# SILICON: A BENEFICIAL SUBSTANCE AND BOOSTER TO MANAGE ENVIRONMENTAL STRESS

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Silicon (Si) is an element grouped under the "beneficial substance" of plant by Association of American Plant Food Control Officials (AAPFCO). In present-day agricultural production system, essentiality of Si to benefit various multi-cropping systems is scientifically proven. Though Si is ubiquitous in the earth crust (28%), its availability for plants is limited. In fact, monocropping of cereal crops for years without supplying any Si fertilization can lead to depletion in the available Si in the soil. On the other hand, field studies showed that use of Si fertilizer can reduce pest and disease infestation along with improving yield and environmental stress tolerance in crop plants.

## FUNCTION OF SILICON IN PLANTS

Plants absorb Si in the form of silicic acid or mono silicic acid (Si ($OH_4$) or $H_4SiO_4$). Si nutrition improves biomass production by maintaining photosynthetic activity, decreasing transpiration rate and stomatal conductance. This help to regulate the uptake and root to shoot translocation of nutrients along with reducing oxidative stress. It also helps in the direct stimulation of plant growth and yield through more upright growth and plant rigidity. Si alleviates environmental stress through mitigating biotic and abiotic stresses, reducing mineral nutrition deficiency and detoxification of heavy metal. (Ali et al., 2020; Prakash et al., 2018; Tubana and Heckman, 2015)

In case of nutrient deficiency, Si increase the nutrient transports in root and favours translocation of nutrients to the shoot, which improves the metabolic pathways and photosynthetic efficiency of plants. To manage the micronutrient/ heavy metal (Al, As, Cd, Pb, Zn) toxicity Si bind with these elements and form a stable complex in the root cell wall, which reduces translocation of these elements from root to shoot. In shoot, Si alleviates element toxicity by sequestering the toxic elements into the leaf vacuoles and simultaneously decreasing the oxidative stress by maintaining redox balance. Figure 1 shows crop response with Si nutrition ($Na_2O_3Si.9H_2O$) under Al toxicity.

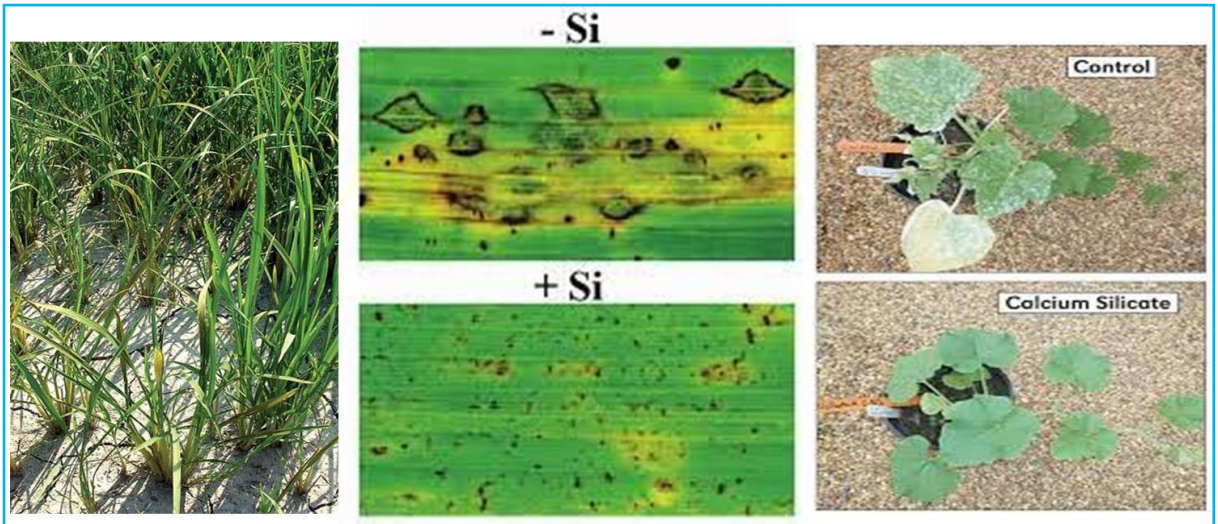

Figure 1. Rice crop under Si nutrition in the acid soils (pH 4.85) of Meghalaya under with Al toxicity (up to 4.3 ppm Al)

