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Silicon: The Vegetable Growth Game-Changer

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Silicon (Si) is abundant in the Earth's crust, comprising around 27.7% of its composition, yet its availability to plants is limited. Plants predominantly utilize monosilicic acid (H_4SiO_4) as their source of silicon, which exists in liquid form in soil (Meena *et al*., 2014). Vegetables face various biotic and abiotic stresses, necessitating an optimal supply of both macro and micronutrients. Studies have shown that silicon application is an eco-friendly approach to enhance crop production. It is commonly recommended in agricultural practices, particularly for cereals. In vegetables, silicon application has been proven to reduce disease susceptibility and improve resilience to abiotic stress conditions. This highlights the significant role of silicon in vegetable crop health and productivity.

The Role of Silicon in Plants

Resistance against biotic Stress

a. Bacterial diseases: Silicon application has been shown to be effective against bacterial pathogens. Research by Wydra *et al.* (2005) demonstrated that silicon accumulation primarily occurs in the roots and a negative correlation exists between root silicon content and bacterial growth. Additionally, Ghareeb *et al.* (2011) reported up-regulated expression of jasmonic acid/ethylene marker genes (*JERF3*, *TSRF1*, and *ACCO*) in tomato plants following silicon application, leading to induced resistance against *Ralstonia solanacearum* infestation. These findings underscore the role of silicon in enhancing plant defense mechanisms against bacterial pathogens, particularly in root tissues and highlight its potential for improving crop resilience to diseases.

b. Fungal diseases: Silicon application has demonstrated efficacy against numerous fungal pathogens. Studies show that both foliar and root applied silicon can effectively control powdery mildew disease in cucumber (Liang *et al*., 2005). Additionally, silicon application enhances the activities of key plant protectants such as superoxide dismutase (*SOD*), catalase (*CAT*), and peroxidase (*POD*), along with increasing the levels of ascorbate (*AsA*) and glutathione (*GSH*) in cucumber leaves (Wei *et al*., 2004). Moreover, silicon application has been found to mitigate oxidative stress induced by *Phytophthora melonis* infection in cucumber (Mohaghegh *et al*., 2011). These findings underscore silicon's role in bolstering plant defense mechanisms against fungal pathogens and oxidative stress, highlighting its potential in crop protection and resilience enhancement.

c. Insect and pest: Studies have highlighted that silicon application enhances host plant resistance to insect pests. Duehl *et al*. (2017) evaluated the effect of silicon application on resistance against the whitefly (*Bemisia tabaci*) in tomato and cucumber, revealing reduced whitefly populations through decreased oviposition, extended growth cycles and increased nymph mortality on cucumber plants. Furthermore, Dugui-Es *et al*. (2010) demonstrated the efficacy of silicon concentration and application frequency in managing the root-knot nematode, *Meloidogyne incognita*, in cucumber. These findings emphasize the potential of silicon application in integrated pest management strategies, contributing to enhanced crop protection against insect pests and nematodes.

Resistance against abiotic Stress

a. Salinity: Salinity drastically affects the vegetables fresh and dry weight, photosynthetic rate, mesophyll conductance, and photosynthetic water use efficiency. Si mediated alleviation of salinity stress is associated with, a significant increase in the activities of antioxidants and decrease in the contents of electrolytic leakage percentage. Likewise, the increase in activities of antioxidants like superoxide dismutase (*SOD*), catalase (*CAT*), was reported in spinach and bitter gourd under salinity.

b. Drought: Si has been reported to confer tolerance to drought by regulating the leaf relative water content, transpiration and stomatal conductance of plants. Shen *et al*. (2010) observed significant effects of Si application on photosynthesis and antioxidant parameters (viz., catalase, peroxidase) of soybean seedlings grown under drought stress.

Methods of Silicon Application on Vegetable Crops

Various methods have been employed for applying the Si on plants.

1. As Si solution
2. Si fertilizers and
3. Foliar spray (The foliar spray could be an efficient method of application of Si, but it has not been adequately tested)

Practical Applications in Vegetable crops

The recognition of silicon's importance in plant health has led to its incorporation into modern agricultural practices. Silicon fertilizers, derived from natural sources such as silica sand or synthetic sources like potassium silicate, are now available to farmers as a means of supplementing silicon levels in the soil. By applying silicon fertilizers to vegetable crops, farmers can improve plant vigor, increase yield and reduce the need for synthetic pesticides and fertilizers. Additionally, silicon has been shown to enhance the shelf life and post-harvest quality of vegetables, making it an attractive option for producers and consumers alike.

Benefits for Vegetable Crops

Vegetable crops stand to benefit significantly from silicon supplementation, particularly in intensive agricultural systems where pests, diseases and environmental stressors pose significant challenges. Studies have demonstrated that silicon-treated vegetables exhibit greater resistance to common pests such as whitefly, aphids, thrips and mites, reducing the need for chemical pesticides and promoting sustainable pest management practices. Furthermore, silicon supplementation has been shown to improve the nutritional quality of vegetables by increasing the accumulation of bioactive compounds such as antioxidants, vitamins and minerals, enhancing their value as nutritious food sources.

Future Directions and Challenges

- These include developing cost-effective silicon fertilization strategies, optimizing application methods for different crop types and growing conditions.
- Understanding the long-term effects of silicon supplementation on soil health and ecosystem functioning.
- Additionally, more research is needed to elucidate the mechanisms underlying silicon-mediated plant responses

Conclusion

Pesticides are intrinsically toxic and deliberately spread in the environment, their production, distribution and use call for strict regulation and control. Regular monitoring of residues in food and the environment is also required. As the global population continues to grow and the demand for nutritious food increases, finding sustainable solutions to enhance crop productivity and resilience has never been more critical. Silicon, once overlooked as a minor element in plant nutrition, is now emerging as a key player in the quest for sustainable agriculture. By harnessing the power of silicon to enhance vegetable crop growth, farmers can improve yields, reduce environmental impact and produce healthier, more resilient crops for the benefit of people and the planet.

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