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IMPACT OF SILICON FERTILIZER ON SOIL AND PLANT: A REVIEW

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ABSTRACT

Silicon is one of the beneficial elements for crops in terms of inducing resistance against biotic and abiotic stresses, improved nutrient balance, depletion of heavy metal toxicity and photosynthetic activity. Since, it is the most abundant element in earth crust after oxygen, fertilization is also needed due to its unavailability. Laterite soil / desilicated soil responds well to silicon fertilization compared to podzolic soil. Phytoliths or plant opal, microscopic siliceous amorphous substance found within the plant cell wall and cell lumen as a result of bio-silicification process. Silicon fertilizer not only improves the resistance against to biotic and abiotic stresses also improve the plant growth parameters, yield parameters and phytolith occluded carbon. Biogeochemical cycle of silicon and fertilization facilitate the silicon accumulation in plant parts as phytolith. In plants, carbon is also occluded in plant opal as Phytolith Occluded Carbon (PhytOC). Now a days, carbon sequestration is an important challenging approaches to mitigate climate change. Phytolith and PhytOC are more stable in the contribution of long term carbon sequestration process. In these study aim to collect the various literature about the silicon fertilizer application on crop growth, yield and nutrient uptake mechanism on a short terms.

Key words : Silicon, Biotic stress, Abiotic stress, Plant growth, Yield, Phytolith occlude carbon.

Introduction

Silicon (Si) is ranked as the second-most abundant element (after oxygen) in the earth's crust with nearly 29% mean content (Sommer *et al.*, 2006). Si content (mostly 1%–45%) in soil ranges depending on soil types (Sommer *et al.*, 2006). Liang *et al.* (2015) reported that Si content in latosols or latosolic red soils (highly weathered soil) in the tropical zone can be less than 1% due to the presence of extremely active desilification and fersialitization processes. In soil, Si mainly presents in various categories of aluminosilicates and quartz (SiO_2), which consist of up to 75%–95% of soil inorganic constituents (Liang *et al.*, 2015; Meharg and Meharg, 2015).

The potential of Si in improving crop yield has been demonstrated in many studies, especially under abiotic and biotic stress conditions (drought, heavy metals, salinity and pathogens) (Epstein, 2009; Keeping and Reynolds, 2009; Meena *et al.*, 2014; Farooq and Dietz, 2015). Si is known for its role in alleviating the negative stress effects on many plant species. Monocotyledons in general and Poaceae species such as rice (*Oryza sativa* L.) in particular are clearly favored due to an enhanced supply of Si (Epstein, 1999; Ma *et al.*, 2007). Despite these benefits, Si is still not classified as an essential element, but considered as a beneficial element. With nearly 154 million hectares harvested each year, rice is one of the most important cereal crops in the world. It is the major source of calorie intake and the staple food for more than three billion people in the world (Datta *et al.*, 2017; Ullah *et al.*, 2017). The demand for rice is steadily increasing due to an increase in global population.

However, certain constraints such as water scarcity, pest infestation, inadequate fertilizer use and growing of low-yielding traditional varieties restrict yield increase (Datta *et al.*, 2017). However, due to low profitability of crop production, limited access to new agricultural technologies and poor soil and crop management by farmers with the recent added concern of climate change. Increasing crop yield per unit area is associated with Si depletion, which is a matter of concern (Savant *et al.*, 1997). Plant available Si in the soils of tropical and subtropical areas including Vietnam is generally low (Meena *et al.*, 2014). Si fertilizer has been used in many countries for improving crop yield (Guntzer *et al.*, 2012). The objective of this study was to evaluate the effects of different combined doses of standard fertilizer practice and Si fertilizer on growth, yield and yield components, and nutrient uptake of crops.

Effect of silicate fertilizers on crop growth

Prakash *et al.* (2011) conducted a field experiment on the effect of foliar spraying of silicic acid on rice. The maximum plant height (99 cm), panicle length (22 cm) and number of tillers (9) were recorded in treatment received silicic acid @ 4 ml L^{-1} + half dose of pesticide (Quinalphos and Carbendazim). Malav *et al.* (2015) conducted a pot experiment with four different levels of calcium silicate on rice. Application of silica @ 300 mg kg^{-1} in low and medium silicon soils recorded the maximum plant height of 88.49 and 88.17 cm, respectively and higher number of tillers (3 $plant^{-1}$) was noticed in the treatment exposed to 300 mg kg^{-1} of silicon as soil application. Pati *et al.* (2016) studied the effect of diatomaceous earth on rice growth, yield and uptake of nutrients in alluvial soil of West Bengal. The growth parameters *viz*., plant height, number of tillers, number of panicles and leaf area index was significantly increased to 3.72, 9.41, 10.57 and 16.67 per cent respectively by the application of diatomaceous earth @ 600 kg ha^{-1}. Cuong *et al.* (2017) evaluated the application of silicon-based fertilizers on rice. The result revealed that application of recommended dose of fertilizers + SiO_2 @ 400 kg ha^{-1} significantly increased the number of tillers per hill to 28 percent. Aziz *et al.* (2020) assessed the effect of rice straw, wheat straw and potassium silicate as silicate sources on maize. The plant height and stem diameters were significantly increased under potassium silicate @ 200 mg kg^{-1} applied plots compared to straw incorporated plots. Siregar *et al.* (2021) studied the effect of silica (SiO_2) on rice under oxisol conditions. Among the growth parameters, the maximum plant height of 118.3 cm was noticed in plots received 600 kg Si ha^{-1}.

