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# Effect of Different Sources of Silicon Fertilizer on Dissolved Silicon (DSi) in Soil Solution and its Bioavailability for Rice Crop in Three Contrasted Soil

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## Abstract

The present investigation was conducted in green house to assess the effect of different sources of silicon on soil solution Si and its bioavailability for rice in three types of soil. Rate of dissolution and release of Si from Si fertilizers varied among different sources and types of soil. Bioavailability of Si increased significantly with application of Si fertilizer and its effectiveness varied among soils and fertilizers. Plant available Si content in post harvest soil decreased in presence of rice crop as evidenced by plant uptake.

Silicon (Si) is one of the most abundant elements in the earth's crust. Though, soils generally contain about 5 to 40 per cent Si, mainly as quartz and crystalline silicates, their contribution to the plant available Si (PAS) pool in soil is very little due to their poor solubility (Epstein, 1999). It has been well documented that monosilicic acid ($H_4SiO_4$) is the only form of dissolved Si present in the soil solutions readily absorbed by the plants (Jones and Handreck, 1965). Nevertheless, the measured concentrations of monosilicic acid in soil solutions were only 0.1 -0.6 mM (Drees *et al.*, 1989). The main factors influencing the soil Si availability or Si supplying power includes types of soil and parent material, soil pH, soil texture, land use and other accompanying ions. Furthermore, DSi concentrations in soil solution are linked to soil temperature and pore water residence time in the soil (Struyf *et al.*, 2009). Rice is considered as a silicon accumulator plant and tends to actively accumulate Si. Although Si has not been recognized as an essential element for plant growth, it helps in alleviating various abiotic stresses like metal toxicity, drought, radiation damage, nutrient imbalance and high temperature. Also, Si plays a crucial role in preventing or minimizing the lodging in cereal crops and biotic stresses, a matter of great importance in terms of achieving higher yield (Guntzer *et al.*, 2012). These beneficial effects of Si can therefore result in increasing the production and productivity of rice. Extensive and repeated cultivation of rice can deplete available Si in soil (Prakash, 2002) and hence there is need for silicon fertilization.

A pot experiment was conducted to assess the effect of Si fertilizers on DSi and its bioavailability in three soils with contrasting pH with and without rice crop. Acidic soil with pH 5.86, neutral soil with pH of 7.10 and alkaline soil with pH of 9.38 were collected from Hassan, Mandya and Hiriyur respectively. The texture of acidic and neutral soil was sandy loam and that of alkaline soil was clay loam as determined by standard pipette method. Bulk soil was collected from each location, air dried and sieved through two mm sieve and used for pot culture studies. Soils were analysed for PAS by extracting with 0.1M calcium chloride (CCSi) and 0.05M acetic acid (AASi). Si concentration of acidic, neutral and alkaline soil was found to be 43.10, 73.82, 109.46 ppm as extracted by 0.05M acetic acid and 30.58, 41.98, 46.18 ppm as extracted by 0.1M Calcium chloride, respectively. Three types of Si sources were used in this experiment *viz.*, calcium silicate ($CaSiO_3$-12% Si), diatomaceous earth (DE -63.7 % $SiO_2$) and rice husk biochar (RHB – 30% Si) and applied at 250 and 500 kg Si $ha^{-1}$.The study was undertaken by filling 5 kg of each soil per pot and mixed thoroughly with graded levels of Si sources. A rhizon was inserted at a depth of 10cm laterally in each pot to collect the soil solution at different interval. There were four treatments *viz.*, $T_1$: $Si_0$+ $RP_0$, $T_2$: $Si_0$+ RP, $T_3$: $Si_1$+ $RP_0$, $T_4$: $Si_1$+ RP ($Si_0$ = without silicon, $RP_0$ = without crop, $Si_1$= with silicon, RP=with crop) and thereby 14 combinations of treatments for one type of soil. Two twenty one days old rice seedlings (Var. Thanu) were transplanted to each pot and moisture content was maintained at submergence. Recommended dose of $P_2O_5$ (SSP), half dose of the recommended $K_2O$ (as MOP) and N (as Urea) were applied as basal dosage. Remaining nitrogen and potash were given as two splits at 30th and 60th day after transplanting. Water samples have been collected by using preinstalled soil solution samplers (Rhizon collector) at 0, 7, 15, 30, 60, 90 and 120 days after transplanting (DAT) and analysed for Si. Straw and grain samples of acidic and neutral soil and only straw samples (due to condensed growth) in alkaline soil were collected at harvest and analysed for Si content and computed for total Si uptake based on yield and content. Post harvest soil samples were collected and analyzed for CCSi and AASi.

