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Sway of silicon fertilizers on carbon sequestration in maize crop ecosystem

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Abstract
Carbon sequestration is typically consummate through soil conservation practices that enhance the storage of carbon or reduce carbon dioxide emissions. Phytoliths or plant opal, microscopic siliceous amorphous substance found within the plant cell wall and cell lumen as a result of bio-silicification process and carbon occluded in the along with it called as phytolith occluded carbon (phytOC). A field trial was conducted to study the effect of silicon fertilizers on plant growth, yield attributes of maize hybrid CO6, phyotolith and PhytOC in lateritic soil (*Typic Rhodulfstalf*). The silicon content, phytolith and phytolith occluded carbon content of maize plant ranged from 0.196 to 0.421%, 13.8 to 25.9% and 2.1 to 4.7% respectively. Plants subjected to Soil Test Crop Response based N, P_2O_5, K_2O + calcium silicate @ 400 kg ha^{-1}+ foliar spray of 1% potassium silicate@ 25th and 45th DAS recorded the highest silicon (0.421%) and phytolith content (25.9%) whereas highest phytOC (4.7%) and carbon sequestration (731.47 kg e CO_2ha^{-1}) was observed in T_6. The highest soil phytolith content of 5.56% was acquired in T_6, phytolith occluded carbon (5.43%) in T_4 indicated the weak positive correlation between phytolith and phytolith occluded carbon.

Keywords: Silica, phytolith, PhytOC, carbon sequestration, climate change and maize

Introduction
Global warming is the existing problem prevailing around the world which led to radical climate change. Carbon dioxide and methane are the primary contributors of global warming process and their emission was increased by 1.2 per cent with the major share of CO_2 by 73 per cent (Olivier *et al.* 2017) [6]. Biogeochemical carbon cycle is the most promising approaches for carbon sequestration to mitigate global climatic change (Song *et al.* 2012) [9]. Carbon gets occluded inside the phytolith available both in soil and plant parts commonly called Phytolith Occluded Carbon (phytOC). Approximately, 0.1 to 6.0 per cent of organic carbon can be occluded in phytoliths during bio-mineralization process and vary with crop genera. Recent studies have shown the importance of phytolith and their role in carbon sequestration process

Greatest accumulators of silica are grasslands, bamboo and cereal crops. Sugarcane and rice are the highest silicon accumulating plants followed by wheat, sorghum and maize. In general, silicon content in soil ranged from 1 to 45% (Sommer *et al.* 2006) [8] and in plants 0.1 to 10% (Epstein 1994).

Maize is one of the third most important cereal crops under Poaceae family. Application of silicon fertilizers on silicon content of plants and soil in the form of phytolith in silicon deficient soil (Laterite soil) is very much remarkable. Based on the above importance on carbon sequestration through phytolith and phytolith Occluded Carbon, a research trail was conducted in Sivagangai District, Tamil Nadu in maize crop under Irugur soil series.

Materials and Methods
Research trial was carried out to study the effect of silicate fertilizers on maize growth and yield parameters during Thaipattam (January to February) at Arasanur, Sivagangai district under Randomized Block Design in Maize hybrid CO 6 .The treatments were as follows; T_1 - STCR based N, P_2O_5, K_2O ha^{-1}, T_2 - T_1 + silica solublizing bacteria @ 5 kg ha^{-1}, T_3 - T_1 + calcium silicate @ 200 kg ha^{-1}, T_4 - T_1 + calcium silicate @ 200 kg ha^{-1}+ silicate solubilizing bacteria @5 kg ha^{-1}, T_5 - T_1+ calcium silicate @ 400 kg ha^{-1}, T_6 - T_1+ calcium silicate @ 400 kg ha^{-1}+ silicate solubilizing bacteria @ 5 kg ha^{-1}, T_7 - T_1+ foliar spray of 1% potassium silicate @ 25th and 45th DAS, T_8 - T_1 + foliar spray of 1% potassium silicate@ 25th and 45th

DAS + silicate solubilizing bacteria @ 5 kg ha^{-1}, T_9 - T_1 + calcium silicate @ 200 kg ha^{-1}+ foliar spray of 1% potassium silicate @ 25th and 45th DAS, T_{10} - T_1+ calcium silicate @ 400 kg ha^{-1}+ foliar spray of 1% potassium silicate@ 25th and 45th DAS.

