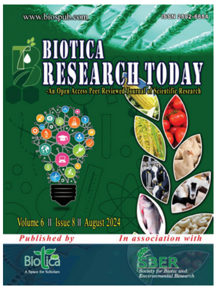

Bio. Res. Today 2024, 6(8):401-402

Biotica Research Today

e-ISSN: 2582-6654

August, 2024

Article ID: RT1703 **Popular Article**

The Mechanistic Insights into Silicon-Enhanced Disease Resistance in Plants

Sreenath Ragiman[1*] and Hariharan Selvam[2]

[1]Division of Plant Pathology, ICAR-IARI Mega University Nagpur Hub, Maharashtra (441 108), India
[2]Division of Entomology, ICAR-IARI Mega University Hyderabad Hub, Telangana (500 030), India

Open Access

Corresponding Author

Sreenath Ragiman

✉: sreenathragiman79@gmail.com

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

How to cite this article?

Ragiman, S., Selvam, H., 2024. The Mechanistic Insights into Silicon-Enhanced Disease Resistance in Plants. *Biotica Research Today* 6(8), 401-402.

Copyright: © 2024 Ragiman and Selvam. 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, though not essential, is abundant in Earth's crust and boosts plant resistance to fungal pathogens. Plants absorb Si as monosilicic acid (H_4SiO_4) through both passive and active transport, involving specific transport proteins. Si accumulates in leaves as insoluble SiO_2 deposits, creating physical barriers against fungal invasion. Additionally, Si triggers biochemical and molecular defenses, increasing production of defense enzymes and secondary metabolites that enhance plant immunity. This article explores the mechanisms through which Si enhances disease resistance, including improving nutrient uptake, modulating antioxidant defenses and activating local and systemic acquired resistance. It also highlights gaps in the current understanding of Si-mediated defense, calling for more research to uncover the complex interactions between Si and plant biochemical pathways.

Keywords: Host-pathogen interaction, Plant disease resistance, Silicon transporters, SiO_2 deposits

Introduction

Silicon is abundant in Earth's crust, but it is not easily accessible to plants (Tripathi *et al.*, 2020). Although not an essential nutrient, Si is beneficial for many terrestrial plants. Plants absorb Si as monosilicic acid (H_4SiO_4) through passive water movement and active transport proteins (Lsi1 and Lsi2), present in many monocots and some dicots. Inside the plant, H_4SiO_4 polymerizes into insoluble SiO_2, accumulating beneath the cuticle, within cell walls, roots and specialized structures (Mandlik *et al.*, 2020). Monocots generally accumulate more Si than dicots, although certain dicots like cucumber can also store significant amounts. Fungal pathogens threaten crop yields, but exogenous Si can reduce disease incidence and increase resistance. Silicon is effective against various diseases, such as rice blast, wheat powdery mildew, maize leaf spot and sorghum anthracnose. Silicon transporters can transport Si from roots to shoots, reducing foliar diseases (Ahanger *et al.*, 2020).

Silicon boosts plant resistance against pathogens by delaying disease onset, reducing colony sizes and limiting lesions. Initially thought to act mainly as a mechanical barrier, silicon is now recognized for rapidly activating plant defenses through hormones like jasmonic acid, salicylic acid and ethylene. It also improves mineral nutrition and overall plant health. Although the exact mechanisms are not fully understood, they likely involve defense gene expression and are similar across plant species. This article explores silicon's role in enhancing resistance to pathogens and identifies knowledge gaps.

Mechanisms of Plant Disease Resistance Activated by Silicon

1. As a Physical Barrier

Silicon accumulates beneath the cuticle and in cell walls, creating a barrier that hinders fungal penetration and reduces disease severity. For example, in barley, silicon-rich layers block *Blumeria graminis* f. sp. *hordei* appressoria, delaying infection. Even if fungi penetrate, silicon-induced papillae and phenolic compounds inhibit growth, enhancing resistance, as seen in cucumbers against Fusarium wilt (Debona *et al.*, 2017).

2. Induce Biochemical and Molecular Defense Mechanisms

Article History

RECEIVED on 26th July 2024 RECEIVED in revised form 04th August 2024 ACCEPTED in final form 05th August 2024

Silicon not only acts as a mechanical barrier but also boosts plant defenses by stimulating the synthesis of defense enzymes (phenylalanine, peroxidase, β-1,3-glucanase and pathogenesis-related proteins) through metabolic pathways (Ahanger *et al*., 2020).