Effect of silicate fertilizers on physiological characters of crop

Bokhtiar *et al.* (2012) evaluated the impact of silicon on plant growth and yield parameters of sugarcane. The higher photosynthetic rate (58.70 mmol/sq.m/s), transpiration rate (7 mmol/sq.m/s) and stomata conductance (0.27 mmol/sq.m/s) were recorded in the treatments received calcium silicate @ 60 g pot^{-1}. Zargar and Agnihotri (2013) investigated the role of silicon on morphological, water stress tolerance and physiological characters of maize. The results indicated that physiological parameters were increased *viz.*, relative water content (66.16), stomata density (1.67) and canopy temperature (1.338) by application of calcium silicate @700 kg ha^{-1}. Xie *et al.* (2014) studied the photosynthetic characters of maize in alluvial soil by the application of silicate sources (0, 45, 90, 150 and 225 kg ha^{-1}). The photosynthetic rate, stomata conductance and transpiration rate of maize were significantly increased to 47.83 m mol m^{-2} s^{-1}, 0.88 mol m^{-2} s^{-1} and 9.86 m mol m^{-2} s^{-1} respectively in sodium meta-silicate @ 150 kg ha^{-1} applied plots during silking and grain filling stages. Amin *et al.* (2016) evaluated the effect of calcium silicate on two maize hybrids *viz.*, P-33H25 and FH-810 under well-watered (100% field capacity) and water deficit situation (60% field capacity) conditions. Application of calcium silicate @ 100 mg kg^{-1} responded well in enhancing photosynthetic rate, leaf water status and osmotic adjustment of maize. Meena *et al.* (2016) documented that addition of silicon @ 300 mg kg^{-1} significantly increased the plant height to 5.8 and 2.9 per cent in loamy sand and silt loam soils respectively compared to control. Bevinakatti *et al.* (2020) investigated the application of silicon on physiological and biochemical parameters of maize crop. The maximum relative leaf water content (61.4%) and transpiration rate (4.16 m mole of H_2O m^{-2} s^{-1}) were recorded in the treatments received potassium silicate @ 60 kg ha^{-1} through soil application. Similarly, higher stomata conductance of 0.543 m mole m^{-2} s^{-1} was noted in the treatment received potassium silicate @ 60 kg ha^{-1} and it was on par with 40 kg ha^{-1} of potassium silicate + foliar spray of silicic acid @ 0.50 percent received maize crop. Jeer *et al.* (2021) studied the effect of diatomaceous earth and silicic acid on yield related attributes of wheat. The enhanced photosynthetic rate of 23.20 mol CO_2 m^{-2} s^{-1} and water use efficiency of 2.36 mmol CO_2 mol^{-1} H_2O were recorded in diatomaceous earth @ 300 kg ha^{-1} applied plants. Oliveira *et al.* (2020) examined the combined effects of EDTA manganese and potassium silicate at different doses on corn and sorghum. Results have shown that increased dry matter production was observed due to the enhanced relative chlorophyll index of 41.75 with 0.47 g L^{-1} of manganese as EDTA and silicon @ 0.476 g L^{-1} as potassium silicate received treatments. Marques *et al.* (2021) evaluated silicon translocation in maize crop subjected to water stress (drought and excess water) conditions and on agronomic, physiological and metabolic aspects. Application of silicon enhanced the epidermal cell thickness to 54% and photosynthetic rate to 54% and transpiration rate to 25% under drought stress condition. Tripathi *et al.* (2021) evaluated the impact of silica-based fertilizers on nodule formation and morphological traits of soybean plant for two years. The plants treated with silicate fertilizers (silicate fertilizer @1.6 kg 20 m^{-2} as basal and sodium meta-silicate @ 2mM as foliar application) performed better in improving stomata conductance to 11 per cent, net photosynthesis to 13 per cent, transpiration rate to 7 per cent, root length to 7 per cent and root nodule counts to 22 per cent over control.

