Plant Archives Vol. 26, No. 1, 2026 pp. 1096-1100 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.149

SILICON-MEDIATED IMPROVEMENT OF GROWTH, YIELD, AND STRESS TOLERANCE IN FRUIT CROPS: A REVIEW

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(Date of Receiving-23-01-2026; Date of Revision-17-03-2026; Date of Acceptance-31-03-2026)

ABSTRACT

Silicon (Si), the second most abundant element in the Earth's crust, is increasingly recognized as a beneficial input in fruit crop production due to its role in improving plant performance under both optimal and stress conditions. This review compiles and critically evaluates published studies on silicon supplementation across major fruit crops, including mango, banana, guava, citrus, papaya, date palm, fig, strawberry, peach, and sapota. Emphasis is placed on the effects of different silicon formulations and modes of application on vegetative growth, physiological attributes, yield components, stress tolerance mechanisms, and postharvest quality. Evidence indicates that silicon influences key processes such as photosynthetic efficiency, antioxidant activity, and structural reinforcement, contributing to improved crop performance. However, considerable variability in responses is observed depending on crop species, environmental conditions, and application strategies. The review highlights optimization and systematic standardization of silicon use to enable its effective integration into fruit production systems.

Key words: Silicon, potassium silicate, fruit crops, abiotic stress, biotic stress, antioxidant defense, sustainable horticulture.

Introduction

Silicon (Si) is one of the most abundant elements on Earth, constituting approximately 27.7% of the Earth's crust and ranking second only to oxygen in the lithosphere. The term "silicon" is derived from the Latin words *silex* or *silicis*, meaning flint or hard stone (Royal Society of Chemistry, n.d.). Although elemental silicon was first isolated in 1824 by the Swedish chemist Jons Jacob Berzelius, its significance in agriculture has only been recognized in recent decades. In soils with pH below 9, silicon predominantly exists as silicic acid, which plants absorb primarily as monosilicic acid (H_4SiO_4).

Historically, silicon was not considered an essential nutrient for higher plants, as deficiency symptoms were not apparent under normal growth conditions (Arnon & Stout, 1939). However, with the revised framework of nutrient essentiality proposed by Epstein and Bloom (2005), silicon has gained recognition as a beneficial, or *quasi-essential*, element. While not strictly required for plant growth under optimal conditions, silicon becomes critical in mitigating stress, contributing significantly to vegetative development, reproductive success, and overall plant resilience.

The functional importance of silicon in modern fruit production has been increasingly acknowledged. Exogenous silicon supplementation in crops such as apple, mango, citrus, peach, pomegranate, avocado, and banana has been shown to improve root architecture, enhance chlorophyll content, optimize photosynthetic efficiency, and elevate fruit quality (Ladon *et al*., 2021). Additionally, silicon applications can delay leaf senescence, reduce physiological disorders, and extend postharvest shelf life by improving fruit firmness and storage stability (Romero-Aranda *et al*., 2006).

Moreover, beyond these growth and quality benefits, silicon provides critical protection against environmental stresses. Under abiotic stress conditions including drought, salinity, chilling, and heavy metal toxicity silicon enhances antioxidant defense systems, stabilizes cellular membranes, regulates ion uptake, and maintains photosynthesis and water-use efficiency. In the context of biotic stress, silica deposition acts as a physical barrier to pathogen invasion and herbivory while priming defense-related signalling pathways that strengthen resistance.

This review systematically compiles and critically analyses recent studies on silicon application in fruit crops, focusing on its effects on vegetative growth, yield, and tolerance to both abiotic and biotic stresses. By synthesizing these findings, the review aims to provide a comprehensive understanding of silicon's multifaceted roles in fruit crop production and to highlight directions for future research.

Silicon acquisition by plants

Plants absorb silicon exclusively as monosilicic acid (H_4SiO_4), mainly through the root epidermis and exodermis, through passive diffusion combined with transporters. The radial movement of silicon from the root cortex to the stele is controlled by two main transporters: Lsi1, an influx channel, and Lsi2, an efflux transporter. Silicon, once loaded into the xylem, is translocated to the aerial organs by the transpiration stream. With the evaporation of water from the leaf surfaces, silicon gets concentrated and polymerizes into amorphous silica (phytoliths), which is deposited in cell walls, intercellular spaces, and epidermal tissues (Fig. 1). These silica bodies reinforce mechanical strength, reduce transpiration, and provide structural protection against abiotic and biotic stresses.

