Silicon Differentially Influences Copper Toxicity Response in Silicon-accumulator and Non-accumulator Species

The threshold between copper (Cu) sufficiency and toxicity is unknown for most floricultural species. Given the use of Cu in pesticides and fungicides, and the common practice of recirculating water for irrigation in the greenhouse industry, there is a high potential for Cu toxicity to occur. Silicon (Si) has been shown to alleviate metal toxicity in some species, though Si is not an essential plant element nor is it included in traditional fertility programs. The amount of Si a species can accumulate in its leaf tissue classifies that species as a Si accumulator (>1000 mg·kg Si) or non-accumulator species (<1000 mg·kg Si), though some research suggests that even a small amount of Si in plant tissue has a beneficial effect. The objective of this study is to compare the response of two species, a Si accumulator zinnia and a Si non-accumulator snapdragon, to Cu toxicity with and without supplemental Si grown in hydroponics.

Zinnia plants were grown hydroponically in six different nutrient solutions, which were combinations of low (0.1 mM) or elevated Si (1.7 mM) and 1.5, 30, or 50 µM Cu. Snapdragons were grown hydroponically in nine different nutrient solutions, with Si concentrations at 0.1, 1.7, or 3.4 mM and Cu concentrations at 1.5, 30, or 50 µM. Visible toxicity symptoms were documented, as well as dry weights, elemental tissue content, and enzymatic activities (phenylalanine ammonia lyase [PAL] and peroxidase [POD]).

Figure 1. Visual symptoms of zinnia and snapdragon exposed to copper (Cu) toxicity. Control zinnia plants (A) have no yellowing in the meristem, whereas zinnia treated for 3 weeks with 50 µM Cu (B) exhibits interveinal chlorosis in this area, which are similar symptoms as iron deficiency. Similarly, control snapdragon plants (C) 4 weeks after transplanting have no yellowing, whereas snapdragon treated for 2 weeks with 100 µM Cu (D) exhibits interveinal chlorosis.

For zinnia, leaf, stem, and root Si concentration was significantly greater when supplemental Si was provided, and visible symptoms of Cu toxicity appeared reduced (Figure 1). The concentration of Si in snapdragon leaves increased with increasing Si supply, and interestingly, increased as Cu supply increased as well. However, visible symptoms of Cu toxicity were not reduced by supplemental Si.

Elemental analysis did indicate that both zinnia and snapdragon accumulated less Cu when supplemented with Si (Figure 2, zinnia not shown). Results from PAL and POD assays also showed that Cu induced stress activity decreased under supplemental Si conditions. This study has shown that Si can reduce Cu toxicity related stress in both Si accumulator and non-accumulator species, though the mechanisms for this process may be different.

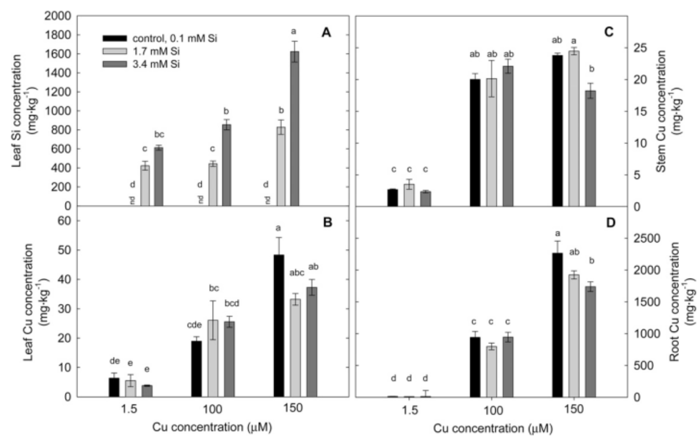

Figure 2. Leaf silicon (Si) concentration (A), and copper (Cu) concentration in leaf (B), stem (C), and root (D) of snapdragon harvested 5 weeks after transplanting seedlings into a hydroponic system containing low (0.1mM), medium (1.7mM), and high (3.4mM) supplemental Si and 3 weeks after exposure to control (1.5 µM), medium (100 µM), and high (150 µM) Cu. Error bars are ± 1 SE, whereas different lowercase letters above the bars within a panel indicate statistically different means based on Tukey's honest significant difference test at $P < 0.05$. Leaf Si concentration was not measured above background levels, so nd = not detectable in those treatments. A value of 0.1 $mg \cdot kg^{-1}$ was inserted in those replicates for statistical purposes.

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