Effect of silicate fertilizers on yield and yield attributes of crops

Owino-Gerroh and Gascho (2005) studied the effect of silicon on phosphate sorption, availability and growth of maize in low pH soil. Application of sodium silicate @ 3.92 mg pot^{-1} enhanced root and shoot biomass to 0.36 and 0.72 mg g^{-1}, respectively. Ali *et al.* (2008) studied the influence of silicate fertilizers on emission of methane and its impact on rice yield at different conditions. The grain yield was significantly increased with silicon @ 4 Mg ha^{-1} to 18 and 13 per cent in tillage and no tillage conditions, respectively. Prakash *et al.* (2011) conducted a field experiment with foliar spraying of silicic acid on rice growth and yield parameters. The highest rice grain yield was observed as 6679 kg ha^{-1} with silicon @ 2 ml L^{-1}, whereas reduction in yield was observed at higher doses @ 4ml L^{-1} of silicon. Bokhtiar *et al.* (2012) evaluated the impact of calcium silicate on plant growth and yield parameters of sugarcane in two different soils. Results showed that maximum dry matter production of 1.14 kg pot^{-1} was observed in plants exposed to silicate @ 60 g pot^{-1}. The higher cane yield of 2.08 and 3.03 kg pot^{-1} were noticed in the treatments received silicate @ 60 and 120 g pot^{-1}, respectively. The highest average sucrose percentage of 0.32 and 0.39 kg ha^{-1} was noticed in the treatments received calcium silicate @ 150 g pot^{-1} in both the soils. Ahmad *et al.* (2013) conducted a field experiment with foliar application of silicon on rice yield and quality parameters. The yield parameters *viz.*, productive tillers and total number of tillers were significantly higher in plants which exposed to silicon. The test weight of rice grain and number of spikes per panicle were statistically higher as 17.98 g and 121.48 respectively with silicon @ 1 per cent applied plots. The rice yield was comparatively higher in treatments received silicon @ 1, 0.5 and 0.25 per cent as foliar application. Castro and Crusciol (2015) evaluated the effects of calcium silicate, magnesium silicate and dolomitic limestone on the yield of soybean and maize crop .The soil acidity was reclaimed by dolomitic limestone and enhanced the yield attributes *viz.*, test weight and grain yield to 39.9g and 8,785 kg ha^{-1} in silicate received treatments. Malav *et al.* (2015) conducted a pot experiment with different levels of calcium silicate on rice growth and yield parameters in varied silicon containing soil. In low silicon soil, grain yield was enhanced from 7.80 to 16.84 g pot^{-1} in silicon level of 200 mg kg^{-1}, whereas highest grain yield of 11.80 g pot^{-1} was observed in silicon application @ 100 mg kg^{-1}. Pati *et al.* (2016) studied the effect of diatomaceous earth as silicon source on rice growth, yield and uptake of nutrients in alluvial zone of West Bengal. The higher grain and straw yield of 5,219 and 7,767.5 kg ha^{-1} was recorded in diatomaceous earth @ 600 kg ha^{-1} applied plants compared with control. Cuong *et al.* (2017) evaluated silicon-based fertilizer on growth, yield and nutrient uptake of rice plants. The highest grain yield of 3,705 kg hm^{-2} was obtained in Recommended Dose Fertilizer (RDF) + silicon 400 kg hm^{-2} and also grain yield, straw yield, no. of grains per panicle and test weight were also enhanced to 23, 20, 6 and 33 per cent, respectively. Siam *et al.* (2018) studied the effects of sodium meta silicate as silicate sources on rice yield and its impact on soil. The result showed that higher dry matter production of 29.48 g pot^{-1} roots and 48.86 g pot^{-1} shoot and rice grain yield of 41.61gm pot^{-1} were recorded under silicate fertilizer @1.87 gm Si pot^{-1} combined with NPK applied plots. Dorairaj *et al.* (2020), explained the impact of silicon on physiological parameters and yield attributes of rice cultivar. Results revealed that silicon @ 4 g pot^{-1} applied as basal combined with top dressing of silicon @ 4 g pot^{-1} at reproductive stage significantly increased the spikelet number per panicle and 100 grains weight. Jeer *et al.* (2021) conducted an experimental study to analyse the effect of diatomaceous earth and silicic acid application on yield attributes of wheat. The greatest number of grains $spike^{-1}$ and 1000 grain weight were recorded by 14 and 11 per cent respectively in the treatment received 300 kg of Diatomaceous Earth ha^{-1} as soil-based application over control. The highest grain yield of 3.31 t ha^{-1} was recorded in the treatments received 300 kg ha^{-1} of diatomaceous earth. Siregar *et al.* (2021) conducted a pot experiment with silica (SiO_2) on rice plants under Oxisol. The increased yield of 34.66 per cent was recorded in silica @700 kg SiO_2 ha^{-1} applied pots.

Effect of silicate fertilizers on quality of crop

Ahmad *et al.* (2013) studied the impact of silicate fertilizers as foliar spray at three different doses on rice yield and quality parameters. The significantly higher protein content of 6.30% and starch content of 77.57% in rice grain were noticed under silicon @ 1 per cent foliar sprayed compared to control plants. Shwethakumari and Prakash (2018) evaluated the impact of silicic acid as foliar spray on soybean yield and its quality parameter in MAUS -2 and KBS -23. Foliar application of silicic acid @ 2 mL L^{-1} significantly improved the protein content of soybean to 39.67± 3.07% and it was on par with 4mL L^{-1} silicic acid spraying. The highest yield of 7.45 ± 0.19 q ha^{-1} was recorded in the treatment receiving silicic acid @ 4 mL L^{-1} in KBS -23 variety. Gomes *et al.* (2005) observed the enzymatic activity of wheat crop with calcium silicate. Plants received with calcium silicate @ 1.855 g kg^{-1} recorded with greatest enzymatic activity *viz.*, Peroxidase (602 µg fresh weight), Polyphenol Oxidase (489 µg fresh weight) and Phenylalanine Ammonia Lyase (0.127 µg fresh weight). Moussa (2006) conducted a study to scrutinize the effect of silicon on physiological response of salt stressed maize. Addition of silicon @ 3 mM enhanced Super Oxide Dismutase to 190 unit mg $protein^{-1}$ and Catalase to 1.3 µ mol H_2O_2 g^{-1} $FWmin^{-1}$ activities. Ahmad and Haddad (2011) investigated the antioxidant enzyme activities in wheat crop under three different conditions (control, drought and silicon –drought). The result revealed that Catalase activity (0.55 µM H_2O_2 dec/min/mg protein), Super Oxide Dismutase (27.98 unit/mg protein), Ascorbate Peroxidase (1.44 µM H_2O_2 dec/min/mg protein) and Peroxidase (0.57 ìM H_2O_2 dec/min/mg protein) were significantly enhanced by exposing wheat under Si- drought stress analogous to control. Rezakhani *et al.* (2020) conducted a research with varied level of silicic acid with phosphate solubilizing bacteria on sorghum plants. The Catalase activity was improved by 62 per cent in 150 mg Si kg^{-1} of applied plots. The Super Oxide Dismutase and Peroxidase activity were improved by 70.24 and 79.3 per cent respectively in plants exposed to 300 mg Si kg^{-1} compared to control. Sun *et al.* (2021) compared the activity of antioxidant enzymes in maize plants exposed with varied silicon doses. The Super Oxide Dismutase, Peroxidase and Catalase activities were significantly enhanced to 31.31, 287.89 and 21.31 per cent, respectively in the plant's treated with silicon @ 15 g L^{-1}.