There was a gradual decrease in DSi from 0 to 15 days and thereafter stabilized in acidic soil. $CaSiO_3$ and RHB treatment recorded significantly higher DSi than DE. During initial period of experiment (0 - 15 DAT), $CaSiO_3$ treatment recorded lower DSi but increased significantly in later part of experiment (30 - 120 DAT) whereas DE treatment recorded significantly higher during initial period later on it decreased. In neutral soil, silicon concentration decreased from 0 – 30 DAT but increased significantly at 60 DAT and then decreased at harvest stage and application of RHB and $CaSiO_3$ significantly increased the Si.

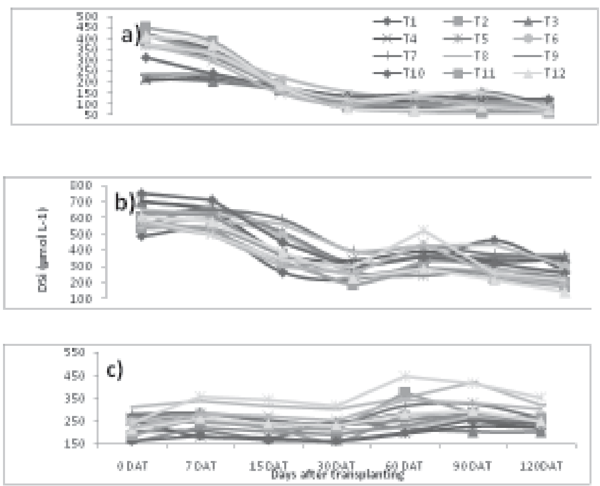


Fig. 1. Effect of Si fertilizer on DSi at different intervals with and without crop in a) acidic, b) neutral and c) alkaline soil ($T_1$: $Si_0$+ $RP_0$, $T_2$: $Si_0$+ RP, $T_3$: $RP_0$+ $CaSiO_3$ @ 250 kg Si ha$^{-1}$, $T_4$: $RP_0$+ $CaSiO_3$ @ 500 kg Si ha$^{-1}$, $T_5$: $RP_0$+ DE @ 250 kg Si ha$^{-1}$, $T_6$: $RP_0$+ DE @ 500 kg Si ha$^{-1}$, $T_7$: $RP_0$+ RHB @ 250 kg Si ha$^{-1}$, $T_8$: $RP_0$+ RHB @ 500 kg Si ha$^{-1}$, $T_9$: RP + $CaSiO_3$ @ 250 kg Si ha$^{-1}$, $T_{10}$: RP + $CaSiO_3$ @ 500 kg Si ha$^{-1}$, $T_{11}$: RP + DE @ 250 kg Si ha$^{-1}$, $T_{12}$: RP + DE @ 500 kg Si ha$^{-1}$, $T_{13}$: RP + RHB @ 250 kg Si ha$^{-1}$, $T_{14}$: RP + RHB @ 500 kg Si ha$^{-1}$).

Si concentration increased during the period from 0 - 90 DAT and then slightly decreased at harvest and application of RHB and DE could increase the Si in alkaline soil (Fig. 1). When Si source is applied to soil, Si dissolves in the soil solution and part of the dissolved Si is adsorbed onto the soil solid phase and then desorbed and redissolved into soil solution (Suhei *et al.*, 2013). The variability in DSi by the application of three different Si sources may be dependent on reactivity based on the soil pH rather than total Si content (Haynes, 2014).

Irrespective of Si sources, Si uptake was higher in neutral soil followed by acidic and alkaline soil. Application of $CaSiO_3$ significantly increased the uptake of Si in acidic and neutral soil whereas application of RHB recorded significantly higher uptake in alkaline soil (Fig. 2).

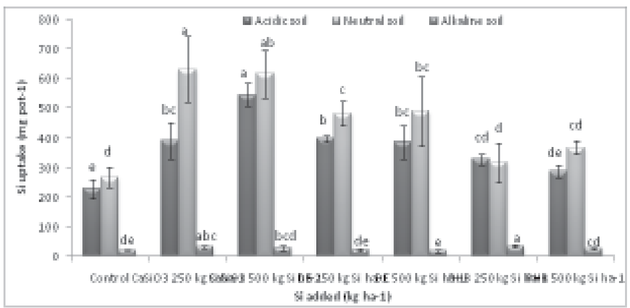


Fig. 2 Effect of different sources of Si on total Si uptake (straw + grain) in acidic, neutral and straw Si uptake in alkaline soil, respectively. (Alphabets indicates the significance level at P< 0.05 via Fisher test with XLSTAT).

