

ROLE OF ENVIRONMENTAL SILICA IN BIOLOGICAL AND MICROBIAL STRESS MANAGEMENT FOR CROP PRODUCTION

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ABSTRACT: The most prevalent mineral in the earth's mantle is silicon, which ranks second only to oxygen, but unlike oxygen, it has not been shown to be necessary for plant development. Plants can only absorb silicon in one of two forms: silicic acid ($\text{Si}(\text{OH})_4$) or mono silicic acid (H_4SiO_4), neither of which is found in the planet's crust as silicon dioxide (SiO_2). Silicon fertilizer has been shown to boost agricultural output and sustainability, and its use has been met with widespread praise. When water is lost via the stomata of a plant, the gel that has been polymerized from the silicon solution in the roots is precipitated out of solution. It has been shown that polymerized gel has no significant part in the physical functions of the plant system. This article reviews the function that silicon in soil, water, and plants plays in protecting ecosystems against abiotic and biotic pressures. The interplay between silicon, plant species, and environments is nuanced.

Keywords: Silicon, Morphological features, environmental sustainability, Genes, Polymerized.

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INTRODUCTION

Silicon is very significant due to the fact that it is second only to oxygen in the abundance of the element in the planet's crust. Approximately 28.1 percent of the planet's crust is made of silicon. About 50%-70% of soil is composed of silicon dioxide (Ma and Yamaji, 2006). Chemical element group 14, atomic number 28.0855; crucial to Earth's biota. An important component for humans and other animals, contrary to lower plants (Liang *et al.*, 2015). A lot of the world's regions, yield losses are a result of environmental pressures, both biotic and abiotic, that change plant growth and development. Plants adapt their survival strategies in response to a variety of stresses. Plant nutrition is crucial for maintaining stress tolerance and promoting healthy development. Tolerance for a wide range of stressors may be obtained from micronutrients (Vanderschuren *et al.*, 2013; Bradacova *et al.*, 2016). Silicon helps plants deal with both biotic (diseases and insect pest attacks) and abiotic (high temperatures, high salt concentrations, dehydration, and improper nutrition) stress (Zhu and Gong, 2014; Wang *et al.*, 2015; Coskun *et al.*, 2016).

Plant and Soil-based sources of silicon: Extremely high concentrations of silicon (between 23 and 47 percent)

may be found in rocks like orthoquartzite and basalt, moreover, this substance may be discovered in the planet's crust (Tubana *et al.*, 2016).

Soil: You may find silica in solid, liquid, and adsorbate forms. Silicon is found in its crystalline solid phase, which includes both primary and secondary silicates. The average range of salicylic acid concentration in various aquifers is 30.38 ppm (Pradeep *et al.*, 2016). The greatest SiO_2 concentration found in the roughly 380 rivers studied in Japan was 61.5 parts per million, while the lowest was just 4.1 parts per million (Kobayashi, 1960). Even in a dust storm, silicic acid may be found in the air. Quartz, an amorphous and crystalline form of the silica silicate, is a recognized carcinogen (Kanatani *et al.*, 2010). Field measurements of nanoparticles may be taken using a tool called a Nano Aerosol Mass Spectrometer (NAMS), which can provide accurate readings down to 20 nm (Bzdek *et al.*, 2014).

Plant: Plants contribute to the silicon cycle by chelating the element from the environment that may then be recycled via human and animal waste, leaf decay, manure, and direct incorporation into fields. Between 0.1% and 10% of dry mass is devoted to silicon (Currie and Perry, 2007). Plants absorb silica in high

concentrations from both irrigation water and the soil's solution. Silica is transported by three different proteins (Lsi1, Lsi2 and Lsi6). While transporting silica out from soil's solution to the plant root, Low Silicon1 (Lsi1) (Ma *et al.*, 2006). Transporting silicon from root cells to the apoplast is the job of low silicon 2 (Lsi2) (Ma *et al.*, 2007). Silicon is transported from vascular bundles to panicles by low silicon 6 (Lsi6) (Babu Rao and Sushmita, 2017). Monocots including rice, sugarcane, barley, and wheat are among the plants that acquire silicon, whereas dicots are nano-accumulators. Soybeans and sugar beets, for example, are dicots that can store silica (Hodson *et al.*, 2005).