Effect of silicate fertilizers on nutrient content and uptake

Owino-Gerroh and Gascho (2005) studied the effect of silicon on phosphate sorption and maize growth under low pH soil. The dry weight of maize shoot and root got increased in 3.92 mg Si /pot with phosphate fertilizer. Prakash *et al.* (2011) conducted a field experiment on the effect of silicic acid on growth, yield parameter and silicon uptake of rice. The result showed that maximum silicon uptake of 80.1 kg ha^{-1} and 320.0 kg ha^{-1} in grain and straw respectively were observed in the plots received silicic acid @ 4 ml L^{-1} + ½ dose of pesticide. Sarto *et al.* (2014) investigated the effect of calcium silicate on nutrient uptake and yield of wheat crop. The potassium and calcium content were substantially increased by 29 and 38 per cent respectively in calcium silicate applied @ 9.6 Mg ha^{-1} plots, whereas micronutrient *viz.*, zinc and manganese concentrations was drastically reduced to 29 and 68 per cent, respectively. Meena *et al.* (2016) studied the combined application of silicon and phosphorus on maize in two different soil types (loamy sand and silt loam). The higher silicon content of 19.40 g pot^{-1} was noticed in 400 mg kg^{-1} of silicon pots. The phosphorus content of 1.67 g pot^{-1} was recorded under 300 mg kg^{-1} of silicon in both the soil. Fe and Mn uptake was statistically improved by the addition of phosphorus rather than silicon. Pati *et al.* (2016) studied the impact of diatomaceous earth as silicon source on growth, yield and uptake of nutrients in rice under alluvial zone of West Bengal. The results showed that the nutrient uptakes *viz.*, silicon, nitrogen, phosphorus and potassium of rice grain were enhanced to 33.78, 44.4, 29.3 and 16.5 per cent respectively by the application of diatomaceous earth @ 600 kg ha^{-1}. Peera *et al.* (2016) evaluated the effect of silicate sources (silicate solubilizing bacteria and fly ash) on silicon uptake and rice yield under lowland ecosystem. The highest silicon uptake of 164.6 kg ha^{-1} was registered with 25 t ha^{-1} of fly ash applied plots. Silicon uptake level was recorded to be the highest in rice straw as 149.5 kg ha^{-1}, followed by rice grains as 62.3 kg ha^{-1} under silicate solubilizing bacteria + Farm Yard Manure and fly ash treatment @ 25 t ha^{-1}. Cuong *et al.* (2017) conducted a field experiment on the effect of silicon-based fertilizers on nutrient uptake and yield of rice crop. The maximum silicon uptake of 284.1 kg hm^{-2} was observed in the treatments received RDF + 400 kg hm^{-2} SiO_2 analogous to control and nitrogen uptake of grains was improved to 37 per cent under RDF+ 400 kg hm^{-2} SiO_2 treatment compared to control. The same trend was noticed in phosphorus and potassium uptake also. Swain and Rout (2018) compared the nutrient uptake of rice varieties with silicon source as diatomaceous earth at four different concentrations. The results confirmed that phosphorus uptake was subsequently increased with 2.0 mM Si concentration and potassium uptake was augmented with 1 -1.5 mM Si concentration. The calcium and magnesium uptake were significantly higher in upland varieties analogous to lowland rice varieties. Siam *et al.* (2018) explored the impact of silicate fertilizers on rice yield and its nutrient uptake. The results showed that nitrogen and phosphorus uptake of rice were significantly increased under application of silicate fertilizers @1.87 gm Si pot^{-1} in roots to 164.69 mg pot^{-1}, shoots to 313.83 mg pot^{-1} and grains to 543.85 mg pot^{-1} compared to non applied pots. Silicon addition significantly influenced the potassium uptake. Aziz *et al.* (2020) assessed the effect of rice straw, wheat straw and potassium silicate on maize growth and yield attributes. The application of potassium silicate @ 200 mg kg^{-1} increased the silica content to 2.30% in maize leaves. The higher potassium content of 260 ppm in maize plant was recorded under potassium silicate @ 400 mg kg^{-1}. Jan *et al.* (2020) conducted an experiment to analyze the uptake of nutrients by rice plant with combined application of nitrogen and silicon. The higher nitrogen uptake of 81.55 kg N ha^{-1} and silicon uptake of 82.46 kg Si ha^{-1} was recorded with the application of 120 kg ha^{-1} nitrogen and 15 per cent silicon. Rezakhani *et al.* (2020) studied the uptake of nutrients by sorghum plants with various concentrations of silica and phosphate solubilizing bacteria. The uptake of phosphorus, silicon and potassium were intensified in silicon treated plants. Frank Stephano *et al.* (2021) investigated the combined effect of silicate fertilizers and straw incorporation. The result showed that total phosphorus uptake of maize was enhanced to 22.9 per cent under straw plus silicon incorporated compared to without silica. Zajaczkowska *et al.* (2020) studied the comparative effect of soil and foliar based application of silicate fertilizers on wheat. The highest (77 per cent) silicon content of shoots was recorded in silicate fertilizer @ 400 mg kg^{-1}, followed by 55 per cent under silicate fertilizer @ 200 mg kg^{-1}. Foliar application of silicon @ 6 mM L^{-1} resulted in enhanced silicon content of 19 per cent in shoots and roots. Marques *et al.* (2021) studied the response of calcium silicate on morphological characters of maize under water stress condition. Application of calcium silicate @ 50, 75 and 100 per cent of Si significantly increased the silica content by 33 per cent and improved its translocation by 56 percent. Results revealed that greater accumulation of silica was observed under stress condition when leaf portion of plants received 75 and 100 per cent of Silicon.