3. Induce Secondary Metabolites

Silicon boosts plant defense against fungal infections by increasing secondary metabolism and phenylpropanoids. It enhances phenolic and flavonoid levels in various plants, improving resistance to diseases like powdery mildew and Fusarium. For instance, silicon-treated cucumbers and bananas show higher phenolic and flavonoid content, enhancing their resistance to specific fungal pathogens (Ahanger *et al*., 2020).

4. Induce Defense-related Enzymes

Silicon boosts key defense enzymes, such as phenylalanine and peroxidase, enhancing plant immunity and possibly defense priming. It upregulates defense-related genes and increases phenolic and lignin accumulation, which reinforces cell walls and blocks fungal spread. In cotton, potassium silicate treatment intensifies phenolic deposition and fungal hyphae degradation in root tissues (Lux *et al*., 2020).

5. Enhance Antioxidants

Silicon boosts plant antioxidant defenses against oxidative stress by increasing the activity of enzymes like superoxide dismutase, ascorbate peroxidase, catalase and glutathione reductase. This helps remove reactive oxygen species, reducing cellular damage and malondialdehyde levels, which indicates less lipid peroxidation. For example, silicon fertilization enhances chestnut resistance to *Cryphonectria parasitica* by raising SOD and CAT activity and lowering MDA and hydrogen peroxide levels. Similarly, silicon application reduces tan spot disease severity in wheat by upregulating SOD and peroxidase (Debona *et al*., 2017).

6. Enhance Nutrient Acquisition

Silicon boosts nutrient uptake and accumulation in plants, enhancing disease resistance. It improves availability of nutrients like sulfate, nitrate and phosphate and increases uptake of key elements such as nitrogen and phosphorus. For example, silicon enhances phosphorus uptake, which strengthens plant defenses. In phosphorus-deficient conditions, silicon increases photosynthesis by 65% and boosts antioxidant activity, reducing oxidative stress in tomatoes.

7. Modulate Stress Signaling Pathways

Exogenous silicon improves plant resistance by modulating stress signaling pathways. In transgenic *Arabidopsis*, silicon boosts resistance to powdery mildew *via* the salicylic acid pathway, but also through SA-independent mechanisms. In rice, silicon enhances resistance to brown spot disease by suppressing ethylene signaling, without relying on SA or jasmonic acid, while it also increases ethylene-responsive transcripts to combat rice blast.

Conclusion

Silicon enhances plant resistance to various fungal pathogens by providing physical barriers and boosting biochemical defenses, including secondary metabolites and defense enzymes. This makes silicon a valuable element for sustainable agriculture. Despite significant progress in understanding Si-induced resistance, the precise biological mechanisms remain only partially understood. Future research should focus on unravelling the complex biochemical pathways influenced by Si, exploring its interactions with plant hormones and identifying the genes involved in Si-mediated defense responses. By advancing our knowledge in these areas, we can better harness the potential of Si to improve crop resilience, reduce reliance on chemical fungicides and promote sustainable agricultural practices.

References

Ahanger, M.A., Bhat, J.A., Siddiqui, M.H., Rinklebe, J., Ahmad, P., 2020. Integration of silicon and secondary metabolites in plants: A significant association in stress tolerance. *Journal of Experimental Botany* 71(21), 6758-6774. DOI: https://doi.org/10.1093/jxb/eraa291.

Debona, D., Rodrigues, F.A., Datnoff, L.E., 2017. Silicon's role in abiotic and biotic plant stresses. *Annual Review of Phytopathology* 55, 85-107. DOI: https://doi.org/10.1146/annurev-phyto-080516-035312.

Lux, A., Lukacova, Z., Vaculik, M., Svubova, R., Kohanova, J., Soukup, M., Martinka, M., Bokor, B., 2020. Silicification of root tissues. *Plants* 9(1), 111. DOI: https://doi.org/10.3390/plants9010111.

Mandlik, R., Thakral, V., Raturi, G., Shinde, S., Nikoli´c, M., Tripathi, D.K., Sonah, H., Deshmukh, R., 2020. Significance of silicon uptake, transport and deposition in plants. *Journal of Experimental Botany* 71(21), 6703-6718. DOI: https://doi.org/10.1093/jxb/eraa301.

Tripathi, D.K., Singh, V.P., Lux, A., Vaculik, M., 2020. Silicon in plant biology: From past to present and future challenges. *Journal of Experimental Botany* 71(21), 6699-6702. DOI: https://doi.org/10.1093/jxb/eraa448.