0.067	0.073
CD at 5%	0.601	0.402	0.194	0.212
B. Levels of silicon (T)				
T_1: Absolute control	66.83	8.67	15.63	18.70
T_2: GRDF	72.50	9.17	16.61	19.61
T_3: GRDF + Si @ 25 kg ha^{-1}	75.00	9.83	16.97	20.12
T_4: GRDF + Si @ 50 kg ha^{-1}	76.50	10.50	17.35	20.72
T_5: GRDF + Si @ 100 kg ha^{-1}	78.50	11.17	17.85	21.51
T_6: GRDF + Si @ 150 kg ha^{-1}	79.33	11.17	18.15	22.18
T_7: GRDF + Si @ 200 kg ha^{-1}	80.00	11.17	18.40	22.61

SE (m) ±	0.388	0.260	0.125	0.137
CD at 5%	1.125	0.752	0.362	0.396
C. Interactions (S x T)				
S_1T_1	65.33	8.33	15.51	18.35
S_1T_2	70.33	8.67	16.53	19.35
S_1T_3	74.33	8.67	16.73	19.87
S_1T_4	75.67	9.67	17.11	20.41
S_1T_5	78.00	11.00	17.53	21.29
S_1T_6	78.67	10.67	18.15	21.86
S_1T_7	79.67	10.67	18.16	22.21
S_2T_1	68.33	9.00	15.74	19.04
S_2T_2	74.67	9.67	16.69	19.86
S_2T_3	75.67	11.00	17.20	20.37
S_2T_4	77.33	11.33	17.59	21.04
S_2T_5	79.00	11.33	18.16	21.73
S_2T_6	80.00	11.67	18.14	22.49
S_2T_7	80.33	11.67	18.65	23.00
SE (m) ±	0.549	0.367	0.177	0.193
CD at 5%	1.591	NS	NS	NS

Yield attributes of rice plants under pot culture

Panicle weight

The panicle weight was significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 2). Vertisols showed significantly highest panicle weight (2.210 g) over the Inceptisols (2.127 g). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest panicle weight (2.522 g) over all the levels of silicon. The panicle weight was significantly increased by application of silicon. This might be due to improvement in photosynthetic activity and better assimilation of carbohydrates in panicle. The increase in panicle weight due to application of silicon was also reported by Singh *et al*. (2007) [12].

Numbers of grains panicle^{-1}

The numbers of grains panicle^{-1} were significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 2). Vertisols showed significantly highest numbers of grains panicle^{-1} (136.14) over the Inceptisols (130.80). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest numbers of grains panicle^{-1} (156.02) over all the levels of silicon. There was significant increase in the numbers of grains panicle^{-1}. This might be due to enhanced photosynthetic activity and availability of nutrients due to the application of silicon. These results resembled to the findings reported by Jawahar and Vaiyapuri (2010) [4].

Grains weight panicle^{-1}

The grains weight panicle^{-1} was significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 2). Vertisols showed significantly highest grains weight panicle^{-1} (2.126 g) over the Inceptisols (2.028 g). The application of GRDF + Si @ 200 kg ha^{-1} was recorded significantly highest grains weight panicle^{-1} (2.392 g) over all the levels of silicon. There was significant increase in the grains weight panicle^{-1} with increased levels of silicon. This might be due to increased photosynthetic activity and better assimilation of carbohydrate in panicles due to silicon. Similar findings were also reported by Munir *et al.* (2003) [7].

Thousand grains weight

The thousand grains weight was significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 2). Vertisols showed significantly highest thousand grains weight (18.57 g) over the Inceptisols (18.28 g). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest thousand grains weight (20.09 g) over all the levels of silicon. The increase in thousand grains weight with application of silicon might be coupled with enhanced photosynthetic activity and efficient translocation of photosynthates. That resulted in better assimilation of carbohydrate and more number of filled grains leads to increase in thousand grains weight. These findings are near to the Singh *et al*. (2005) [10] and Singh *et al*. (2007) [12].

Table 2: Effect of soil types, levels of silicon and their interactions on yield attributes of rice plants under pot culture

	Panicle weight (g)	No. of grains panicle^{-1}	Grains weight panicle^{-1} (g)	1000 grains Weight (g)
A. Soil types (S)				
S_1: Inceptisols	2.127	130.80	2.028	18.28
S_2: Vertisols	2.210	136.14	2.126	18.57
SE (m) ±	0.025	0.832	0.015	0.043
CD at 5%	0.071	2.411	0.043	0.123
B. Levels of silicon (T)				
T_1: Absolute control	1.765	110.03	1.689	16.90
T_2: GRDF	1.993	116.55	1.922	17.52
T_3: GRDF + Si @ 25 kg ha^{-1}	2.078	125.20	1.992	17.82
T_4: GRDF + Si @ 50 kg ha^{-1}	2.180	133.88	2.085	18.50
T_5: GRDF + Si @ 100 kg ha^{-1}	2.272	143.98	2.167	18.89
T_6: GRDF + Si @ 150 kg ha^{-1}	2.368	148.65	2.292	19.24
T_7: GRDF + Si @ 200 kg ha^{-1}	2.522	156.02	2.392	20.09
SE (m) ±	0.046	1.557	0.028	0.080
CD at 5%	0.133	4.511	0.081	0.231
C. Interactions (S x T)				
CD at 5%	NS	NS	NS	NS

Yield of rice plants under pot culture

Grain yield

The grain yield was significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 3). Vertisols showed significantly highest grain yield (36.20 g pot^{-1}) over the Inceptisols (33.75 g pot^{-1}). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest grain yield (43.15 g pot^{-1}) over all the levels of silicon. However, it was at par with GRDF + Si @ 150 kg ha^{-1} (41.28 g pot^{-1}). Vertisols recorded significantly highest grain yield over Inceptisols. This might be due to high nutrient status and moisture holding capacity of Vertisols which is the prime requirement of paddy. The application of silicon to upland paddy enhanced the sturdiness in plant and helps to grow erect without lodging. The erectness exposed the plant to sunlight and enhanced the photosynthetic activity and assimilation of organic constituents. These assimilates promotes the growth and development of crop, as well as reduce the incidence of pest and disease. The crop grows vigorously and utilized the nutrient and moisture from soil which are turn into the economic yield of upland paddy. This might be the reason for increasing the grain yield of upland paddy. Similar findings had also reported by Singh *et al*. (2007) [12] and Aarekar (2014) [1].