Effect of silicate fertilizers on soil properties

Boniao *et al.* (2002) compared the effects of various amendments on soil properties. They incubated 200 grams of air dried soil with peat, ground basalt, pyroclastics and calcium silicate @ 200 t ha^{-1} for nine months. The result revealed that soil pH and Cation Exchange Capacity was distinctly increased from 4.3 to 7.1 and 0.81 to 48.40 c mol (p+) kg^{-1} respectively after three months of incubation period. Bokhtiar *et al.* (2012) evaluated the effect of calcium silicate on yield attributes of sugarcane and soil properties in two different soils. Upon calcium silicate application, there was a significant change in pH and sodium acetate extractable silica. In two different soils, exchangeable potassium (0.458 and 0.393 c mol kg^{-1}), calcium (20.54 and 27.67 c mol kg^{-1}) and magnesium levels (0.747 and 1.317 c mol kg^{-1}) were significantly greater with calcium silicate applied @ 150 g pot^{-1} which consist of 30 percent of SiO_2 and 25 per cent of CaO. Karunakaran *et al.* (2013) evaluated the effect of different silicate sources on soil properties and nutrients. Results confirmed that soil pH and Electrical Conductivity was raised upon the addition of sodium silicate (with 99% purity) from 7.04 to 9.86 and from 0.31 to 0.61dS m^{-1} respectively under 30 days after incubation. Similarly, pH and Electrical conductivity of soil was slightly increased from 8.35 to 8.37 and 0.48 to 0.49 dS m^{-1} respectively, when silicic acid was added as a silicon source. Sarto *et al.* (2014) investigated the effect of calcium silicate on nutrient uptake and yield of wheat crop. The soil pH was linearly increased from 4.6 to 6.6 with application of calcium silicate from 0 to 9.6 Mg ha^{-1}. Castro and Crusciol (2015) studied the effect of dolomite limestone, calcium silicate and magnesium silicate on ameliorating soil acidity in soybean and maize. The hydroxyl concentration was escalated with addition of slag (calcium and magnesium silicate) to ECC (80%), CaO (34%), MgO (10%), SiO_2 (22%) and enhanced the soil microbial activity and mineralization process. Elisa *et al.* (2016) analysed the effect of calcium silicate in alleviating aluminium toxicity in an acid sulphate soil. It was concluded that soil pH was gradually increased from 2.90 to 3.95 due to the addition of calcium silicate @ 3 Mg ha^{-1} whereas aluminium level in the respective soil was declined from 4.26 to 0.82 c mol p$^{(+)}$ kg^{-1}. White *et al.* (2017) conducted a field study with two levels of nitrogen and five levels of silicate slag on wheat crop. The soil pH was gradually increased from 5.6 to 7 with addition of silicate slag @ 9 Mg ha^{-1} and nitrogen @145 kg ha^{-1}. Rao *et al.* (2018) studied the effect of various silicate sources on soil physicochemical properties of laterite paddy soils. The soil pH and organic carbon were significantly increased from 4.50 to 5.71 and 1.14 to 1.39 per cent respectively in the treatment received fine silica @ 50 kg ha^{-1} + rice husk ash @ 125 kg ha^{-1} + foliar spray of potassium silicate @ 0.5 % analogous to other treatments. But electrical conductivity and texture was not influenced by silicate fertilizers. El-sayed *et al.* (2018) studied the effect of silicon and humic acid application on bread wheat under water stress condition and on soil properties. The soil properties *viz*., pH and organic carbon were not significantly influenced by silicate fertilizers.

