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Geochemical patterns and microbial contribution to iron plaque formation in the rice plant rhizosphere

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Rice is the major food source for more than half of the world population and 80 percent of the worldwide rice cultivation is performed on water logged paddy soils. The establishment of reducing conditions in the soil and across the soil-water interface not only stimulates the microbial production and release of the greenhouse gas methane. These settings also create optimal conditions for microbial iron(III) reduction and therefore saturate the system with reduced ferrous iron. Through the reduction and dissolution of ferric minerals that are characterized by their high surface activity, sorbed nutrients and contaminants (e.g. arsenic) will be mobilized and are thus available for uptake by plants. Rice plants have evolved a strategy to release oxygen from their roots in order to prevent iron toxification in highly ferrous environments. The release of oxygen to the reduced paddy soil causes ferric iron plaque formation on the rice roots and finally increases the sorption capacity for toxic metals.
To this date the geochemical and microbiological processes that control the formation of iron plaque are not deciphered. It has been hypothesized that iron(II)-oxidizing bacteria play a potential role in the iron(III) mineral formation along the roots. However, not much is known about the actual processes, mineral products, and geochemical gradients that establish within the rhizosphere. In the present study we have developed a growth set-up that allows the co-cultivation of rice plants and iron(II)-oxidizing bacteria, as well as the visual observation and in situ measurement of geochemical parameters. Oxygen and dissolved iron(II) gradients have been measured using microelectrodes and show geochemical hot spots that offer optimal growth conditions for microaerophilic iron(II) oxidizers. First mineral identification attempts of iron plaque have been performed using Mössbauer spectroscopy and microscopy. The obtained results on mineraology and crystallinity have been compared to mineralogical data from purely biotic (microaerophilic) and abiotic iron mineral formation processes.