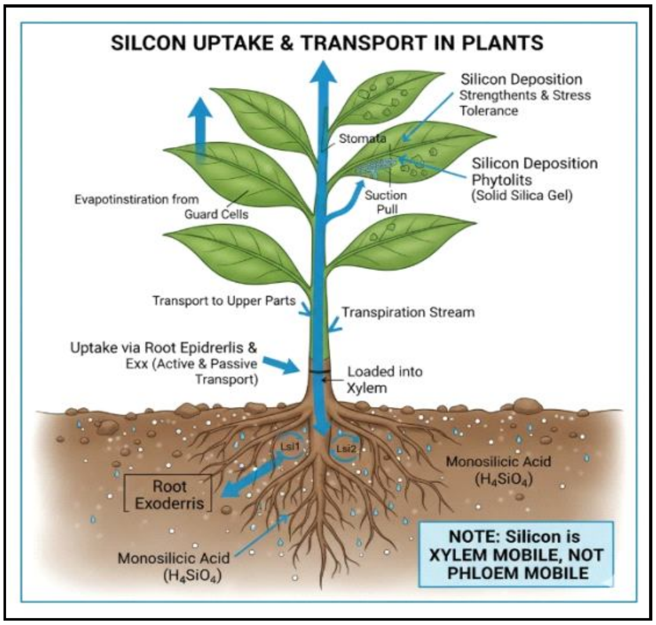

Fig. 1: Diagram of silicon uptake in plants.

Growth, yield and quality

One of the most critical contributions of silicon in fruit crops is its ability to enhance photosynthetic performance. Silicon deposition beneath the cuticular layer forms a semi-rigid barrier that reduces non-stomatal water loss, protects chloroplast ultrastructure, and stabilizes mesophyll tissues under stress (Ma & Yamaji, 2015; Liang *et al.*, 2021). This preservation of chloroplast integrity allows plants to maintain higher rates of photosynthesis, resulting in improved assimilate production and greater dry-matter accumulation. The enhanced carbohydrate supply supports superior fruit growth, size development, and overall marketable quality.

Furthermore, silicon reinforces structural integrity by strengthening cell walls and vascular tissues. This structural fortification results in more erect, sturdy, and stress-resilient canopies that capture light efficiently and support heavier fruit loads with minimal mechanical damage. Silicon also directly influences fruit quality attributes by increasing firmness, reducing physiological disorders such as cracking or russeting, and prolonging postharvest shelf life—traits that significantly benefit handling, storage, and long-distance transport (Savvas & Ntatsi, 2015; Cooke & Leishman, 2016).

Lalithiya *et al.*, (2013).observed maximum number of leavesper shoot (130.33), maximum number of shoots per m^2 (23.96), increase in number of flowers per m^2(250.16), maximum fruit yield per tree and per hectare (124.81 kg & 12.48 tonnes respectively) by the foliar application of potassium silicate at 8 ml/L in sapota cv. Kalipatti. An increase in T.S.S. (25.16^o brix) and chlorophyll (8.47 mg g^{-1} FW) content was also recordedmaximum with the same treatment application.

Habasy (2016) in their two-year research period observed that foliar application Potassium silicate 0.2% thrice (in the mid of March, April& May)on Navel Orange positive response in growth traits like shoot length, leaf area, leaf NPK content. Application of potassium silicate thrice at 0.1% gave statistically similar results in regards with initial fruit setting percentage, other growth parameters and biochemical parameters in both the years.

Das *et al.*, (2017). demonstrated that in guava cv. L-49 application of RDF at the rate of 200:80:150 g NPK per plant in combination with 3 kg per plant Diatomaceous Earth increased the fruit weight (150.99 g), Fruit volume (165.95 ml), fruit girth (70.82 mm), peel weight (1.33 g). Additionally, it also boosted the quality traits like T.S.S. (12.05^o brix), sugars, acidity (0.18%), ascorbic acid (172.95 mg100g^{-1}).