Effect of Silicate fertilizer on carbon sequestration and climate change

Ali *et al*. (2008) studied the influence of silicate fertilizers on emission of methane from rice field and its impact on rice yield. Slag type silicate fertilizer was applied at five different rates on rice crop where, methane emission was suppressed from 158 mg CH_4 m^{-2} h^{-1} to 116 mg CH_4 m^{-2} h^{-1} due to the increased carbon dioxide activity and iron concentration in soil. Ali *et al*. (2009) investigated the effect of silicate slag amendment in tillage and no tillage farming systems on methane emission in rice. Irrespective of silicate application, methane emission was reduced in no tillage farming system compared to tillage. Methane flux was declined by 20 per cent in control tillage and 36 per cent in no tillage system in all season. Parr and Sullivan (2011) examined the silica phytolith accumulation on carbon bio-sequestration in wheat cultivars collected from 25 different countries. Results revealed that carbon sequestration potential of these cultivars were up to 0.246 t-e-CO_2 ha^{-1} y^{-1}. Zuo and Lu (2011) explored the carbon sequestration potential of millets phytolith under dry farming condition. Results shown that 0.023 ± 0.015 and 0.020± 0.010 t CO_2 equivalents were sequestered in common millet and foxtail millet, respectively. On average, 2.37×10^6 t e CO_2 was sequestered in common millet. Song *et al*. (2012) investigated the phytolith and Phytolith Occluded Carbon content under grasslands of China. Results revealed that Phytolith Occluded Carbon production rate from China grass lands was 0.6×10^6 t CO_2 yr^{-1} whereas 41.4×10^6 t CO_2 yr^{-1} in world grasslands. Li *et al*. (2013) explored the capacity of phytolith in silicon accumulator -rice towards carbon bio-sequestration. The carbon sequestration potential ranged from 0.03 to 0.13 Mg-e-CO_2 ha^{-1} $year^{-1}$in five different rice cultivars. About 1.94×10^7 Mg-e-CO_2 from the atmosphere could have been sequestered by rice growing areas across the world annually. Song *et al*. (2013) investigated the potential of phytolith sink distributed in different crop lands around the world and its role on carbon bio-sequestration. Results revealed that 26.35 ± 10.22 Tg of CO_2 was sequestered in global crop lands. Contribution to phytolith Carbon sink was made by rice (25 per cent), maize (23 per cent) and wheat (19 per cent). Song *et al*. (2013) analysed the Phytolith Occluded Carbon production in China forest. The phytolith carbon sink was 1.7 ± 0.4 Tg CO_2 yr^{-1} in China's forest and 30 per cent of C sink was contributed by Bamboo. Afforestation and reforestation of bamboo could raise the phytolith carbon sink up to 6.8 ± 1.5 and 27.0±6.1 Tg CO_2 yr^{-1} in China's forest and worldwide, respectively. Li *et al*. (2013) studied the carbon sequestration potential of phytolith in herb-dominated fens in wetland ecosystem. Phytolith carbon bio-sequestration flux ranged from 0.003 to 0.077 t CO_2 ha^{-1}. They also estimated that carbon sequestration flux about 1.14×10^7 t CO_2 equivalents had been sequestered annually in fens grown lands across the world. Song *et al*. (2014) scrutinized the role of phytolith on climate change by using crop production data of various crops *viz*., rice, wheat, corn and others. Result of this study revealed that CO_2 sequestered in Chinese croplands was 4.39 ± 1.56 T gyr^{-1} and crop management practices could enhance the phytolith potential, carbon sequestration and climate change mitigation. Yang *et al*. (2015) studied the distribution of silica in various plant species found in China forest which plays an important role in carbon sequestration process. Results showed that herbs were the highest silicon accumulator followed by trees and shrubs. Carbon sequestration potential in terms of PhytOC production rate reached $0.48 \pm 0.20 \times 10^6$ t CO_2 $year^{-1}$ and 44 per cent was contributed by understory vegetation consist of herbs and shrubs. Song *et al*. (2015) examined the impact silicate fertilizers on carbon bio-sequestration in paddy soil. The exogenous application of silicate fertilizers significantly enhanced the phytOC level from 0.94×10^6 tonnes CO_2 yr^{-1} to 2.17×10^6 tonnes CO_2 yr^{-1}. Rajendiran *et al*. (2016) investigated the rice phytolith potential in long term carbon sequestration process. The carbon sequestration rate in phytolith of rice cultivars ranged from 0.05 to 0.12 Mg-e-CO_2 ha^{-1} $year^{-1}$. Globally, 16.4 Tg-e-CO_2 was estimated as annual potential sink rate of Phytolith Occluded Carbon in soils through rice phytolith. Song *et al*. (2017) explored the carbon sequestration potential of phytolith in global terrestrial biomes. Biome data *viz*., productivity, phytolith and silica content were analysed as 156.7± 91.6 Tg CO_2 yr^{-1} and was sequestered in global terrestrial biomes. Amidst terrestrial ecosystem, 40 per cent of grassland, 35 per cent of cropland and 20 per cent of forest were the dominant contributors of phytolith carbon sink. Similarly, Asia, Africa and South America are recognized as the major contributors.

Conclusion

From this above study concluded that application of silica fertilizer increasing the crop growth parameter, nutrient uptake, plant resistance and yield. Apart from that silica will increasing the carbon sequestration rate of soil and then they are acting as a potential source of carbon sink material in the form of phytolith occluded carbon through soil.

References

Ahmad, S.T. and Haddad R. (2011). Study of silicon effects on antioxidant enzyme activities and osmotic adjustment of wheat under drought stress. *Czech J. Gen. Plant Breed.*, **47 (1)**, 17-27.

Ali, M.A., Lee C.H. and Kim P.J. (2008). Effect of silicate fertilizer on reducing methane emission during rice cultivation. *Biology and Fertility of Soils*, **44(4)**, 597-604.

Ali, M.A., Lee C.H., Lee Y.B. and Kim P.J. (2009). Silicate fertilization in no-tillage rice farming for mitigation of methane emission and increasing rice productivity. *Agricult., Ecosys. Environ.*, **132(1-2)**, 16-22.

Amin, M., Ahmad R., Ali A., Aslam M. and Lee D. (2016). Silicon fertilization improves the maize (*Zea mays* L.) performance under limited moisture supply. *Cereal Research Communications*, **44(1)**, 172-185.

Aziz, A., Tahir M.A., Sarwar G. and Sher M. (2020). Effect of Rice and Wheat Straw and K-Silicate Application on Maize Growth. *Pak. J. Agricult. Res.*, **33 (4)**, 905-910.

Bevinakatti, H.P., Potdar M., Arvindkumar B. and Navalagatti C. (2020). Effect of silicon nutrition on physiological and biochemical parameters of maize at different dates of sowing. *J. Pharmacog. Phytochem*., **9(3)**, 213-218.