*STCR – Soil Test Crop Response

*DAS - Days after Sowing

Phytolith extraction

Extraction of phytolith from soil was done by heavy liquid floatation technique (Lentfer and Boyd 1999) [5]. Phytolith extraction from plant samples were followed by the procedure given by Rovner, (1983) [7], Bowdery (1989) [3].

Determination of phytolith Occluded Carbon

Phytolith Occluded Carbon was determined by alkali dissolution spectroscopy method (Yang *et al.* 2014).

Carbon sequestration

Total carbon sequestrated in plants was calculated by multiplying dry matter of plant, phytolith content, carbon content of the phytolith and the carbon (C) and converted to carbon dioxide (CO_2) by using conversion 44/12 or 3.67 and expressed as kg e-CO_2 ha^{-1}.

Statistical analysis

The statistical analysis was done with SAS 9.4 software package.

Results and Discussion

Effect of silicon fertilizers on silicon content of maize leaves

Exogenous application of silicate fertilizers enhanced the silicon content of maize leaf and stem ranged from 0.196 to 0.421%, (Table1) and the highest (0.421%) was observed in the treatment subjected to STCR based N, P_2O_5, K_2O fertilizers + calcium silicate @ 400 kg ha^{-1}+ foliar spray of 1% potassium silicate @ 25th and 45th DAS (T_{10}) and followed by T_9 (STCR based N, P_2O_5, K_2O + calcium silicate @ 200 kg ha^{-1}+ foliar spray of 1% potassium silicate @ 25th and 45th DAS) with silicon content of 0.38%.The increased silicon content in maize plants might be due to the application of potassium and calcium silicate fertilizers. This positive impact of potassium silicate on silicon content confirmed with the study of Aziz *et al.* (2020) [2] in maize crop.

Effect of silicon fertilizers on total carbon content of maize leaf: Silicon application significantly improved the total carbon content of maize plant which is presented in table 1. The highest total carbon content of 32.79% was recorded in the treatment T_{10} (STCR based N, P_2O_5, K_2O+ calcium silicate @ 400 kg ha^{-1}+ foliar spray of 1% potassium silicate @ 25th and 45th DAS) followed by T_6 (31.77%) and both were statistically on par with each other. The least percentage of carbon was noticed in control.

Effect of silicon fertilizers on phytolith content and PhytOC content of maize leaf

An increased phytolith percentage of maize was recorded in silicon exposed plants and the maximum phytolith content (25.9%) was notified in the treatment T_{10} followed by T_6 with 24.8% (Table 1.). The increased maize phytolith content and phytOC content might be due to the solubilisation by silicate solubilising bacteria with applied silicon fertilizers. This was substantiated with the findings of Sun *et al.* (2019**)** [11] in rice cultivar. The shape of phytolith and silica sheets is observed from SEM image (Fig 1a). The Fig 1 b predicts the EDS peaks of carbon and potassium (59.68% on weight basis) dominated with silicon and potassium (0.84% on weight basis) as third highest peak.

The highest phytOC content (4.7%) was observed in T_6 succeeded by the treatment received STCR based N, P_2O_5, K_2O + calcium silicate @ 200 kg ha^{-1}+ silicate solubilising bacteria @ 5 kg ha^{-1} i.e.T_4 (4.1%) . This result was substantiated with investigation of Song *et al.* (2015) [10] observed strong positive correlation between phytolith percentage and phytolith occluded carbon whereas Zimin *et al.* (2013) [12] recorded the weak positive correlation between them.

