# Do Plants Need Silicon?©

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**Silicon (Si) may not be strictly considered an essential nutrient, but is accumulated by plants at macro-concentrations. Fertilization of various hydroponic and field-grown crops with Si has been shown to significantly increase herbage and reproductive yields, moderate the effects of some environmental stresses, and reduce the severity of some fungal diseases and pest attacks. Analysis of potting media and their substrates for plant available monosilicic acid suggests that they may be deficient in Si. Amending soilless media with soluble Si increases plant productivity and decreases severity of fungal diseases, but this may be moderated by other nutrient imbalances, resulting in loss of optimal productivity. Some options to amend media with Si are presented.**

## INTRODUCTION

Silicon is accumulated by plants at macro-concentrations of 0.1% to 10% of dry matter, reflecting its commonality, as well as its apparent nontoxicity (Epstein, 1994). Silicon added to hydroponics nutrient solutions and its fertilization of rice and sugarcane has been shown to significantly increase crop yields, moderate the effects of some environmental stresses, and reduce the severity of some fungal diseases and pest attacks (Bélanger et al., 1995; Epstein; 1999; Jones and Handreck, 1967). This paper discusses some effects of use of silicon in plant nutrition with brief description of recent research of its use to supplement potting mixes.

Monosilicic acid is absorbed by roots, carried in the transpiration stream and usually concentrates in foliar more than in root tissues (Jones and Handreck, 1967; Raven, 1983). Regular foliar application of K silicate solutions (500 mg Si $litre^{-1}$) may enhance Si uptake in some species (Reynolds et al., 1996). Silicon is immobilized in epidermal phytoliths as "amorphous silica", or bound into cellulose and proteins, and thus increases in concentration with increasing ages of the tissues, dependent on species, cultivar, and availability of Si (Epstein, 1994, 1999). "High Si accumulator" plants accumulate Si to =1% dry matter (DM) as compared with "low Si accumulators", which contain Si <1% DM (Epstein, 1999). Bryophyta, some Pteridophyta, Gymnosperms, Cyperales, and Poales accumulate Si at 6% to 10% DM, while certain dicots (Cucurbitaceae, Urticales, Ranunculales, and Magnoliales) contain 1% to 3% Si in DM.

Increased growth and/or yields of 10% to 50% in response to fertilization with Si occurs for a range of high accumulator plants, and for low-accumulator species also, in families Malvaceae, Rutaceae, and Euphobiaceae (Bélanger et al., 1995; Chen et al., 2001; Epstein, 1999). Silicon fertilization is accredited with increased rooting of cuttings and nodulation of legumes (Gillman and Zlesak, 2000; Nelwamondo and Dakora, 1999). Greater production of herbage is promoted by silicification causing harder, more erect leaves, which intercept more light, contain more chlorophyll with greater Rubisco activity, and are slower to senesce (Epstein, 1994, 1999).

Increased Si in nutrient solution may increase Zn uptake if deficient and promotes P translocation to grain in cereals (Epstein, 1994, 1999). Increasing the availability of Si decreases Ca uptake and toxic uptake of P, Na, Al, Fe, and Mn, but may induce P deficiency at very high Si availability (Clark, 1993; Epstein, 1994, 1999; Yeo et al., 1999). Increased fertilization with N and P reduces percent Si accumulated in cereals, while greater Si accumulation occurs with K fertilization as sulphate than as chloride (Jones and Handreck, 1967).

Monosilicic acid in sap (0.5% to 8% of total Si) is likely to be the active form of Si involved in plant metabolism, as it is in diatoms, and with protection against diseases (Fawe et al., 1998; Lewin and Reiman, 1969; Raven, 1983). Severity of fungal foliar and root diseases can be reduced by Si amendment of nutrient solutions, soil, or of foliar sprays (Bélanger et al., 1995; Epstein, 1999). The physical barrier of deposited Si was believed to give protection against pathogens and insects (Epstein, 1994; Jones and Handreck, 1967). Recent research now indicates that plants fertilized with Si produce more fungistatic compounds more rapidly when challenged by pathogens, than untreated plants, but will lose this protection when removed from sources of Si (Fawe et al., 1998).

## MODIFYING POTTING MEDIA TO INCLUDE SILICON

Analysis of potting media available in Sydney suggested they may have been deficient in Si (Jeffery et al., 1997). The minimum monosilicic acid required in mixes was calculated to be 12 mg·$litre^{-1}$ of Si, based on 0.38 to1.0 mM Si (19-50 mg·$litre^{-1}$ of Si) used in hydroponic solutions (Menzies and Bélanger, 1996). Monosilicic acid was measured as molybdate reactive silicate in extractions of samples (1:1.5 mix: 2.0

mmol·litre$^{-1}$ DTPA) and has a maximum solubility of 65 mg·litre$^{-1}$ in aqueous solutions at pH range 2 to pH 8.5 (Anon, 1993; Rayment and Higginson, 1992; Savant et al., 1999; Strickland and Parsons, 1972). At higher concentrations it forms polysilicic acids, which, with other soluble silicates, release monosilicic acid on dilution. All Si found in extract comprises total soluble Si, measured by atomic absorption spectrophotometry.

