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Silicon uptake by wheat and rice: Effects of Si pools and pH

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Silicon (Si) is the second most abundant element of earth´s crust and thus plays an important role in global matter cycles. Although Si is a quantitatively major inorganic constituent of higher plants, it is generally not considered to be essential. However, Si has beneficial effects on plant growth because it reduces various types of abiotic and biotic stress. These beneficial effects are mostly associated with the ability of plants to accumulate amorphous (phytogenic) Si. Phytogenic Si is the most active Si pool in the soil in terrestrial biogeosystems because of its high surface : volume ratio, amorphous structure and high water solubility. Despite the high abundance of Si in terrestrial biogeosystems and its importance e.g. for the global C cycle, little is known so far about fluxes of Si cycling in these systems, especially between soil and plants.

Therefore, the aim of our study was to elucidate the contribution of various soil Si pools (crystalline, amorphous or water soluble) to the Si uptake by plants. The experiment was done with 2 plant species – wheat (*Triticum aestivum*) as weak Si accumulator, and rice (*Oryza sativa*) as strong Si accumulator. Further hypothesis was that the rate of Si weathering and cycling is higher in planted than unplanted soil because of the effect of root exudates, transpirational pull of plants and active Si uptake by roots and consequently disequilibrium between dissolved and solid Si compounds. Therefore, also treatments without plants were applied. As dissolution of Si pools and Si uptake by plants is affected by pH, the effect of pH was estimated. Wheat and rice were grown on Si free pellets mixed with one of the following Si pools: quartz sand (SiO_2, crystalline), anorthite ($CaAl_2Si_2O_8$, crystalline), silica gel (H_4SiO_4, amorphous) or Si salt solution ($Na_2O_7Si_3$, soluble). Plants were grown at pH of either 4.5 or 7 in modified Hoagland nutrient solution. Aboveground biomass, roots and soil solution were sampled 4 times in intervals of 7 days, and analysed for Si content by ICP-OES.

Total Si amounts in plant biomass increased approximately in a linear way from 1^{st} to last sampling, with higher values in aboveground biomass compared to roots, and higher relative contents (normalized on dry biomass) in rice compared to wheat. At pH 4.5, plants grew best on anorthite compared to other Si pools, as shown by highest amounts of biomass and highest chlorophyll contents at this treatment. However, pH had no significant influence on rates of Si uptake. Plants grown on Si gel and in Si salt solution had the highest relative Si contents, indicating that Si uptake depends on the availability of Si, or the conversion of the respective substrate Si into silicic acid: Si from salt solution is already plant available, and conversion of amourphous silica gel to disslved pools occurs faster than conversion of crystalline Si pools. In treatments with wheat grown on quartz sand, total Si content was higher than the value theoretically calculated based on transpiration stream. This implies that Si uptake by Si accumulators like wheat and rice is driven by both passive and active processes. Generally, plants grown on Si free substrate had lower amounts of aboveground biomass and showed less structural stability than plants grown on pellets mixed with a Si pool, demonstrating the beneficial effects of Si for plant growth.

These results show that Si uptake by plants, as well as plant growth, are significantly affected by the type of Si pool and, in part, by pH. Si uptake by plants from soil occurs mainly from dissolved pools as well as from pools which are easily converted to such dissolved Si.