In another work developed by Arthi *et al.*, (2020) the soil application of potassium silicate at the rate of 50 kg/ha in banana cv. Grand Naine positively influenced the length of bunch (69.5 cm), number of hands per bunch (9.6), fingers per hand (16.6), weight of finger (175.4 g), length of fingers (19.9 cm) and girth of finger (8.95 cm).

According to Gonchikari *et al.,* (2020), the application of salicylic acid (200 ppm) in combination with potassium silicate, applied twice (first at the flower bud initiation stage and again two weeks after fruit set) markedly enhanced the storability of mango cv. Alphonso. This treatment resulted in notable improvements in fruit firmness (4.97 kgcm^{-2}), a reduction in physiological weight loss (17.21%) after 15 days of storage and consequently extended the overall shelf life.

As reported by Panchal *et al.,* (2020), foliar application of potassium silicate at a concentration of 3 ml L^{-1} plant^{-1}, applied sequentially during the 2nd, 3rd, and 4thmonths after planting, significantly enhanced the productivity of banana cv. Grand Naine. The treatment produced maximum bunch length (87.67 cm), bunch girth (105 cm), and finger number per bunch (169.67), culminating in the highest fruit yield (109.87 t ha^{-1}).

Results from a two-year trial by Patel *et al.,* (2020) revealed that integrating ortho-silicic acid (0.4%) with seaweed extract (2%) as foliar sprays in 3rd, 4th, 5th, & 6th month after planting substantially enhanced quality of papaya cv. Red Lady by improving firmness, prolonging shelf life, and enriching organoleptic traits, including visual and sensory parameters. Moreover, the dual application of potassium silicate (0.4%) and ortho-silicic acid (0.4%) showed least reduction in physiological loss in weight during the storage period.

Findings from El-Salhy *et al.*, (2021) demonstrated that foliar application of potassium silicate (20 ml L^{-1}) in date palm cv. Saidy substantially improved both yield and quality, evidenced by higher fruit weight per bunch (12.37 kg), greater yield per palm (124.13 kg), increased fruit length (3.63 cm), and elevated moisture content (15.61%). The treatment further enriched fruit quality by raising total soluble solids (80.66 °Brix) and total sugars (73.24%).

According to Hussein and Kassem (2021), the application of 2% potassium silicate significantly improved both yield and fruit quality in fig cv. Sultani. The treatment increased fruit weight (26.6 g) and total yield per tree (6.76 kg), while simultaneously enhancing biochemical attributes such as total soluble solids (21.31 °Brix), titratable acidity (0.192%), reducing sugars (10.53%), and total anthocyanin content (64.49 mg 100 g^{-1}).

Evidence provided by Soliman *et al.,* (2021) demonstrated that strategic foliar application of potassium silicate (3000 ppm) across critical bloom stages (25%, 50%, and 75%) substantially elevated fruit quality, reflected in increased sugar accumulation (18.78%), greater fruit dimensions (length 5.67 cm; diameter 5.94 cm), and enhanced firmness (1787.3 g cm^{-2}). In alignment, Shehata and Farag (2024) established that dual applications of potassium silicate (200 mg L^{-1}) in conjunction with proline (400 mg L^{-1}) during pit hardening and late fruit growth phases resulted in significant gains in fruit weight, stone weight, diameter, and firmness, underscoring the synergistic role of silicon and osmo-protectants in fruit development.

Abiotic stress

Silicon plays a vital role in helping fruit trees cope with various abiotic and abiotic stresses. It maintains cellular integrity and function under high temperatures, reducing heat-induced damage. Si also improves photosynthetic efficiency and detoxifies reactive oxygen species (ROS), enhancing plant performance under salinity stress. Furthermore, it increases water-use efficiency and strengthens antioxidant defense systems, alleviating the negative effects of drought on plant growth.

