THE INFLUENCE OF SILICON IN SUPPRESSING RICE DISEASE AND THEIR RESIDUAL EFFECT

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Abstract: Silica (Si) plays a significant role in improving yields in a wide range of crops by increasing resistance to stress and enhancing growth through a number of well-documented mechanisms. Silica is a most abundant mineral element (18%) in soil and plays a significant role in crop production and resistance crop diseases. Silicon can lower the electrolyte leakage from rice leaves and, therefore, promote greater photosynthetic activity in plants grown under water deficit or heat stress. Silicon increases the oxidation power of rice roots, decreases injury caused by climate stress such as typhoons and cool summer damage in rice, alleviates freezing damage in sugarcane, favours' super cooling of palm leaves, and increases tolerance to freezing stress in some plants. Silicon reduces the availability of toxic elements such as manganese, iron and aluminium to roots of plants such as rice and sugarcane and increases rice and barley resistance to salt stress. Silica results did show that there was a relationship between Si content and blast susceptibility and developed resistance of all cucurbitaceous family fungal diseases.

Keywords: Silica, Disease resistance, Rice, Soil minerals

INTRODUCTION

Rice is considered to be a Si accumulator and tends to actively accumulate Si to tissue concentrations of 5% or higher (22). Relatively large amounts of plant available Si appear to be very important for both robust growth and fungal disease resistance of rice (23).Silicon (Si) is the second most abundant mineral element in soil comprising approximately 18% of the earth's crust (5). In warm sub-humid and humid tropical ecoregions, a high degree of weathering, mainly as desalination, has resulted in the development of soil orders rich in iron and aluminium oxides and low in nutrient bases and Si (Fig. 1) (13).
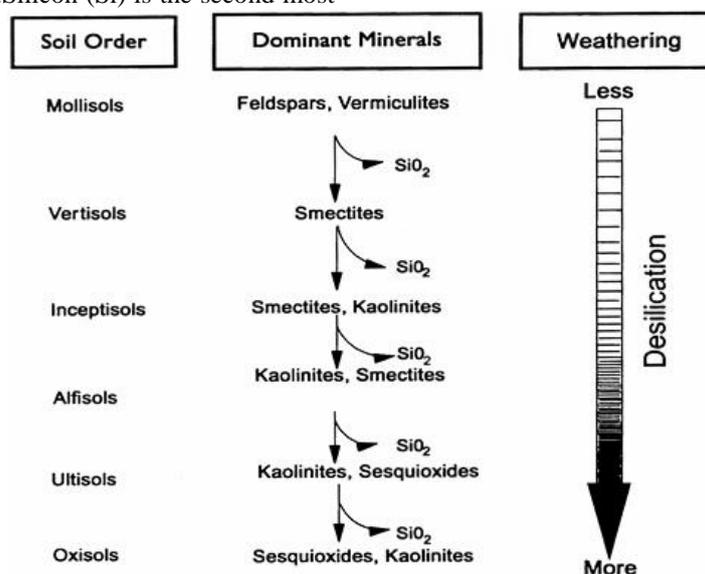

Fig. 1. A simplified acid weathering sequence in soils. Source: Friesen et al. (9)

Some of these soil orders such as Ultisols and Oxisol account for 22% of the area of major soil orders in the tropics. These orders occupy great amounts of land (approximately 1,666 million hectares) in Africa and South and Central America. Histosols and sandy Entisols also contain low levels of Si. As a result of Si leaching, the soluble Si content of tropical soils, such as Ultisols and Oxisols, is generally less than in most temperate soils (8). This might be one of the unidentified causes of lower rice productivity of many tropical/subtropical soils compared to with that of temperate soils. Although most soils can contain considerable levels of Si, repeated cropping can reduce the levels of plant-available Si to the point

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that supplemental Si fertilization is required for maximum production. Abundance of four soil orders in three important continents where rice is grown. Ultisols and Oxisols are characteristically low in plant available silicon.

Many plants are able to absorb Si. Depending upon the species, the content of Si accumulated in the biomass can range from 10 to greater than 100 g/kg (5). Plant species are considered Si accumulators when the concentration of Si (in dry weight basis) is greater than 1 g/kg (7). Relative to monocots, dicots such as tomato, cucumber, and soybean are considered to be poor accumulators of Si with values less that 1 g/kg in their biomass. Dryland grasses such as wheat, oat, rye, barley, sorghum, corn, and sugarcane contain about 10 g/kg in their biomass, while aquatic grasses have Si content up to 50 g/kg (12).

Silicon is accumulated at levels equal to or greater than essential nutrients in plant species belonging to the families Poaceae, Equisetaceae, and Cyperaceous. In rice, for example, Si accumulation is about 108% greater than that of nitrogen. It is estimated that a rice crop producing a total grain yield of 5000 kg/ha will remove Si at 120 to 470 kg/ha from the soil . Therefore, applications of calcium silicate at 5000 kg/ha (Si at 1000 kg/ha) appear to be sufficient for supplying enough Si to the plant so that the tissue content will be 3% or greater (19). Concentrations between 3 and 5% may be the minimum tissue levels needed for disease control (4). Silicon is considered a plant nutrient "anomaly" because it is presumably not essential for plant growth and development. However, soluble Si has enhanced the growth, development and yield of several plant species including *Equisetum*, rice, sugarcane, wheat, and some dicotyledonous species (5, 12). Plants absorb Si exclusively as monosilicic acid, also called orthosilicic acid (H_2SiO_4), by diffusion and also by the influence of transpiration-induced root absorption known as mass flow (5).