Effect of silicon fertilizers on carbon sequestration

Potential rate of carbon sequestration in maize leaves was observed in this study (Table 1).The carbon sequestration in maize leaves varied among the treatments and the greatest potential was generated in T_6 (731.47 kg e CO_2 ha^{-1}) followed by T_{10} (647.04 kg e-CO_2 ha^{-1}). T_6 had the highest carbon sequestration rate because of the solubilisation of calcium silicate by silicate solubilising bacteria, therefore the available silicon was increased in soil and plant. The variations in phytolith and carbon sequestration rate was graphically related and presented in fig 2.

Table 1: Effect of silicate fertilizers on carbon, silicon content, phytolith, phytOC and carbon sequestration rate in maize plant.

Treatments	Silicon content (%)	Total Carbon (%)	Phytolith (%)	Phytolith Occluded Carbon (%)	Carbon sequestration (kg e CO_2ha^{-1})
T_1	0.196	25.80	13.8	2.1	158.0
T_2	0.206	26.10	15.3	2.9	257.65
T_3	0.226	27.90	19.4	3.2	370.50
T_4	0.247	30.66	22.7	4.1	569.97
T_5	0.297	26.80	21.7	3.8	489.35
T_6	0.354	31.77	24.8	4.7	731.47
T_7	0.231	26.40	17.6	3.1	324.63
T_8	0.254	27.60	19.2	2.6	304.08
T_9	0.38	28.28	22.4	3.7	516.16
T_{10}	0.421	32.79	25.9	3.9	647.04
SEd	0.0063	0.42	0.27	0.11	9.83
CD (P=0.05)	0.0131	0.88	0.58	0.22	20.65

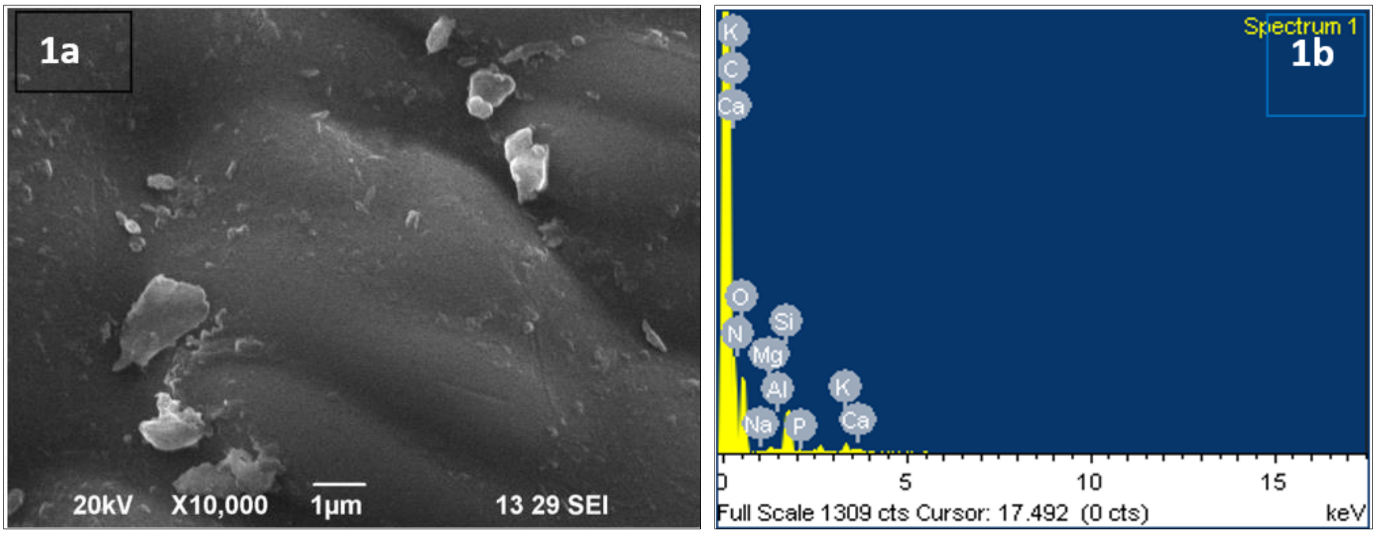

Fig 1: (1a) Scanning Electron Microscopic image of phytolith and silica sheets from Maize leaves and tissues, (1b) EDS spectra of phytolith and leaf tissues.

