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Silicon: Its Manifold Roles in Soil and Plant System

Pedda Ghouse Peera S. K.
Department of Soil Science and Agricultural Chemistry
Tamil Nadu Agricultural University, Coimbatore-3
Email: ghouse.agri@gmail.com

Silicon plays a very important role in drought tolerance as silicon fed plants maintains higher leaf water potential. Si improves plant tolerance against both biotic and abiotic stresses but its role against abiotic stresses is important.

Introduction

Silicon plays a very important role in drought tolerance because silicon fed plants maintains higher leaf water potential. This is assumed to be due to the formation of silica-cutical double layer on the epidermis. In addition, endodermal tissue, which plays an important role in water transport across the root, accumulates large amounts of silicon in mature drought-tolerant plants. Silicon (Si) is one of the most prevalent beneficial elements, performing an essential function in healing plants in response to environmental stresses. However, the concentration and absorption trend of Si varies in plants genotype and organisms. Although Si improves plant tolerance against both biotic and abiotic stresses but its role against abiotic stresses is important. Silicon plays an important role in alleviating salt stress in plants, decreases sodium uptake and its translocation to the shoots of salt sensitive plant by decreasing transpiration.

Forms of Si in Soil

Each kilogram of soil usually contains Si ranging from 50 to 400 grams. Silicon dioxide (SiO_2) is the common form of Si in soil. Vermiculite, smectite, kaolin (rich minerals in soils), orthoclase, feldspars, plagioclase (silicates in the form of crystal), amorphous silica, and quartz are the main Si components in most soils structures. The major soluble forms of Si in the soil are poly- and monosilicic acids. However, monosilicic acid occurs mostly in a feebly adsorbed condition and has low capability to migrate inside the soil.

Silicon and Plants

Variability of Si Contents in Various Plant Species: Among plants, sugarcane (*Saccharum officinarum*), rice (*Oryza sativa*), and wheat (*Triticum* spp.) absorb the largest amount of Si, with 300–700, 150–300, and 50–150 kg Si ha^{-1}, respectively. Generally, Si uptake in graminaceous plants is much higher than its uptake in other plant species. The majority of dicotyledon plants, such as cucumbers (*Cucumis sativus*), melons, strawberries, and soybeans (*Glycine max* L. Merr) absorb Si inertly. Nonetheless, some plants especially dicotyledon, such as tomatoes (*Solanum lycopersicum*), beans, and other plants, are not able to absorb Si from soil.

Absorption Forms of Si by Plants: Monosilicic acid or orthosilicic acid (H_4SiO_4) is the Si forms that are absorbed by plants root. Consequently, Si accumulates in the epidermal tissues, and a layer of cellulose membrane-Si is created when Ca and pectin ions are present, which provides protection to the plant. Although Si is found plentifully in both silicate and oxidase forms in the soil, Si solubility in the soil solution is an obstacle for plant absorption because monosilicic acid is the only form of Si that plants can absorb.

Silicon and Abiotic Stresses: It has been widely reported that Si is able to suppress both physical stress, such as drought, high temperature, UV, loading, and freezing, and chemical stress, including salinity, nutrient imbalance, and metal toxicity.

Silicon and Salinity Stress: Silicon can increase the antioxidant enzyme activity in plants under salt-stress. The induced oxidative damage by salt can be decreased through decreasing in level of electrolyte leakage percentage (ELP), lipid peroxidation (LPO), and H_2O_2 content. This enzymatic protection mechanism helps plants to overcome salinity stress damage.

From the physical stand point, Si is able to decrease the plasma membrane permeability in leaf cells of plants which resulted in reducing the lipid peroxidation levels thus increase absorption and transportation of K and decrease the uptake and transportation of Na from the roots to shoots of under salinity.

Silicon and Heavy Metals

a. Silicon and Manganese Toxicity: Silicon is able to suppress Mn toxicity either by reducing the soluble apoplastic concentration of Mn in the cell wall or with apoplastic Mn detoxification. Silicon suppresses Mn toxicity in cucumbers by reducing the effects of membrane lipid peroxidation and increasing the enzymatic and nonenzymatic activities of antioxidants.

b. Silicon and Cadmium Toxicity: The alleviating function of Si on Cd toxicity is not limited to the immobilising role through increased pH of soil, Si also aids in Cd detoxification in maize. These studies have suggested that Si is able to covalently bind with heavy metals and form an unstable silicate form which subsequently suppresses the toxicity of the metals and is easily degraded to silicon dioxide (SiO_2).

c. Silicon and Aluminium Toxicity: The Al concentration can increase during Si treatment by forming hydroxyl-aluminosilicate complexes in the shoots of the plant. As a consequence of the increasing concentration the amount of Al transportation raised between the roots and shoots.

Silicon and Nutrient Imbalance

(1) Silicon and Phosphorus. Silicon is able to increase crop yield under P-deficiency stress. Supplying Si in nutrient solutions of rice resulted in an increase of rice shoot dry weight. Under P-deficiency, internal accessibility of P is controlled by other metals, such as Mn and Fe. Therefore, Si can increase P accessibility indirectly by decreasing the availability of Fe and Mn in plants.

(2) Silicon and Nitrogen. The Si accumulation in the leaf blades and stems of rice decreases the mutual shading and sensitivity of plants to diseases caused by high nitrogen availability particularly when over dosage of N happened in soil with dense planting.

Silicon and Biotic Stresses

Plant opal or glass and hard coating of SiO_2 polymerisation in the plant cuticle layer is the possible mechanism for reducing disease susceptibility by Si. The physical hindrance created by SiO_2 enhances the mechanical impedance to fungus and the intensity of neck and leaf blasts in both sensitive and partially resistant rice cultivars.

Conclusion

Understanding the roles of Si on higher plants may improve their growth and productivity yield and decrease their susceptibility to a wide range of diseases. It is reasonable to recommend Si as a useful element involved in cellular processes.

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