Silicon is deposited in the epidermal layers of plant tissues, forming a mechanical barrier that limits the penetration and feeding activity of pathogens and herbivorous insects. This reinforcement of cell walls deters fungal invasion and insect feeding

Findings from Helaly *et al.*, (2017) demonstrated that supplementation with potassium silicate (15 g plant^{-1}) conferred notable drought tolerance in mango cv. Fagri Kalan. Compared with untreated stressed plants, silicon-fed trees exhibited superior vegetative vigour (16.9% increase), expanded leaf area (50.2 cm²), and improved physiological performance, reflected in higher relative growth rate (0.16 mg g^{-1} week^{-1}), net assimilation rate (0.57 g m^{-2} week^{-1}), and relative water content (65.6%). Stress-induced malformation of panicles was reduced to only 2.5%. In addition, the treatment enriched leaf nutrient composition (N 1.46%, P 0.20%, K 1.27%) and strengthened antioxidant defences through elevated POX (80.3 µg g^{-1} FW h^{-1}) and SOD (116.2 µg g^{-1} FW h^{-1}) activities. Furthermore, the fruits showed improved total sugar (13.1%) and titrable acidity content (0.17%).

Zahedi *et al.,* (2020) observed that foliar application of Se/SiO, nanoparticles (100 mg L^{-1}) to moderately drought-stressed strawberry plants (cv. Gaviota) markedly improved growth and yield traits compared to the severely drought stressed plants. They recorded higher number of leaves (8.06 vs. 5.96), inflorescences

(2.33 vs. 1.33), flowers (14.70 vs. 5.33), fruits (5.93 vs. 3.60), fruit size (20.30 g vs. 13.66 g), fruit firmness (5.70 N vs. 3.24 N), fruit weight (13.12 g vs. 8.92 g), and yield (79.31 g vs. 31.74 g).

El-Sheery *et al.*, (2020) reported that foliar application of 100 mg L^{-1} nano ZnO combined with 150 mg L^{-1} nano Si to salt-stressed mango plants (cv. Ewais) enhanced growth and yield traits, recording higher leaf area (64.60 cm^2), improved leaf NPK content (1.945%, 0.2575%, and 1.190%), greater number of fruits per tree (224.5), fruit weight per tree (59.4 kg), and proline content (7.35 mg g^{-1} FW), while reducing floral malformation (14.8%) compared to untreated salt-stressed plants.

Aras (2020) reported that application of 2 mM CaSiOƒ to salt-stressed apple plants (cv. Fuji) enhanced resilience to salinity, as evidenced by improved RGR (3.99 mg g^{-1} $week^{-1}$), stomatal conductance (270.26 mmol m^{-2} s^{-1}), rootstock diameter (22.52 mm), scion diameter (15.50 mm), and shoot length (42.60 cm) compared to untreated salt-stressed plants.

Khan *et al.*, (2020) reported that application of silicon in combination with GA_3 to heat-stressed date palm cv. Khalas plants, conferred significant tolerance by increased abscisic acid and salicylic acid contents, enhanced shoot and root length, and increased chlorophyll a and b levels compared to untreated stressed plants.

Biotic stress

Mkhize *et al.*, (2012) demonstrated that pre- and post-harvest applications of silicon (K_2SiO_3) significantly reduced citrus green mold (*P. digitatum*) lesion size in citrus cvs. Eureka, Navel, and Valencia. Among treatments, Si applied alone and in combination with phosphorous acid (5 ml L^{-1}) markedly decreased lesion diameter compared to the control, with the lowest disease severity observed when silicon (5.35 ml L^{-1}) was combined with phosphorous acid (5 ml L^{-1}).

Ali *et al.*, (2024) observed that foliar application of Diatom at 350/ g/ 100/ L^{-1} reduced mango shield scale infestation across developmental stages, with 9.8, 16.3, and 10.0 leaves infested at the immature, adult, and ovipositing adult stages, respectively.

Physiological disorder

Mohsen & Ibrahim (2021) concluded that foliar application of K_2SiO_3 (0.3%) combined with Kaolin (2%) significantly improved yield and peel thickness while reducing sunburn and fruit splitting in 10-year-old Murcott tangerine trees, recording the highest yield per tree (87.5/ kg and 84.3/ kg), maximum peel thickness (2.87/ mm inand 2.91/ mm), and lowest sunburned (5.07% and 4.91%) and split fruits per tree (2.32% and 2.71%) in both the study period.