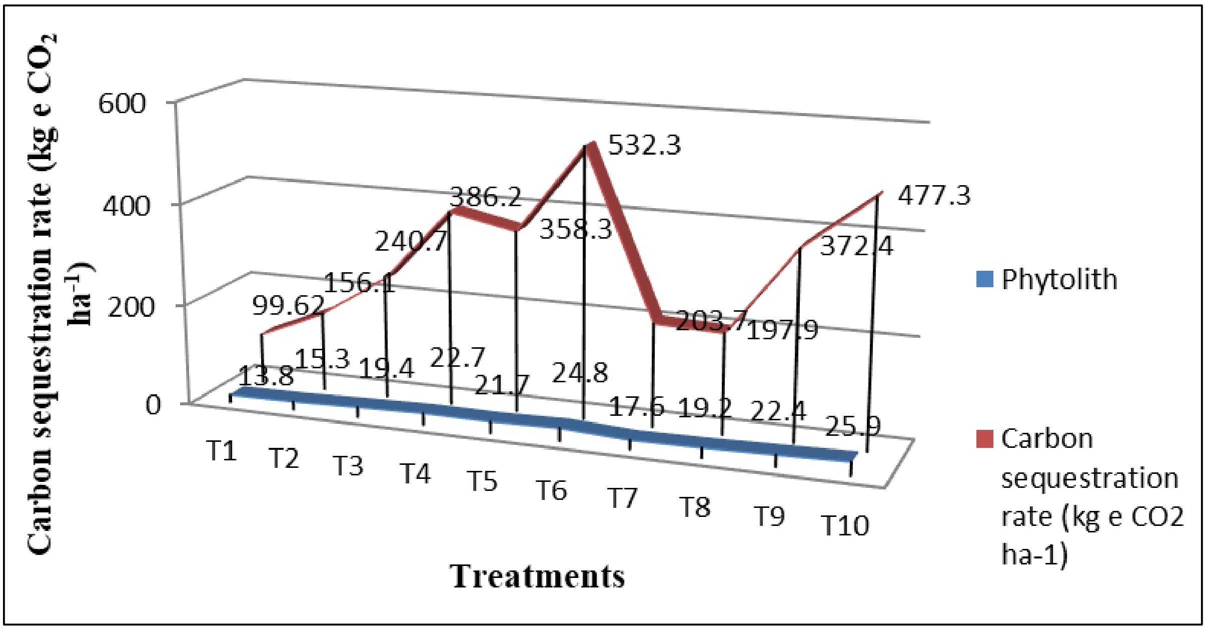

Fig 2: Relationship between phytolith (%) and carbon sequestration rate (kg e CO_2 ha^{-1})

Conclusion

Exogenously applied silicon significantly enhanced the silicon and phytolith content in both soil and plants. Maximum silicon and phytolith content was recorded in the treatment T_{10}, whereas phytolith occluded carbon and the rate of carbon sequestration in silicon phytolith was highly recorded in the treatment T_6 for about 731.47 kg e CO_2 ha^{-1} followed by the treatment T_{10} (647.04 kg e CO_2 ha^{-1}). Recent studies were focused on silicon and its role especially in *Poaceae* family. Therefore, the results concluded that, significant response was observed in silicon, phytolith, phytOC and carbon sequestration rate in maize eco systems with silicon application.

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