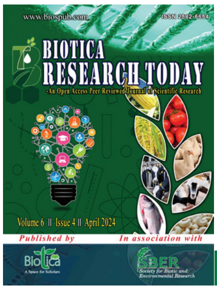

Bio. Res. Today 2024, 6(4):212-214

Biotica Research Today

e-ISSN: 2582-6654

April, 2024

Article ID: RT1632

Popular Article

Silicon: A Promising Solution for Pests and Abiotic Stress Management

Sushma Chongtham[1], Lham Dorjee[2*] and Sajad Hussain[3]

[1]Division of Entomology, [2]Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi (110 012), India
[3]Dept. of Botany and Microbiology, Hemvati Nandan Bahuguna Garhwal University, Uttarakhand (246 174), India

Open Access

Corresponding Author

Lham Dorjee

: lamdorg12@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Chongtham, S., Dorjee, L., Hussain, S., 2024. Silicon: A Promising Solution for Pests and Abiotic Stress Management. *Biotica Research Today* 6(4), 212-214.

Copyright: © 2024 Chongtham *et al.* This is an open access article that permits unrestricted use, distribution and reproduction in any medium after the author(s) and source are credited.

Abstract

Silicon (Si) offers a sustainable solution for crop productivity loss due to biotic and abiotic stressors. Major advantages of Si include its environmentally friendly nature and compatibility with other methods of pest management. Si acts against pest and abiotic stressors through various mechanisms. It serves as a physical barrier, boosts biochemical defenses and regulates stress-related gene expression, enhancing resistance. Si also improves photosynthetic efficiency, increases the uptake of K and P, gas exchange, and reduces the Na^+ uptake by enhancing H^+-ATPase activity of the root plasma membrane and by osmotic adjustment under salinity and drought stress. Si mitigates metal toxicity by forming silicate complexes like sodium metasilicate and amorphous silica, lowering metal availability and toxicity, such as lead and cadmium, through increased soil pH. Nevertheless, the degree of damage, plant genotype and silicon availability influence silicon-mediated protection. Further large-scale field experiments are needed to fully harness Si's potential in sustainable agriculture stress management.

Keywords: Abiotic stress, Defense response, Pests, Silicon

Introduction

As per the FAO, United Nations, pests account for an annual loss of 20-40% in global crop production, while abiotic stress can potentially reduce crop yields by up to 70%, with many crops falling short of realizing their full genetic potential. In light of these challenges, silicon (Si) emerges as a promising solution. After oxygen, silicon is the most prevalent element in the crust, constituting 28% of the total and forming up to 70% of soil mass. Typically, soil harbors 14-20 mg Si L^{-1} of Si concentrations. Si uptake generally occurs through roots in the form of two aqueous silicate species: monosilicic acid (H_4SiO_4) and some disilicic acid. Si content exhibits variability among plant species and even subspecies. Furthermore, the translocation of Si through the xylem varies noticeably from species to species and even at different growth stages. Monocots demonstrate greater efficiency in Si accumulation as compared to dicots. Once deposited in the plant system, Si confers numerous beneficial effects, particularly on gramineous plants. Additionally, Si is environmentally friendly and has been demonstrated to be compatible with other conventional methods employed in disease and pest management. Considering the potential of Si, in this article, we have delved into its role in the management of both pest infestations and abiotic stresses. We have also discussed various possible mechanisms through which biotic as well as abiotic stress are mitigated.

Advantages of Silicon

Si enhances plant growth, leading to increased yield and improves their tolerance to stressful conditions such as abiotic conditions (metal toxicity, salinity, temperature and oxidative phenolic browning) and biotic conditions (fungal, bacterial, viral and insect pest attack). In addition, Si can improve root water uptake, regulate endogenous plant phytohormone balance and activation of antioxidant system. Improvement in the physiological and mechanical characteristics of plants can be attributed to conferring the capacity in various ways to overcome various abiotic and biotic stresses. Furthermore, Si has been discovered

Article History

RECEIVED on 21st April 2024 RECEIVED in revised form 25th April 2024 ACCEPTED in final form 26th April 2024

to facilitate embryogenesis, organogenesis and growth characteristics, as well as morphological, anatomical and physiological traits of leaves.

