Silicon in Host Plant Resistance: A Sustainable Strategy for Pest Management

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ABSTRACT

The impact of silicon (Si) is dependent upon crop system. In rice it minimises the damage caused by the stem borer and the planthopper, in sugarcane and wheat it minimises borers and aphids, and in cucumber and tomato it suppresses whiteflies, thrips and leaf miners. After reinforcing physical barriers, silicon activates systemic acquired resistance (SAR) and precondition plants to accelerate response to defense by jasmonic acid, salicylic acid, and ethylene signalling. This two-fold action limits the use of chemical pesticides, dealing with resistance and environmental issues. Incorporation of silicon in Integrated Pest Management (IPM) provides an effective and sustainable solution and this can be used together with biological manipulation, resistant varieties, cultural management and judicious application of insecticides. Silicon contributes to such strategies as increasing pest suppression, protecting the health of the soil, and improving the stability of yields, which means it is an important part of modern, environmentally safe agriculture.

INTRODUCTION

Demand of sustainable agricultural methods is being spurred by a growing interest in the environment as it is being degraded, environmental pesticides resistance, and the danger that pesticides use pose to the health of mankind with the shortage of biodiversity due to use of chemical pesticides in farming (Kalleshwarswamy *et al.*, 2022). The Integrated Pest Management (IPM) is the group that ought to address these problems since it tries to build biological, cultural, mechanical and chemical procedures in a manner whereby, the destructiveness incurred in controlling the pests ends up being of little hype both economically and environmentally. One of the major IPM plans the application of which causes you to use such plants which cannot naturally be attacked by the pests is Host Plant Resistance (HPR). Traditional components of genetic breeding against the pest are antixenosis, antibiosis and tolerance. However, the silicon nutrition application as the strategy to encourage HPR may become more of interest due to a possibility to enable plants to get rid of a variety of insect pests (Pavani *et al*., 2023). An example of a low cost alternative created as a replacement to synthetic pesticides to the environment is a silicon supplement.

1. Silicon in Agriculture:

The second highest component of the earth crust is silicon and, therefore the extent of availability of the element to the plants can be attributed to the solvable form of the element mono silicic acid (Si (OH) $_4$) (Epstein, 1999). Silicon Silicon does not qualify to be one of the fundamental factors despite the fact that it has been discovered to be fairly useful in the majority of crops particularly the monocots; rice, wheat and sugarcane. Abiotic stress in which the plants react to with the help of silicon are drought, salinity and metal toxicity. Remarkably, the silicon can provide the plant with the resistance against the biotic stress factor, i.e. the attack of insect and the attack of pathogen by giving the physical resistance to the invasion of a plant, and also by bringing the biochemical resistance that is involved in the activation of the biochemical defence issues With all that, the silicon can be dubbed as the quasi essential element.

2. How does plants uptake silicon..? (Fig 1)

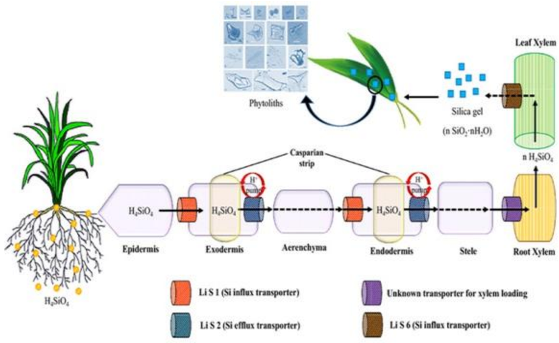

Fig1: Mechanism involed in uptake of silicon form soil

The one present in the soil is in the form of Silicic acid (H_4SiO_4) which is the form to which plants can be absorbed. This begins at the lowest point whereby the molecules of silicic acid are attracted to the plant roots. entry of silicic acid into the plant proceeds through special proteins referred to silicon influx transporters (indicated in brown color in the diagram) which become incorporated in the root epidermis.

Descending to the Root: A Twisted Path After descending to the root, the silicic acid has to move through several things before it reaches the vascular system of the plant

- ✓ Epidermis and Exodermis: Silicic acid enters the exodermis once it goes through the outer most epidermal cell. In these layers there exist some influx, efflux transporters that regulate the flow (in brown and blue, respectively) and assure that silicon is circulated in the right direction and at the right rate. This silicic acid continues on their way and gets into the aerenchyma, a spongy platform and here the transportation of water and nutrients occurs in an effective manner.
- ✓ In endodermis and Casparian strip: Endodermis is also a selective barrier and

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Endodermis has the Casparian strip which is to make sure that the substances will enter into the cells through cell membrane and not through the inter-cellular spaces. In this case, some energy gradient is produced as the proton pumps (H +pumps signified by the red circles) pump silicic acid through this membrane. In translocation of silicon to the central zones of the plant the simultaneous action of influx and efflux transporters takes place.

- ✓ Entrance into the Vascular system: The Stele and The Xylem Once entry has been through the endodermis the next compartment or chamber is the vascular system of the root and this is the channel into the root from where the vascular tissue of the plant is present. In the given case, other transporters (or some of which remain unknown at the moment; delimitated in purple unknown transporters) transport silicic acid to the root xylem. Plant water movement system has been thought of as like a highway and it (xylem) is like the waterway in such water movement. Silicic acid has been transported to xylem extending up to the leaves.