Managing Crop Production under Abiotic and Biotic Stresses: Silicon's Role

Silicon's Importance in Countering Abiotic Stress: Some physiological processes, including as ion absorption, metabolism, photosynthetic, osmotic stress behavior, seedling growth, and nutrient uptake, may be altered by abiotic stresses such drought, soil salinity, improper nutrition, and heavy metals.

Drought: Evaporation causes water loss, stomatal closure, or a decrease in photosynthetic activity. Stomata are primarily responsible for transpiration. Evaporation rates may be improved by implanting silicon beneath the epidermis to produce a Si-cuticle dual layer. Plants treated with Si exhibit increased tolerance to water stress through many pathways. The cellular membrane aquaporin is regulated and protected against reactive oxygen pollutants by silicon treatment in plants. Silicon increases root hydraulic conductivity. Better water uptake and transport are both made possible by increased root hydraulic conductivity, which in turn keeps photosynthesis going strong and helps plants weather drought (Luyckx *et al.*, 2017).

Salinity: When there is a lot of salt in the soil, plants experience stress from osmotic, oxidative, and ionic forces. Groundwater, soil, and crop yields are all negatively impacted by salinity. The presence of silicon inhibits the uptake of sodium and chlorine. Silicon, precipitating as SiO₂, blocks bypassed movement during respiration, mitigates the toxicity of NaCl in rice (Yeo *et al.*, 1999). Oxidative damage and ion toxicity are reduced by silicon treatments with hydrogen peroxide (Abdelaal *et al.*, 2020). Several aspects, such as the type of culture (soil vs. hydroponic), route of administration (root vs. foliar), type of silicon (silica stomas vs. silica materials), content, time, or velocity, alter the impact of silicon on salinity stress (Zhu *et al.*, 2019) (Zhu *et al.*, 2019).

Heavy metals: People and the ecosystem may be at risk from heavy metals and essential minerals in contaminated soil (Imtiaz *et al.*, 2016). Several metals' toxicity may be reduced by using silica. There was a significant decrease

in the toxicity of metals such aluminium, zinc, iron, and manganese as a result of silicon, and phosphorus availability was enhanced (Guntzer *et al.*, 2012).

Silicon enhances the oxidizing capability of rice roots, lowering the toxicity of ferrous iron and making more of it available to the plant (Ma and Takahashi, 2002). Plants like wheat, rice, cucumbers, soybeans, etc. are also severely impacted by high levels of aluminium and manganese. Soil levels of phytotoxic aluminium may be lowered by combining silicon and aluminium to generate inert alumino-silicates and inhibiting the apoplastic route.

Improper Nutrition: Due to issues with plant functioning (such as the failure to create chlorophyll content and the failure to form food), nutritional imbalances have a wide-ranging impact on agricultural output. In phosphorus-deficient barley and rice, silicon has a positive impact. The two elements manganese (Mn) and iron (Fe) regulate the plant's access to phosphorus; silicon promotes plant access by decreasing Mn and Fe levels (Ma, 2004). The reciprocal shadowing and plant sensitivity brought on by excessive nitrogen availability may be mitigated by increasing silicon availability. Hormonal and metabolic changes caused by silicon treatment in magnesium-deficient maize plants result in increased growth, chlorophyll content, and sugar content (Hosseini *et al.*, 2019).

Silicon's Importance in countering biotic Stress: Yield loss and decreased crop output may be attributed to a wide variety of biotic stressors. Biotic stress is the main factor behind crop loss globally (Wang *et al.*, 2003). Applying silicon to plants makes them more resilient to abiotic stresses.

Procedures for preventing the spread of illness and eradicating insect infestations: In order to prevent the spread of illness, silicon uses two different techniques. As a physical barrier, silicon may be put on the surface of the tissue or just under the leaf cuticle to prevent the entry of insects, pests, and fungi (Samuels *et al.*, 1991). The second set of defenses involves sending signals to the body's defensive systems so that they may make substances like phenolics, phytoalexins, and lignin (Ma and Yamaji, 2006).