Straw yield

The straw yield was significantly influenced by soil types and levels of silicon. However, results were non-significant in case of their interactions (Table 3). Vertisols showed significantly highest straw yield (39.42 g pot^{-1}) over the Inceptisols (37.60 g pot^{-1}). The application of GRDF + Si @ 200 kg ha^{-1} recorded significantly highest straw yield (46.54 g pot^{-1}) over all the levels of silicon. However, it was at par with GRDF + Si @ 150 kg ha^{-1} (45.00 g pot^{-1}). There was significant increase in the straw yield with increased levels of silicon. This might be due to role of silicon in improvement of photosynthetic activity, water and nutrient use efficiency. That ultimately results into better vegetative growth. The higher straw yield was mainly associated with increased plant height and number of tillers per hill. The accumulation of silicon in plant parts reduces its lodging and enhanced resistance against biotic and abiotic stress. All these factors ultimately might have resulted into higher straw yield. These results are in conformity with the findings of Singh *et al*. (2007) [12] and Aarekar (2014) [1].

Table 3: Effect of soil types, levels of silicon and their interactions on yield of rice plants under pot culture

	Grain yield (g pot^{-1})	**Straw yield (g pot^{-1})**
A. Soil types (S)		
S_1: Inceptisols	33.75	37.60
S_2: Vertisols	36.20	39.42
SE (m) ±	0.414	0.433
CD at 5%	1.198	1.253
B. Levels of silicon (T)		
T_1: Absolute control	22.71	25.88
T_2: GRDF	30.06	33.49
T_3: GRDF + Si @ 25 kg ha^{-1}	32.65	36.63
T_4: GRDF + Si @ 50 kg ha^{-1}	36.11	39.64
T_5: GRDF + Si @ 100 kg ha^{-1}	38.90	42.40
T_6: GRDF + Si @ 150 kg ha^{-1}	41.28	45.00
T_7: GRDF + Si @ 200 kg ha^{-1}	43.15	46.54
SE (m) ±	0.774	0.809
CD at 5%	2.242	2.344
C. Interactions (S x T)		
CD at 5%	NS	NS

Conclusion

The soil samples collected from order Vertisols and application of general recommended dose of fertilizers along with silicon @ 200 kg ha^{-1} showed significantly highest growth, yield attributes, grain and straw yield of rice plants. The results of this study highlight the role of silicon in improving growth and yield of rice. In conclusion, the calcium silicate as a source of silicon can produce beneficial effect on the silicon accumulator plants like rice.

References

1. Aarekar SA, Pawar RB, Kulkarni RV, Pharande AL. Effect of silicon on yield, nutrients uptake by paddy plant and soil properties. J Agri. Res. Tech. 2014; 39(2):328-331.
2. Amarasiri SL, Perera WR. Nutrient removal by crops in the dry zone of Sri Lanka. J. Trop. Agri. 1975; 131:61-70.
3. Anonymous. Agricultural Statistics at a Glance 2014. Government of India, Ministry of Agriculture. Oxford University Press, New Delhi, India. 2014, 74.
4. Jawahar S, Vaiyapuri V. Effect of sulphur and silicon fertilization on growth and yield of rice. Int. J Curr. Res. 2010; 9:36-38.
5. Jones LHP, Handreck KA. Silica in soils, plants and animals. Adv. Agron. 1967; 19:107-149.
6. Mukherjee D, Sen A. Influence of rice husk and fertility levels on the growth and yield of wetland paddy (*Oryza sativa* L.). Agric. Sci Digest. 2005; 23(4):284-286.
7. Munir M, Carlos ACC, Heilo GF, Juliano CC. Nitrogen and silicon fertilization of upland rice. Sci. Agricola. 2003; 60(4):761-765.
8. Panse VG, Sukhatme PV. Statistical method of Agricultural Workers, ICAR, New Delhi, India. 1985; 143-147.
9. Savant NK, Datnoff LE, Snyder GH. Depletion of plant available silicon in soils: A possible cause of declining rice yields. Commun. Soil Sci. Plant Anal. 1997; 28:1245-1252.
10. Singh AK, Singh R, Singh K. Growth, yield and economics of rice (*Oryza sativa*) as influenced by level and time of silicon application. Indian J Agronomy. 2005; 50(3):190-193.

11. Singh K, Singh R, Singh JP, Singh Y, Singh KK. Effect of level and time of silicon application on growth, yield and its uptake by rice (*Oryza sativa*). Indian J. Agric. Sci. 2006; 76(7):410-413.
12. Singh K, Singh R, Singh KK, Singh Y. Effect of silicon carriers and time of application on rice productivity in a rice-wheat cropping sequence. IRRN. 2007; 32(1):30-31.
13. Snyder GH, Jones DB, Gascho JG. Silicon fertilization of rice on Everglades Histosols. J. Am. Soc. Soil Sci. 1986; 50:1259-1263.
14. Yoshida S. The physiology of silicon in rice. Tech. Bull. No. 25. Food and Fertilizer Technical Centre, Taipei, Taiwan. 1975, 27.