It is obvious that application of different Si fertilizer could increase the Si uptake as evidenced by earlier studies (Kanto *et al.*, 2004) but efficiency of different source varied with the types of soil. Post harvest soil silicon decreased significantly in treatment with crop plants was mainly attributed to plant uptake (Table I) irrespective of Si sources. Calcium chloride extractable Si was higher in neutral and alkaline soil than acidic

TABLE I

*Silicon concentration in post harvest soil*

| Treatments | Acidic soil | | Neutral soil | | Alkaline soil | |
|---|---|---|---|---|---|---|
| | CCSi | AASi | CCSi | AASi | CCSi | AASi |
| Ck – without crop | 31.8 (cd) | 76.7 (def) | 49.9 (ab) | 81.4 (ef) | 42.8 (d) | 116.4 (d) |
| Ck– with crop | 28.3 (cdef) | 62.8 (f) | 42.3 (cd) | 80.3 (f) | 44.9 (bcd) | 115.2 (d) |
| **Without crop** | | | | | | |
| $CaSiO_3$ @ 250 kg Si $ha^{-1}$ | 28.1(cdef) | 105.2 (b) | 45.8 (abcd) | 112.0 (b) | 44.3 (bcd) | 143.1(ab) |
| $CaSiO_3$ @ 500 kg Si $ha^{-1}$ | 26.7(defg) | 104.0 (a) | 43.5 (abcd) | 133.0 (a) | 45.5 (bcd) | 131.3 (abcd) |
| DE @ 250 kg Si $ha^{-1}$ | 33.6 (bc) | 78.1(def) | 49.8 (abc) | 87.2 (cde) | 41.2 (d) | 122.5 (bcd) |
| DE @ 500 kg Si $ha^{-1}$ | 33.8 (bc) | 84.6 (cdef) | 51.8 (a) | 88.0 (cde) | 43.3 (cd) | 119.7 (cd) |
| RHB @ 250 kg Si $ha^{-1}$ | 38.1(ab) | 79.6 (cdef) | 53.0 (a) | 88.7 (cd) | 45.2 (bcd) | 130.18 (abcd) |
| RHB @ 500 kg Si $ha^{-1}$ | 40.7 (a) | 95.0 (bcd) | 51.5 (a) | 84.4 (def) | 48.4 (ab) | 127.8 (abcd) |
| **With crop** | | | | | | |
| $CaSiO_3$ @ 250 kg Si $ha^{-1}$ | 21.8 (g) | 98.3 (bc) | 37.7 (d) | 108.7 (b) | 44.0 (bcd) | 146.4 (a) |
| $CaSiO_3$ @ 500 kg Si $ha^{-1}$ | 25.1(fg) | 150.0 (a) | 37.9 (d) | 139.2 (a) | 44.7 (bcd) | 143.1(ab) |
| DE @ 250 kg Si $ha^{-1}$ | 26.3 (efg) | 62.4 (f) | 43.0 (bcd) | 87.1(cde) | 43.1(cd) | 133.7 (abc) |
| DE @ 500 kg Si $ha^{-1}$ | 28.0 (cdef) | 72.4 (ef) | 41.2 (cd) | 91.4 (cd) | 42.5 (d) | 133.5 (d) |
| RHB @ 250 kg Si $ha^{-1}$ | 31.6 (cde) | 78.6 (cdef) | 41.9 (cd) | 91.5 (cd) | 47.7 (bc) | 117.7 (cd) |
| RHB @ 500 kg Si $ha^{-1}$ | 30.7(cde) | 71.4 (ef) | 51.2 (a) | 92.2 (c) | 52.4 (a) | 121.1(cd) |
| LSD @ 5 % | 5.73 | 19.28 | 8.21 | 6.96 | 4.44 | 18.15 |

(Ck – Check, Alphabets in parenthesis indicates the significance level at $P< 0.05$ via Fischer test with XLSTAT)

soil whereas acetic acid extractable Si was higher in alkaline soil than neutral and acidic soil. Plant available Si content of post harvest soil as estimated by acetic acid when treated with $CaSiO_3$ was found to be on par among the treatments with and without crop in both acidic and neutral soil.

DSi and its bioavailability varied among different soils and sources of Si fertilizer. $CaSiO_3$ and RHB performed better in acidic and neutral soil whereas DE and RHB in alkaline soil.

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