## SILICON DEFICIENCY IN RICE CROP

Unlike essential nutrients, Si deficiency is not quite common in irrigated rice. However, it is common in areas with poor soil fertility, old and degraded paddy soils. Si deficiency conjointly happen in organic soil, highly weathered and leached tropical soil within the rainfed lowland and upland areas. Continuation of intensive farming with Si accumulating plant like rice and removing of straw and rice husk after harvest leads Si deficiency in rice cultivated area. Some common symptoms of Si deficiency observed in the rice fields are as follows

- Softening and drooping Leaves and culms become resulting mutual shading
- Reduced photosynthetic activity and grain yield
- Increased disease and pest damage like blast, brown spot, stem borer
- Reduced number of panicles, filled spikelet per panicle and plants susceptible to lodging

Si deficiency in rice crops can me managed through recycling of rice straw (5-6% Si) and rice husks (10% Si) and Si fertilizers application @ 120-200 kg Si/ha (Prakash et al., 2018).




**a)** Droopy leaves (Photo by Gary Breitenbeck, LSU Ag Center) (www.knowledgebank.irri.org/images/stories/si-deficiency-lsu-ag-center. jpg)

**b)** Development of leaf blast symptoms in rice without additional silicon. www.ipni.net/publication/nutrifacts-na.nsf/0/A7B4AB4D35C153BF85257ECE006E0E34/$FILE/NutriFacts-NA-14.pdf

**c)** Suppress Powdery mildew disease on pumpkin plants in response to adding calcium silicate to soil (Source: Heckman 2013)

Figure 2. Response of crops affected by Si deficiency

## SILICON ACCUMULATING PLANT

Based on the mechanisms of Si uptake, plant species are categorized into three major groups viz., high accumulation (>1.5% Si), intermediate accumulation (0.5-1.5% Si): and low accumulation (<0.5% Si) plants (Bloodnick et al., 2021; Liang et al., 2007; Ma and Takahashe 2002). Major high Si accumulator plants are bamboo, barley, cornifers, ferns, equisetum, mosses, rice, sorghum, sugarcane, wheat etc. Intermediate Si accumulators include chrysanthemum, cucumber, marigold, maize, pumpkin, rose, squash, sunflower etc. Low accumulators consist of bean, begonia, gerbera, geranium, tomato etc.

## SILICON SOURCE

Some common Si sources are grouped as follows (Tubana and Heckman, 2015; Bamboriya et al., 2019; Prakash et al., 2021)

**Chemical form of Silicon:** Wallastonite ($CaSiO_3$), talc ($MgSiO_3$), silica gel, $K_2SiO_3$, $Na_2SiO_3$, silicic acid, silica blend

**Industrial by-product:** Iron/steel slag, electric furnace slag, blast furnace slag, processing mud, fly ash

**Plant material-based Silica:** Miscanthus biochar, rice hull fresh and ash

**Silicon solubilizing bacteria (SSB):** Microbes like *Bacillus flexus*, *B. mucilaginosus*, *B. megaterium* and *Pseudomonas fluorescens* produce organic acid and takes part in Si weathering. They supply $H^+$ ions to the medium and promote hydrolysis and organic acids like citric acid, oxalic acid, keto acids and hydroxyl carbolic acids which form complexes with cations and make the silica available to the plant in an assimilable form. SSB can also help in the release of other plant nutrients like potassium, calcium and magnesium from the silicates. Si deficiency in crop plants can be corrected through SSB based biofertilizers either as seed treatment (10g/kg seeds), seedling treatment (seedling dip in Si biofertilizer slurry for 30minutes prior to planting) and soil application (3-5kg/acre). Si biofertilizers can be applied even with drip irrigation (3kg/acre).

## FUTURE PERSPECTIVES

Adoption of Si as a nutrient will be higher in tropical and other regions where rice and other Si accumulating plants are cultivated abundantly. However, there is a need to identify, evaluate and validate locally available, cost-effective, agronomically effective and environment-friendly Si sources ideal for Si deficient soils of different regions. Being and environmental friendly option Si biofertilizers seems to a good option to manage Si deficiency in different crops and soils.

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