Recent analyses have found media contained 6 to 11 mg·litre$^{-1}$ of monosilicic acid with at least 20% more Si in other soluble forms. Selected substrates used in mixes showed only diatomite and two types of rice hull ashes released sufficient monosilicic acid (24 to 83 mg·litre$^{-1}$ of Si) that would be useful when incorporated into mixes. Combustion processes vary the monosilicic acid available from rice hulls (Prakash, 1999). Pyroclay® (hydroponics product from 358715 B.C. Ltd, Langley, BC, Canada; Morgan, 1999), bentonite and blood and bone supplied >20 mg·litre$^{-1}$ monosilicic acid, but no extra Si reserves. Basalt dusts, sands, sawdusts, and raw pine bark fines or pieces >10 mm released very little monosilicic acid (2 to 5 mg ·litre$^{-1}$ of Si) or total soluble Si. Other sources of Si for media could include calcium silicate slag (Albright and Wilson America, Glen Allen, VA; Calcium Silicate Corporation, Columbia, TN) or Cal-Phos FMP (A-Mag Corporation, Qld), but have very slow dissolution. Highly soluble K silicate releases monosilicic acid on dilution of concentrates (Kasil® and Kasolv®; PQ Australia Pty Ltd, Melbourne), or metasilicates, for liquid fertilization of media and foliar sprays. Silicates are generally alkaline (pH 9 to 10) and require acidification.

The project also formulated potting media to provide 12 mg·litre$^{-1}$ of Si to promote growth and health of plants, compared with plants grown in the Si-deficient Control mix (Muir, et. al., 2001). The Control and Si-fertilized mixes (+Si Mix) contained coir, coarse sand, and 1 to 2 cm bark, (5:3:2, by volume) with 4-g Fused Potassium Silicate fertilizer (Globe, Patons, Sydney) added per litre Si fertilized mix. Agrichar® Mix was prepared Agrichar® (Biocon, Griffith, NSW), coir, sand, and bark (5 : 4 : 4 : 7, by volume) to provide similar characteristics as the other mixes, within the Australian Standard (Anon, 1993). Soluble and controlled-release fertilizers (CRF) were used to adjust nutrient levels and reduce pH. RH-propagation mix [composted ricehulls (Biocon, Griffith, NSW), Agrichar®, sand (8:5:7, by volume)] was compared with a Control Propagation mix [sand and perlite, (1:1, v/v)].

## EFFECTS ON PLANTS GROWN IN POTTING MEDIA AMENDED WITH SILICON

Addition of Si to potting media significantly increased yields of herbage and fruit of cucumbers (*Cucumis sativus*) and herbage and flowers of native daisy (*Helichrysum adenophorum*). There were no effects of Si on growth of snapdragon (*Antirrhinum majus*) and waratah (*Telopea speciosissima*). Snapdragons matured more slowly, while waratahs and wheat produced less dry matter in Agrichar® Mix. Use of urea to supply N in Agrichar® Mix, rather than CRF as in other media, probably contributed to N deficiency in waratah and wheat, as indicated by mineral analysis of tissues. There was greater seedling loss of flannel flowers (*Actinotus helianthi*) and remaining plants produced fewer flowers when grown in +Si Mix, possibly due to greater electroconductivity of the mix, compared with that of Control Mix. Such results indicate the complexity of amending potting mixes with Si, especially with substrates rich in Si, rather than with fertilizer for which more simple adjustments can be made.

Powdery mildew (*Sphaerotheca fuliginea*) and root infection (*Pythium aphanidermatum*) of cucumbers were reduced by growing the plants in +Si Mix, as observed elsewhere in hydroponic cucumbers (Bélanger et al., 1995). Those growing in Agrichar® Mix were less affected by mildew than those in +Si Mix, indicating that the extra K available in Agrichar® Mix may have increased plant protection (Bennett, 1993; Nichols, 2001).

"Low Si accumulators" also can be shown to benefit from disease protection by Si added to mix. Black mould (*Colletotrichum gloeosporioides*) was less severe on native daisies grown in Agrichar® Mix than in +Si Mix, with those in Control Mix most affected. Pea seedlings grown in +Si Mix demonstrated increased pathogenic related enzyme production prior to challenge by also and less lesions resulted from inoculation of leaves, compared with seedlings grown in Control Mix (Dann and Muir, 2001). Mineral analysis confirmed that wheat and cucumbers were high accumulators of Si, while the others were low Si accumulators. Seedling peas (*Pisum sativum*), cucumbers, and rock melons (*Cucumis melo*) were able to accumulate significantly more Si from RH-propagation mix, compared with those from Control Propagation mix, by 3 weeks after sowing.

## CONCLUSION—DO PLANTS NEED SILICON?

Several species have been shown to suffer adverse effects on growth, or deficiency of other nutrients, if grown without Si, but only horsetails (*Equisetum arvense*) will not grow in the absence of Si (Epstein, 1994, 1999). Not all plants respond significantly to Si fertilization, nor in every situation however, or the response is unknown. It is not possible, therefore, to claim essentiality of Si as a nutrient under the rules of Arnon (1993), despite the widespread responses by plants fertilized with Si, even by low Si accumulators (Epstein, 1999).

The brief review presented above strongly suggests that Si is more important to plant growth by its presence, than by demonstrating effects of its deficiency. Many plants may not need additional Si to reproduce, but plant breeders may need to consider its effects when selecting varieties based on growth in particular growing media. Plant propagators also may well believe their plants need Si fertilization to improve crop productivity and health for increased profit.

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