The content of Si in rice shoots cannot be accounted for only by diffusion and transpiration (5). The concentration of Si in the xylem of rice is usually many times higher than that of the soil solution; indicating that the uptake of Si might be metabolically driven (21). Silicon is deposited in the form of silica gel or biogenetic opal as amorphous $SiO_2 \cdot nH_2O$ in cell walls and intercellular spaces of root and leaf cells as well as in bracts (14). Silicon also can be found in the form of monosilicic acid, colloidal silicic acid, or organ silicone compounds in plant tissues (12).

The beneficial effects of Si to plants under biotic and/or abiotic stresses have been reported to occur in a wide variety of crops such as rice, oat, barley, wheat, cucumber, and sugarcane. Leaves, stems, and culms of plants, especially rice grown in the presence of Si, show an erect growth, thereby the distribution of light within the canopy is greatly improved (5,

20). Silicon increases rice resistance to lodging and drought and dry matter accumulation in cucumber and rice (1 and 18). Silicon can positively affect the activity of some enzymes involved in the photosynthesis in rice and turf grass (17) as well as reduce the senescence of rice leaves (13). Silicon can lower the electrolyte leakage from rice leaves and, therefore, promote greater photosynthetic activity in plants grown under water deficit or heat stress (2). Silicon increases the oxidation power of rice roots, decreases injury caused by climate stress such as typhoons and cool summer damage in rice, alleviates freezing damage in sugarcane, favors super cooling of palm leaves, and increases tolerance to freezing stress in some plants (10). Silicon reduces the availability of toxic elements such as manganese, iron and aluminium to roots of plants such as rice and sugarcane and increases rice and barley resistance to salt stress (11).

Silicon and Rice Diseases: A Brief History

Probably, the first researcher who suggested that Si was involved in rice resistance to blast (*Magnaporthe grisea* (T. T. Hebert) Yaegashi & Udagawa) Barr (anamorph *Pyricularia grisea* (Cooke) Sacc.) was a Japanese plant nutrient chemist named Isenosuke Onodera. Onodera (15) published a milestone paper entitled 'Chemical studies on rice blast disease'. This is the first report on Si research published in a scientific journal of agronomy. For this study, he collected rice plants from 7 different regions in western Japan. Onodera compared the chemical composition of the rice plants infected with blast with that of healthy ones grown in the same paddy field. He observed that diseased plants always contained less Si in comparison to healthy ones obtained from the same field, and that the natural Si content found in rice tissue depended on the paddy field in which the plants had been grown. His finding did not necessarily mean that blast infection was reduced by the Si content of the rice plants or that plants with less Si content were more susceptible. His results did show that there was a relationship between Si content and blast susceptibility (16). Although he did not intend to study the role of Si in rice resistance to blast, his discovery certainly stimulated further Si research in Japan.

Grain discoloration, caused by a complex of fungal species such as *Bipolarisoryzae*, *Curvularia* sp., *Phoma* sp., *Microdochium* sp., *Microspore* sp., and *Fusarium* sp., is another important constraint for irrigated and upland rice production worldwide. Prabhu et al. Showed that the severity of grain discoloration in several irrigated and upland rice genotypes decreased linearly as the rates of SiO_2 in the soil increased. The severity of grain discoloration was reduced by 14.5%, on average, at the rate of 200 kg/ha of SiO_2, while grain weight increased 20%.

Stem rot (*Magnaporthesalvinii*Cattaneo), leaf scald and sheath blight also have been efficiently

suppressed by Si applications (5). Regarding bacterial diseases, Chang et al. (3), recently reported a significant reduction in lesion length of bacterial leaf blight (*Xanthomonasoryzae*pv. *oryzae*) of 5 to 11% among four rice cultivars following Si application. The reduction in lesion length was positively correlated with a decrease in the content of soluble sugar in leaves of plants amended with Si. Rice cultivars accumulating high levels of Si in roots also showed increased resistance to the root-knot nematode *Meloidogyne* spp. (20).

Outlook and Future Silicon Research Needs

Silicon fertilization of rice grown in soil orders with Si levels less than optimal offers promising results with respect to reduced rice susceptibility to diseases and improved yields. Interestingly, Si can control rice diseases to the same general degree as is typically obtained by using fungicide applications and also contributes to reducing the amount of fungicides needed. Consequently, sources of Si and their management practices should be developed and practiced in integrated pest management programs for those crops where Si has been demonstrated to have a positive effect.

Some Si sources have residual activity that persists over time, raising the possibility that applications need not be made annually. Also, after the first initial Si amendment, subsequent application rate requirements might be considerably lower due to these residual effects. However, silicate slags are considered to be expensive Si sources so there is a need to find or develop cheaper and more efficient sources of Si. Recycling of rice hulls and/or straw may be one possible alternative.

Rice genotypes may differ in their Si content, and or respond differently to Si application. Genetics definitely plays an important role in Si accumulation and merits further consideration while selecting genotypes for other important agronomic traits. The strategic combination of a fine-grade Si formulation with a 'Si-accumulator' cultivar/genotype also would reduce application rate requirements, thereby minimizing the cost of the Si amendment program.

The fact that Si plays an important role in the mineral nutrition of many plant species is not in doubt nor is its ability to efficiently control several plant diseases. Effective, practical means of application and affordable sources of Si are needed for use in row crop agriculture in particular. As the need for environmentally friendly strategies for management of plant diseases increases, Si could provide a valuable tool for use in crops capable of its accumulation. The use of Si for controlling plant diseases would be well-suited for inclusion in integrated pest management strategies and would permit reductions in fungicide use. As researchers and growers become aware of Si and its potential in agriculture, it is likely that this often overlooked element will be recognized as a viable means of sustainably managing important plant diseases worldwide.

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