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Lignin decomposition and microbial community in paddy soils: effects of alternating redox conditions

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Paddy soils are characterised by interchanging cycles of anaerobic and aerobic conditions. Such fluctuations cause continuous changes in soil solution chemistry as well as in the composition and physiological responses of the microbial community. Temporary deficiency in oxygen creates conditions favourable to facultative or obligates anaerobic bacteria, while aerobic communities can thrive in the period of water absence. These alterations can strongly affect soil processes, in particular organic matter (OM) accumulation and mineralization. In submerged soils, lignin generally constitutes a major portion of the total OM because of hampered degradation under anoxic conditions. The alternating redox cycles resulting from paddy soil management might promote both degradation and preservation of lignin, affecting the overall composition and reactivity of total and dissolved OM.

We sampled soils subjected to cycles of anoxic (rice growing period) and oxic (harvest and growth of other crops) conditions since 700 and 2000 years. We incubated suspended Ap material, sampled from the two paddy plus two corresponding non-paddy control soils under oxic and anoxic condition, for 3 months, interrupted by a short period of three weeks (from day 21 to day 43) with reversed redox conditions. At each sampling time (day 2, 21, 42, 63, 84), we determined lignin-derived phenols (by CuO oxidation) as well as phospholipids fatty acids contents and composition.

We aimed to highlight changes in lignin decomposition as related to the potential rapid changes in microbial community composition. Since the studied paddy soils had a long history of wet rice cultivation, the microbial community should be well adapted to interchanging oxic and anoxic cycles, therefore fully expressing its activity at both conditions.

In non-paddy soil changes in redox conditions caused modification of quantity and composition of the microbial community. On the contrary, in well-established paddy soils the microbial community appeared to be affected by alternating redox conditions more in quantity that in quality. Bacteria represented the largest portion of the living microorganisms, responding promptly to changes in soil redox status. However we did not detect any sign of lignin biodegradation. Relative short (3 weeks) changes in redox conditions had no effect on lignin decomposition or oxidation state. Also, lignin was not altered during oxic incubation. Since fungi represented only small portion of the microbial biomass in the studied soils, they were obviously not capable to cause much degradation, even under favourable conditions.

On the contrary, changes in redox conditions strongly affected lignin extractability, regardless of the initial content and direction of change in both paddy and non-paddy soils. This was likely a result of (partial) dissolution and/or pH-induced changes of the surface properties of Fe and Mn hydrous oxides causing the release of mineral-associated lignin-derived phenols. Thus, we speculate that oxidised lignin fragments produced during the (oxic) dry period do not remain in the soils but percolate with water drainage during the flooding period.