Diseases: The presence of silicon in the body increases protection against several illnesses. It is the fungus *Magnaporthe grisea* that causes rice blast, a disease that manifests itself in two stages: the vegetative (leaf blast) and the reproductive (neck blast) phases of rice development (Ma, 2004). Treatment with silicon prevents leaf and neck blast in a variety of plant life stages. The fungus *Sphaerotheca fuliginea* causes powdery mildew on strawberries, wheat, and cucumbers. Plants are better able to resist powdery mildew when their silicon concentration is higher. Bacterial blight, stem rot, rice

brown spot, corynespora, and cucumber fusarium wilt may all be prevented by raising silicon accessibility (Datnoff *et al.*, 2002). Infectivity is a result of resistance enzymes as -1, 3-glucanase, phenylalanine ammonia lyase (PAL), chitinase, and superoxide dismutase (Waewthongrak *et al.*, 2015).

Insect pest: Insect pest resistance increases with silicon levels in the growing medium and soil. Silicon helps harden cuticle, making it more insect resistant. Applications of silicon fertilizer to the soil increased rice

absorption by 32% and decreased the ability of *Diatraea saccharalis* to bore into the crop (Sidhu *et al.*, 2013). A higher silicon content deposition in the ectodermal layers of sugarcane's internodes increased the plant's opposition to *Eldana saccharina* (Keeping *et al.*, 2009). Calcium silicate used by foliar spray greatly boosted white fly nymph mortality, preventing considerable output losses in crops including wheat, rice, cucumber, cotton, and sugarcane (Correa *et al.*, 2005).

Table 1: Drought-resistance mechanisms of common crops with citations.

Stress	Crop	Mechanisms	Reference
Drought	Sorghum	the pace of respiration and other physiological processes will speed up.	Yin <i>et al.</i> , 2014
Drought	Bluegrasses	Plants' morpho-physiological processes and their water-relationships both speed up.	Saud <i>et al.</i> , 2014

Table 2: Salinity-Resistance Mechanisms of Common Crops with citations.

Stress	Crops	Mechanisms	Reference
Salinity	Okra	Reduction of Sodium ions and Chlorine throughout roots and shoots	Abbas <i>et al.</i> , 2015
Salinity	Canola	Lower levels of hydrogen peroxide and toxic ions.	Abbas <i>et al.</i> , 2015

Table 3: Heavy Metal-Resistance Mechanisms of Common Crops with citations.

Stress	Crops	Mechanisms	Reference
Cu	Wheat	A decrease in Cu translocation to the shoot.	Keller <i>et al.</i> , 2015
Pb	Cotton	The production of enzymatic antioxidants increases.	Bharwana <i>et al.</i> , 2013

Table 4: Disease-stress tolerance mechanisms in Common crops, with citations

Disease	Crops	Mechanisms	Reference
Leaf Blast	Rice	Both -1, 3-glucanase and chitinase activities rise.	Souza <i>et al.</i> , 2015
Powdery mildew	Black gram	The production of proteins involved in immunity improved.	Parthasarathy and Jaiganesh, 2016
Anthraxnose	Tomato	An increase in cuticle thickness.	Somapala <i>et al.</i> , 2016

Table 5: Insect-pest stress Tolerance mechanisms of Common crop with citations.

Insect-pest	Crops	Mechanisms	References
Stalk Borer	Sugar Cane	Length and percentage of stalk were cut down.	Keeping <i>et al.</i> , 2013
Fall armyworm	Rice	Both larval survival and food selection are influenced by the adult's diet.	Nascimento <i>et al.</i> , 2014

Conclusion: According to the studies that were looked at, only oxygen and silicon are found in the asthenosphere in terms of abundance. Silica produces a sustainable food production system by shielding plants from both biological and environmental hazards. The availability or application of silicon on a consistent basis promotes plant development and enhances yields. Many studies have shown that silicon has positive benefits on plants, but since these effects vary depending on plant genotype, environmental factors, and other factors,

additional study is needed to fully understand how silicon affects plant response in stressful situations.

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