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Immobilization of copper by biochar in Cu-enriched agricultural soils depends on interactions with soil organic carbon

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The appearance of downy mildew (*Plasmopara viticola*) in European vineyards of the 19^{th} century was the starting point for the search of effective fungicides to avoid severe yield losses. Copper has been found as an important ingredient for several fungicides that have been used in agriculture and horticulture. For organic viticulture, several diseases can only be antagonized with Cu-containing fungicides as the application of organic fungicides is not permitted. This long-lasting dependence on Cu-fungicides has led to a gradual Cu enrichment of vineyard soils in traditional wine-growing areas, locally exceeding 300 mg/kg. Although these concentrations do not affect the vines or wine quality, they may impair soil microbiological functions in the top soil layer or the root growth of green cover plants. Therefore, measures are demanded that reduce the bioavailability of copper, thereby reducing the ecotoxicological effects. The use of biochar and compost as soil amendment has been suggested as a strategy to immobilize Cu and reduce the exchangeable fractions. In our study we have tested the hypothesis that biochar immobilizes the bioavailability of Cu for soil cover crops and reduces soil pore water concentrations. This study had the objective to test the interactions of compost and biochar with respect to Cu immobilization in vineyard soils.

A Cu-enriched vineyard soil (250 mg Cu kg^{-1}) was analyzed both in greenhouse and field experiments. In both experiments, soil with or without biochar and/or compost and mixtures of the two components were used. In the greenhouse experiments, was used as test plant *Lolium multiflorum* for Cu uptake; in the field, *Lolium perenne* and *Trifolium repens* were analyzed.

Greenhouse experiment: Soil pore water concentrations showed clearer differences in Cu concentration than *Lolium multiflorum* shoots. Compost increased dissolved organic carbon (DOC) and Cu in soil pore water and biochar reduced it significantly. The mixtures of compost and biochar produced intermediate results.

Field experiment: Cu concentrations in the roots of soil cover crops were higher than above-ground parts. Biochar as soil additive (4 kg m^{-2}) and a biochar-compost mixture at a high application rate (10 kg m^{-2}) reduced the Cu uptake into the roots. Compost without biochar or the mixture at a lower dose (4 kg m^{-2}) either had no or even a mobilizing effect on Cu. Apparently the effects of compost and biochar are opposite. Biochar is only able to exert an immobilizing effect if soil organic carbon content is not too high; otherwise only very high biochar addition rates can counteract the effect of compost.

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