Conclusion

Silicon application has emerged as a reliable and effective strategy to enhance growth, stress tolerance, and fruit quality in diverse fruit crops. Its role in strengthening antioxidant defense, improving physiological efficiency, and providing structural protection against biotic stresses is well evident in this review. Despite these advances, several critical gaps remain. Standardized protocols for silicon application, including optimal concentrations, timing, frequency, and method of delivery, are yet to be established for most fruit crops. The interaction of silicon with other biostimulants, mineral nutrients, and plant growth regulators warrants deeper investigation. Furthermore, long-term fieldlevel studies under diverse agro-climatic and soil conditions are essential to validate findings from short-term and controlled experiments.Collectively, these findings affirm that silicon supplementation is a scientifically sound and practically viable strategy for improving productivity, stress resilience, and postharvest quality in fruit crops. Translating this knowledge into crop-specific recommendations and extension-ready guidelines will be critical to mainstreaming silicon use in sustainable horticultural systems worldwide.

References

Ali, E.A., Attia S.A. and Elgamal H.E.M. (2024). The role of some different silicon formulations and windbreaks to control mango shield scale insect (*Milviscutulus mangiferae* (green)(*Hemipetra coccidae*) on mango trees affected by Aeolian deposits. *Egyptian journal of desert research*, **74(2)**, 459-493.

Aras, S. (2020). Silicon nutrition in alleviating salt stress in apple plant. *Acta Scientiarum Polonorum Hortorum Cultus*, **19(1)**, 3–10. https://doi.org/10.24326/asphc.2020.1.1.

Arnon, D.I. and Stout P.R. (1939). The essentiality of certain elements in minute quantity for plants with special reference to copper. *Plant Physiology*, **14(2)**, 371–375. https://doi.org/10.1104/pp.14.2.371.

Arthi, V., Sriramachandrasekharan M.V., Manivannan R. and Shakila A. (2020). Effect of silicon fertilization on agro-morphological traits of Grand Naine banana grown in typic Ustifluvent soil. *International Journal of Plant & Soil Science*, **32**, 38–46. https://doi.org/10.9734/IJPSS/2020/v32i1930395.

Cooke, J. and Leishman M.R. (2016). Consistent alleviation of abiotic stress with silicon addition: A meta-analysis. *Functional Ecology*, **30(8)**, 1340–1357. https://doi.org/10.1111/1365-2435.12713.

Das, K.K., Swamy G.S.K., Kumbar S., Gangadharappa P.M.

and Jagadeesha R.C. (2017). Effect of silica on physical and biochemical characters of guava. *International Journal of Current Microbiology and Applied Sciences,* **6(4)**, 1527–1532. https://doi.org/10.20546/ijcmas.2017.604.187.

Elsheery, N.I., Helaly M.N., El-Hoseiny H.M. and Alam-Eldein S.M. (2020). Zinc oxide and silicone nanoparticles to improve the resistance mechanism and annual productivity of salt-stressed mango trees. *Agronomy,* **10(4)**, 558-578. https://doi.org/10.3390/agronomy10040558.

Epstein, E. and Bloom A.J. (2005). Mineral nutrition of plants: Principles and perspectives (2nd ed.). Sunderland, MA: Sinauer Associates.

El-Salhy, A.M., Ahmed E.F., Badawy I.F.M. and Samouni M.T.M. (2021). Response of date palm (*Phoenix dactylifera* L.) to foliar application of potassium silicate. *Egyptian International Journal of Palms,* **1(1)**, 29–38.

Gonchikari, L., Madhumathi C., Rama Krishna M., Tanuja Priya B. and Kadiri L. (2020). Effect of salicylic acid and potassium silicate on shelf life of mango (*Mangifera indica* L.) cv. Alphonso. *International Journal of Chemical Studies,* **8**, 437–440. https://doi.org/10.22271/chemi.2020.v8.i2g.8805.

Helaly, M.N., El-Hoseiny H., El-Sheery N.I., Rastogi A. and Kalaji H.M. (2017). Regulation and physiological role of silicon in alleviating drought stress of mango. *Plant Physiology and Biochemistry,* **118**, 31–44. https://doi.org/10.1016/j.plaphy.2017.05.021.

Habasy, R.E.S.Y. (2016). Response of Navel Orange Trees to Potassium Silicate Application. *Assiut Journal of Agricultural Sciences*, **47**, 164 – 172. https://doi.org/10.21608/ajas.2016.2602.

