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Impact of rice-straw biochars amended soil on the biological Si cycle in soil-plant ecosystem

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Biochar used as soil amendment can enhance soil fertility and plant growth. It may also contribute to increase the plant mineralomass of silicon (Si). However, very little studies have focused on the plant Si cycling in biochar amended soils. Here, we study the impact of two contrasting biochars derived from rice straws on soil Si availability and plant Si uptake. Rice plants were grown in a hydroponic device using Yoshida nutrient solution, respectively devoid of H_4SiO_4 (0 ppm Si: Si-) and enriched with it (40 ppm Si: Si+). After 12 weeks, the plants were harvested for further pyrolysis, conducted with holding time of 1h at 500°C. The respective rice-biochars are Si-/biochar and Si+/biochar. They exhibit contrasting phytolith contents (0.3 g Si kg^{-1} vs. 51.3 g Si kg^{-1}), but identical physico-chemical properties. They were applied in two soils differing in weathering stage: a weathered Cambisol (CA) and a highly weathered Nitisol (NI). We then studied the effects of the amended biochar on $CaCl_2$ extractable Si using a 64-days kinetic approach, on the content of soil biogenic Si, and on the uptake of Si by wheat plants grown for 5 weeks. We also quantified Si mineralomass in plants. We compared the effects of biochars to that of wollastonite (Wo)–($CaSiO_3$), a common Si-fertilizer.

Our results show that Si+/biochar significantly increase the content of BSi in both soils. In CA, the cumulative content of $CaCl_2$ extractable Si amounts to 85 mg kg^{-1} after Si+/biochar amendment, which is below the amount extracted after Wo application (100 mg kg^{-1}). In contrast, in NI, the cumulative content of $CaCl_2$ extractable Si is 198 mg kg^{-1} in the Si+/biochar amended treatment, which is far above the one measured after Wo application (93 mg kg^{-1}). The Si-/biochar has no effect on the cumulative content of $CaCl_2$ extractable Si in either soil type.

Biochars and wollastonite increase the biomass of wheat on both soils. The increase is, however, larger in NI than in CA. In terms of Si uptake by wheat , Si-/biochar does not increase the Si content of plants in either soil type. As expected, Si+/biochar and wollastonite significantly increase the Si content of wheat plants grown on both soils. The increase caused by Si+/biochar is, larger in NI (10 mg Si pot^{-1}) than that in CA (5 mg Si pot^{-1}). This result is in line with the release of $CaCl_2$ extractable Si in both soils amended by Si+/biochar, confirming the validity of $CaCl_2$-extraction to estimate the pool of bioavailable Si.

Our data highlight that phytolith-rich biochar readily contributes to the pool of bioavailable Si, further taken up by plant roots, and increases Si mineralomass in plants as well as plant growth. Thus it provides an alternative to wollastonite application. The effect is particularly large in the highly weathered Nitisol. Under such conditions, the impact of phytolith rich biochar is not limited to the enhancement of Si biological cycle, but is extended to the increase of soil pH, CEC and organic matter content.