Role of Si against Insect and Pest Attack

The first ever evidence suggesting the role of silicon host resistance against insects and pests was reported back in 1980s through leaf silicification. Since then many studies have been conducted suggesting and giving firm pieces of evidence on how Si induces resistance to various insects and pests. Different mechanisms were found to be associated with conferring the resistance but the nearly common mechanism is increased in various antioxidant enzymes like superoxide dismutase (SOD), polyphenol oxidase (PPO), peroxidase (POX), phenylalanine ammonia-lyase (PAL), catalase (CAT) activities and lower malondialdehyde (MDA) concentration (Figure 1). Si application can remarkably induce the defense against various insects and pests in sugarcane, maize, rice crops, *etc*. In addition, Si may directly affect the physiology of the insect thereby negatively affecting the growth and their feeding behavior, reducing leaf digestibility, causing mandible wear, feeding rate, negative impact on oviposition, *etc*. eventually rendering increased mortality. For instance, the fertility rate and honeydew secretion were drastically reduced when *Nilaparvata lugens* were allowed to feed on plants treated with Si (Yang *et al.*, 2017). It is well established that the application of Si makes the plant hard thereby it becomes difficult for the insect to chew and digest the plant components and hence pose a major constraint in their survival. In addition, Si-application results in morphological changes in mandibles and midgut. Nevertheless, much variability has been recorded for Si-based defense. The induction of silicon mediated defense is influenced by silicon availability in soil, plant genotype, transpiration rates and the extent and type of damage inflicted upon the plant by insects (Hartley and DeGabriel, 2016).

Mitigation of Abiotic Stress

Alleviation of Metal Toxicity

Si mitigates metal toxicity and reduces phytotoxicity by forming silicate complexes like sodium metasilicate and amorphous silica, reducing metal availability and toxicity, such as lead (Pb) and cadmium (Cd) by increasing the soil pH. Si application reduces Reactive Oxygen Species (ROS) and boosts antioxidant activities under metallic toxicity stress such as arsenic and zinc stress in maize and cotton, respectively, *etc.* (Figure 1). Similar mechanisms are thought to be operating in the Si-mediated mitigation of metal phytotoxicity in many plants of Cadmium (Cd), Chromium (Cr), Boron (B), Iron (Fe), Lead (Pb) and Manganese (Mn). Co-precipitation of other metals by silicon is another important mechanism by which metal toxicity can highly be mitigated as it has been observed in rice plants that the translocation of Cu, Pb, Zn and Cd from culm to leaves was dramatically lowered post silicon application. In addition, Si regulates Fe-related genes such as MsIRT1, MsNramp1 and OsFRO1 under cadmium stress in alfalfa roots thereby alleviating the toxicity (Farooq *et al.*, 2016).