Hussien, M.A. and Kassem M.S. (2021). Influence of spraying kaolin, silicon and calcium on productivity and quality of Sultani fig. *Egyptian Journal of Horticulture,* **48(1)**, 9–18.https://doi.org/10.21608/ejoh.2020.52431.1153.

Khan, A., Bilal S., Khan A.L., Imran M., Shahzad R., Al-Harrasi A. and Lee I.J. (2020). Silicon and gibberellins: synergistic function in harnessing ABA signaling and heat stress tolerance in date palm (*Phoenix dactylifera* L.). *Plants*, **9(5)**, 620. DOI: https://doi.org/10.3390/plants9050620.

Lalithya, K.A., Hipparagi K. and Thippeshappa G.N. (2013). Influence of silicon and micronutrients on yield and quality traits of sapota cv. Kalipatti under hill zone. *Crop Research*, **46(1to3)**, 150-152.

Ladon, T., Verma P. and Chauhan A. (2021). Role of silicon in sustainable fruit production under stress conditions: A review. *Agricultural Reviews,* **42(4)**, 455–459. https://doi.org/10.18805/ag.R-2123.

Liang, Y., Nikolic M., Bélanger R., Gong H. and Song A. (2021). *Silicon in Agriculture: From Theory to Practice*. Springer. https://doi.org/10.1007/978-94-017-9978-2.

Ma, J.F. and Yamaji N. (2015). A cooperative system of silicon transport in plants. *Trends in Plant Science,* **20(7)**, 435–442. https://doi.org/10.1016/j.tplants.2015.04.007.

Mkhize, N., Bower J.P., Bertling I. and Mathaba N. (2012). Response of citrus physiology to phosphorus acid and silicon as elicitors of induced disease resistance. In *II All Africa Horticulture Congress,* **1007** (135-141). DOI: 10.17660/ActaHortic.2013.1007.12.

Mohsen, F. and Ibrahim M. (2021). Reducing fruit sunburn and splitting in Murrcot tangerine fruits by using silicate application. *Arab Universities Journal of Agricultural Sciences,* **29(1)**, 437–445. DOI: 10.21608/ajs.2021.54154.1314.

Patel, D., Ahlawat T.R., Jena S. and Chaudhary A. (2020). Effect of silicon and seaweed extract on physical and sensory quality of papaya cv. Red Lady. *International Journal of Current Microbiology and Applied Sciences,* **9**, 504–510. https://doi.org/10.20546/ijcmas.2020.901.055.

Panchal, R.K., Patil S.J. and Chawla S.L. (2020). Yield and yield attributes of banana (*Musa paradisiaca* L.) cv. Grand Nain influenced by foliar application of silicon. *International Journal of Chemical Studies,* **8(6)**, 2156–2157. https://doi.org/10.22271/chemi.2020.v8.i6ae.11091.

Romero-Aranda, R., Jurado O. and Cuartero J. (2006). Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. *Journal of Plant Physiology,* **163(8)**, 847–855. https://doi.org/10.1016/j.jplph.2005.05.010.

Royal Society of Chemistry. (n.d.). *Silicon - Element information, properties and uses*. Royal Society of Chemistry. https://periodic-table.rsc.org/element/14/silicon.

Savvas, D. and Ntatsi G. (2015). Biostimulant activity of silicon in horticulture. *Scientia Horticulturae,* **196**, 66–81. https://doi.org/10.1016/j.scienta.2015.09.010.

Soliman, N.G., Nomier S.A., Ibrahim M. and Gad M.M. (2021). Effect of spraying nano-chitosan and nano-silicon on physicochemical fruit quality and leaf mineral content of Florida Prince peach trees. *Zagazig Journal of Agricultural Research,* **48(5)**, 1215–1226..

Shehata, R. and Farag K.M. (2024). Effect of potassium silicate, glycine betaine and proline on fruit quality of peaches in newly reclaimed land exposed to heat stress. *Horticultural Studies*, **41(2)**, 42–49. https://doi.org/10.16882/HortiS.1479089.

Zahedi, S.M., Moharrami F., Sarikhani S. and Padervand M. (2020). Selenium and silica nanostructure-based recovery of strawberry plants subjected to drought stress. *Scientific Reports,* **10(1)**, 17672. https://doi.org/10.1038/s41598-020-74273-9.