The End of Silicon: The Leaves

Initial direction of water with its nutrients into the leaves happens when they pass through the xylem and move upwards; moving silicic acid, too. There is unloading of silicon in the leaf xylem where it begins to accumulate in the leaf tissues. In the present case, it is converted and turned into a silica gel (hydrated silicon dioxide). This gel solidifies over time into small forms known as phytoliths which can be seen as the inset photos presented at the top of the diagram. They have been found in the elongated shape and are utilized as a plant defense measure and power due to their phytolith characteristics. Phytolith is a tiny, glassy item which became trapped within the plant tissues. Many are the meanings of their functions:

• Support: Phytolith interlocks their walls therefore making plants to stand up straight.

• Protection: Phytoliths are highly strong and thus act as a protection mechanism against both herbivores and pathogens.

• Water Control: With the use of silicon deposits, there is no water loss; therefore, drought resistance is obtained in plants.

3. Mechanisms of Silicon-Induced Host Plant Resistance

3.1. Physical Barriers: Some of the most likely methods silicon can add resistance antagonizing pests are the creation of the physical walls in plant organs. In the depositions the silicon is deposited as amorphous silica layer onto the wall of cells to enhance abrasion and hardness of the cell walls. This reduces palatability and digestibility of herbivores tissues. When the insects chew, mouthparts are worn by erosive silicon rich tissues and feeding becomes slow. Probably in silicon-amended cane an example sugarcane borer (Eldana saccharina) larvae will tunnel and develop more slowly. In Rice, the accumulation of silicon in epidermal cell obstructs the invasion of sap-sucking pests, one of which is the brown planthopper (*Nilaparvata lugens*) (Kalleshwarswamy *et al.*, 2022). Moreover, silicon source (rice husk biochar) at field level decreased the level of fall armyworm infestation due to the transformation of bio-physical/ bio-chemical properties in maize plant (Pavani *et al.*, 2023).

3.2. **Biochemical and Induced Defenses:** Besides the barriers of mechanics, silicon provokes the biochemical responses in order to enhance resistance. It can prepare plant defenses thereby causing an exaggerated and rapid reaction within the event of a pest invasion. Priming results into mass production of protective secondary metabolic compounds such as phenolics, flavonoids and phytoalexins. It involved the jasmonic acid (JA) and salicylic acid (SA) defense signaling. Strengthening of immunity such as cell wall related immunity like silico deposition. To illustrate, silicon-treated rice plant exerting a better effect of JA-induced comprising resistance to chewing insects, reducing grain damages and dropping pest survival rates.

3.3. **Effects on Pest Performance and Behavior:** Silicon is found to reduce the survival, fecundity and feeding preference of pests. It is e.g.: Aphids show poor reproduction on silicon-treated cucumbers and wheat. The Whiteflies do not feed on the tomato plants that have been treated as opposed to the untreated ones. The Lepidoptera larvae are killed by silicon-amended rice and sugarcane as the process retards the growth of the larvae and their survival (Nagaratna *et al*., 2022). Such is the result of physical deterrence powdered together with a reduced digestibility and induced plant defense.

4. Silicon's Role Across Major Crop Systems

One old time silicon accumulator is rice. One of the well-known ways of relieving damages to rice by its principal pests- stem borers (*Scirpophaga incertulas*), leaf folders (*Cnaphalocrocis medinalis*) and also the planthoppers (*Nilaparvata lugens*) is improvement in the use of silicon. Silicon makes rice grow more rice grains and lodging resistance, as well. The supplementation of silicon has been established to be of great significance in decreasing the destruction of sugarcane borer (*Eldana saccharina*). Laboratory and field experiments revealed that silicon-immunized cane can restrict the amount of larvae and rotting roots that in turn boosts the health of crops and their productivity (Keeping & Reynolds, 2009). Silicon decreases aphid due to colonization or in the case of existence of absences on cereals and tolerance on fungal pathogen. The fact that quality and the grain production improve because of the amending silicon reduces the burden pressure, which is carried by the pests and the diseases (Epstein, 1999)

5. Integration into Integrated Pest Management (IPM)

Silicon allows synergetic and compatible approach in the IPM structures. The key strengths include the following:

a. Biological compatibility; silicon-stressed pests become more susceptible to the attack of natural enemies because the defense mechanism is slowed down (Keeping., 2009). Reduced pesticides application: And silicon can reduce the number and amount of used pesticides by reducing the population of pests and the level of damages.

b. Increased crop tolerance: Silicon has been shown to increase crop resistance to pests, and abiotic conditions leading to development of tolerant crops. Combination of silicon fertilization with IPM is economical and sustainable to the farming community particularly those that are more willing to reduce in the use of pesticides and other adverse environmental impacts.

6. Challenges and Future Perspectives

Silicon has poorly played its role in the adopted use despite its potentials as there exist some issues linked to the practical application of silicon as follows: Variable crop responses, not all crops can accumulate silicon to the same extent. Better uptake ought to be breed. Awareness among farmers is Low i.e., The knowledge transfer and extension services will be required to provide the benefits of silicon. Silicon fertilizers in the market ought to be economical and available to the growers as well and also it has a research gap as there should be more research on application of silicon, on formulation of silicon and on interaction with other components of IPM.

CONCLUSION

Silicon is an effective, but under-exploited instrument of improving resistance to insect pests in the host plant. Silicon can act as an ecologically sound alternative to chemical pesticides because it enhances the physical barriers, primes the biochemical resistance and lowers performance of the pests. When incorporated in IPM strategies, it can lead to easier abidance of cropping systems, less harm to the environment and better food security. With the pressure that agriculture is experiencing on climate change, pest resistance, and sustainability, silicon fertilization can become a better focus of research and practice.

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