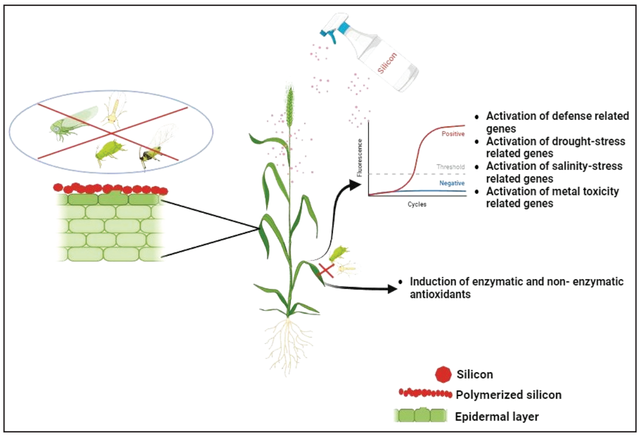

Figure 1: Si-mediated alleviation of insect pest stress and abiotic stress

Alleviation of Salt Stress and Drought Stress

Silicon is observed to alleviate the drought stress in rice, tomato and maize by increasing the uptake of K and P, enhancing the gas exchange and Relative Water Content (RWC) affecting photosynthesis and transpiration, and boosting water use efficiency. The decrease in transpiration primarily occurs due to the silicification of leaves and endodermis, which acts as barriers preventing water loss from plant tissue (Figure 1). Si mitigates salinity stress by enhancing photosynthesis, improving stomatal conductance and transpiration rate of leaves while reducing Na^+ and Cl^- concentrations in plants. Si causes reduction of uptake of Na^+ by triggering H^+-ATPase activity of the root plasma membrane and by osmotic adjustment. It counters drought and salt-caused oxidative stress by boosting the antioxidant systems including both enzymatic as well as non-enzymatic, such as CAT and SOD, *etc*. activities. Si also regulates compatible solutes and phytohormone synthesis, including ABA, IAA, JA and SA, which can enhance a plant's ability to tolerate salt or water stress. Silicon treatment has been found to modify key salt and drought stress genes such as 4 genes pertaining to the AsA-GSH cycle and 5 genes pertaining to flavonoid biosynthesis, reducing MDA and H_2O_2 levels in drought-stressed wheat (Ma *et al.*, 2016). Si-induced up-regulation of root aquaporin genes was observed in sorghum which is thought to increase the hydraulic conductivity of the roots and facilitate the uptake of water during osmotic stress (Liu *et al.*, 2014).

Conclusion

Silicon plays an undeniably important role in enhancing plant resilience to environmental stressors by boosting disease resistance against fungi, bacteria and other pests, while also aiding in reducing the effects of abiotic stressors such as metal toxicity, drought and salt stress. Si primarily protects plants against various pests by serving as physical barriers through polymerization and silicification under the cuticle and epidermal cell wall. Additionally, Si can trigger biochemical resistance by activating enzymes involved in defense, hormones and antimicrobial compounds. Si also controls the expression of genes associated with salinity, drought and metal-toxicity stress at the molecular level. Moreover, the application of silicon enhances photosynthesis and greatly improves antioxidant metabolism which is crucial for eliminating reactive oxygen species. Nevertheless, Si-mediated defense is highly variable based on the Si availability, plant genotype, extent of damage, *etc*. Furthermore, large-scale studies need to be conducted to achieve more concrete data on the application of Si for the management of pest and abiotic stress.

References

Farooq, M.A., Detterbeck, A., Clemens, S., Dietz, K.J., 2016. Silicon-induced reversibility of cadmium toxicity in rice. *Journal of Experimental Botany* 67(11), 3573-3585. DOI: https://doi.org/10.1093/jxb/erw175.

Hartley, S.E., DeGabriel, J.L., 2016. The ecology of herbivore-induced silicon defenses in grasses. *Functional Ecology* 30(8), 1311-1322. DOI: https://doi.org/10.1111/1365-2435.12706.

Liu, P., Yin, L., Deng, X., Wang, S., Tanaka, K., Zhang, S., 2014. Aquaporin-mediated increase in root hydraulic conductance is involved in silicon-induced improved root water uptake under osmotic stress in Sorghum bicolor L. *Journal of Experimental Botany* 65(17), 4747-4756. DOI: https://doi.org/10.1093/jxb/eru220.

Ma, D., Sun, D., Wang, C., Qin, H., Ding, H., Li, Y., Guo, T., 2016. Silicon application alleviates drought stress in wheat through transcriptional regulation of multiple antioxidant defense pathways. *Journal of Plant Growth Regulation* 35, 1-10. DOI: http://dx.doi.org/10.1007/s00344-015-9500-2.

Yang, L., Han, Y., Li, P., Wen, L., Hou, M., 2017. Silicon amendment to rice plants impairs sucking behaviors and population growth in the phloem feeder *Nilaparvata lugens* (Hemiptera: Delphacidae). *Scientific Reports* 7(1), 11001. DOI: https://doi.org/10.1038/s41598-017-01060-4.