Bokhtiar, S., Huang H.-R. and Li Y.-R. (2012). Response of sugarcane to calcium silicate on yield, gas exchange characteristics, leaf nutrient concentrations and soil properties in two different soils. *Communications in Soil Science and Plant Analysis*, **43(10)**, 1363-1381.

Boniao, R., Shamshuddin J., Van Ranst E., Zauyah S. and Syed Omar S. (2002). Changes in chemical properties and growth of corn in volcanic soils treated with peat, ground basalt pyroclastics and calcium silicate. *Communications in Soil Science and Plant Analysis*, **33 (7-8)**, 1219-1233.

Castro, G.S.A. and Crusciol C.A.C. (2015). Effects of surface application of dolomitic limestone and calcium-magnesium silicate on soybean and maize in rotation with green manure in a tropical region. *Bragantia*, **74**, 311-321.

Cuong, T.X., Ullah H., Datta A. and Hanh T.C. (2017). Effects of silicon-based fertilizer on growth, yield and nutrient uptake of rice in tropical zone of Vietnam. *Rice Science*, **24 (5)**, 283-290.

Dorairaj, D., Ismail M.R., Sinniah U.R. and Tan K.B. (2020). Silicon mediated improvement in agronomic traits, physiological parameters and fiber content in *Oryza sativa*. *Acta Physiologiae Plantarum*, **42(3)**, 1-11.

Elisa, A., Ninomiya S., Shamshuddin J. and Roslan I. (2016). Alleviating aluminum toxicity in an acid sulfate soil from Peninsular Malaysia by calcium silicate application. *Solid Earth*, **7(2)**, 367-374.

El-sayed, M., Soliman G. and Ahmed A. (2018). Impact of Silicon and Humic Acid Application under Water Stress Condition on some Bread Wheat Cultivars and Some Soil Properties. *Assiut J. Agricult. Sci*., **49(4)**, 138-157.

Frank Stephano, M., Geng Y., Cao G., Wang L., Meng W. and Meiling Z. (2021). Effect of silicon fertilizer and straw return on the maize yield and phosphorus efficiency in Northeast China. *Communications in Soil Science and Plant Analysis*, **52(2)**, 116-127.

Gomes, F.v.B., Moraes J.C.d., Santos C.d.D.d. and Goussain M.r.M. (2005). Resistance induction in wheat plants by silicon and aphids. *Scientia Agricola*, **62**, 547-551.

Jan, R., Aga F., Reshi M. and Rather K. (2020). Impact of Nitrogen and Silicon on Growth Parameters and Nutrient Uptake of Transplanted Rice (*Oryza sativa* L.) under Temperate Conditions. *Int. J. Curr. Microbiol. Appl. Sci*., **9**, 2189-2195.

Jeer, M., Yele Y., Sharma K. and Prakash N. (2021). Exogenous application of different silicon sources and potassium reduces pink stem borer damage and improves photosynthesis, yield and related parameters in wheat. *Silicon*, **13**, 901-910.

Karunakaran, G., Suriyaprabha R., Manivasakan P., Yuvakkumar R., Rajendran V., Prabu P. and Kannan N. (2013). Effect of nanosilica and silicon sources on plant growth promoting rhizobacteria, soil nutrients and maize seed germination. *IET Nanobiotechnol*., **7(3)**, 70-77.

Li, Z., Song Z. and Jiang P. (2013). Biogeochemical sequestration of carbon within phytoliths of wetland plants: a case study of Xixi wetland, China. *Chinese Sci. Bull*., **58(20)**, 2480-2487.

Ma, J.F. and Takahashi E. (2007). *Soil, fertilizer and plant silicon research in Japan*. Elsevier.

Malav, J.K., Patel K., Sajid M. and Ramani V. (2015). Effect of silicon levels on growth, yield attributes and yield of rice in Typic Ustochrepts soils. *Ecology Environment and Conservation* **21**.

Marques, D.J., Bianchini H.C., Maciel G.M., de MendonC'a T.F.N. and e Silva M.F. (2021). Morphophysiological Changes Resulting from the Application of Silicon in Corn Plants under Water Stress. *J. Plant Growth Regulation*, 1-16.

Meena, O., Patel K. and Malav J. (2014). Influence of Silicon and Phosphorus on Growth, Yield and Nutrient Uptake by Maize (*Zea mays* L.) in *Typic Ustochrepts* Soils. *Indian J. Ecol*., **43(1)**, 89-92.

Moussa, H.R. (2006). Influence of exogenous application of silicon on physiological response of salt-stressed maize (*Zea mays* L.). *Int. J. Agricult. Biol*., **8(3)**, 293-297.

Oliveira, K.S., de Mello Prado R. and de Farias Guedes V.H. (2020). Leaf spraying of manganese with silicon addition is agronomically viable for corn and sorghum plants. *J. Soil Sci. Plant Nutr.*, 1-9.

Owino-Gerroh, C. and Gascho G. (2005). Effect of silicon on low pH soil phosphorus sorption and on uptake and growth of maize. *Commun. Soil Sci. Plant Anal*., **35(15-16)**, 2369-2378.

Parr, J.F. and Sullivan L.A. (2011). Phytolith occluded carbon and silica variability in wheat cultivars. *Plant and Soil*

342(1), 165-171.

Pati, S., Pal B., Badole S., Hazra G.C. and Mandal B. (2016). Effect of silicon fertilization on growth, yield, and nutrient uptake of rice. *Commun. Soil Sci. Plant Anal.*, **47(3)**, 284-290.

Peera, S.P.G., Balasubramaniam P. and Mahendran P. (2016). Effect of silicate solubilizing bacteria and fly ash on silicon uptake and yield of rice under lowland ecosystem. *J. Appl. Nat. Sci.*, **8(1)**, 55-59.

Prakash, N., Chandrashekar N., Mahendra C., Patil S., Thippeshappa G. and Laane H. (2011). Effect of foliar spray of soluble silicic acid on growth and yield parameters of wetland rice in hilly and coastal zone soils of Karnataka, South India. *J. Plant Nutr.*, **34(12)**, 1883-1893.

Rajendiran, S., Coumar V., Dotaniya M. and Kumar A. (2016). Carbon occlusion potential of rice phytoliths: Implications for global carbon cycle and climate change mitigation. *Appl. Ecol. Environ. Res.*, **14(2)**, 265-281.

Rezakhani, L., Motesharezadeh B., Tehrani M.M., Etesami H. and Hosseini H.M. (2020). Effect of silicon and phosphate-solubilizing bacteria on improved phosphorus (P) uptake is not specific to insoluble P-fertilized sorghum (*Sorghum bicolor* L.) plants. *J. Plant Growth Regul.*, **39 (1)**, 239-253.

Rao, G.B., Yadav P. and Syriac E.K. (2018). Effect of silicon on soil physico-chemical properties in laterite derived paddy soils of Kerala. *J. Krishi Vigyan*, **6(2)**, 75-77.

Sarto, M.V., Mansano I., do Carmo Lana M., Rampim L., Rosset J.S., Ergio, Wobeto J.R., Ecco M., Bassegio D. and da Costa P.F. (2014). Effect of silicate on nutrition and yield of wheat. *Afr. J. Agricult. Res.*, **9(11)**, 956-962.

Shwethakumari, U. and Prakash N. (2018). Effect of foliar application of silicic acid on soybean yield and seed quality under field conditions. *J. Indian Soc. Soil Sci.*, **66(4)**, 406-414.

Siam, H.S., Abd El-Moez M., Holah S.S. and Abou Zeid S. (2018). Effect of silicon addition to different fertilizer on yield of rice (*Oryza sativa* L.) plants. I-Macro nutrients by different rice parts. *Middle East J. Appl. Sci.*, **8**, 177-190.

Siregar, A., Sipahutar I., Anggria L. and Yufdi M. (2021). Improving rice growth and yield with silicon addition in Oxisols. *IOP Conf. Ser.: Earth Environ. Sci.*

Song, A., Ning D., Fan F., Li Z., Provance-Bowley M. and Liang Y. (2015). The potential for carbon bio-sequestration in China's paddy rice (*Oryza sativa* L.) as impacted by slag-based silicate fertilizer. *Scientific Reports*, **5(1)**, 1-12.

Song, Z., Liu H., Stromberg C.A., Yang X. and Zhang X. (2013). Phytolith carbon sequestration in global terrestrial biomes. *Sci. Total Environ.*, **603**, 502-509.

Song, Z., Wang H., Strong P.J. and Guo F. (2014). Phytolith carbon sequestration in China's croplands. *Europ. J. Agron.*, **53**, 10-15.

Song, Z., Wang H., Strong P.J., Li Z. and Jiang P. (2012). Plant impact on the coupled terrestrial biogeochemical cycles of silicon and carbon: implications for biogeochemical carbon sequestration. *Earth-Sci. Rev.*, **115(4)**, 319-331.

Song, Z., Parr J.F. and Guo F. (2017). Potential of global cropland phytolith carbon sink from optimization of cropping system and fertilization. *PLoS One*, **8(9)**, e73747.

Sun, Y., Xu J., Miao X., Lin X., Liu W. and Ren H. (2021). Effects of exogenous silicon on maize seed germination and seedling growth. *Scientific Reports*, **11(1)**, 1-13.

Swain, R. and Rout G.R. (2018). Effect of Silicon interaction with nutrients of rice. *J. Exp. Biol. Agricult. Sci.*, **6**, 717-731.

Tripathi, P., Na C.-I. and Kim Y. (2021). Effect of silicon fertilizer treatment on nodule formation and yield in soybean (*Glycine max* L.). *Europ. J. Agron.*, **122**, 126172.

White, B., Tubana B.S., Babu T., Mascagni H., Agostinho F., Datnoff L.E. and Harrison S. (2017). Effect of silicate slag application on wheat grown under two nitrogen rates. *Plants*, **6(4)**, 47.

Xie, Z., Song F., Xu H., Shao H. and Song R. (2014). Effects of silicon on photosynthetic characteristics of maize (*Zea mays* L.) on alluvial soil. *The Scientific World J.*, **2014**.

Yang, X., Song Z., Liu H., Bolan N.S., Wang H. and Li Z. (2015). Plant silicon content in forests of north China and its implications for phytolith carbon sequestration. *Ecological Research*, **30(2)**, 347-355.

Zajaczkowska, A., Korzeniowska J. and Sienkiewicz-Cholewa U. (2020). Effect of soil and foliar silicon application on the reduction of zinc toxicity in wheat. *Agriculture*, **10(11)**, 522.

Zargar, S.M. and Agnihotri A. (2013). Impact of silicon on various agro-morphological and physiological parameters in maize and revealing its role in enhancing water stress tolerance. *Emirates J. Food Agricult.*, 138-141.

Zuo, X. and L.C. (2011). Carbon sequestration within millet phytoliths from dry-farming of crops in China. *Chinese Sci. Bull.*, **56(32)**, 3451-3456.