Geophysical Research Abstracts
Vol. 18, EGU2016-1713, 2016
EGU General Assembly 2016

How rice roots form their surrounding: Distinctive sub-zones of oxides, silicates and organic matter

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Most of the rice (*Oryza sativa*) worldwide is grown under flooded conditions in bunded fields (paddies). Inundation during long periods of the year leads to anoxic conditions in the soil. The rice plant is well adapted to these conditions by being able to transport oxygen via aerenchyma from the atmosphere to the roots. This plant mediated O_2 transport also influences the adjacent soil. Driven by the O_2 leakage into the rhizosphere, reddish ferric oxides and ferric hydroxides precipitate along the root channels. Thus, radial gradients of ferric Fe and with it co-precipitated organic substances form.

Detailed investigations of element gradients on a submicron scale within the oxide coatings are still missing. Nano-scale secondary ion mass spectrometry (NanoSIMS) analyses can help to visualize and study the interplay of the various soil components at a submicron scale like, e.g., the attachment of organic material to minerals or the architecture of microstructures. The aim of the present study was to evaluate the composition and size of oxide coatings around rice roots concerning the distribution of organic matter and its spatial relation to oxides and silicates.

Samples were taken from the plough pan of a paddy field close to the National Rice Research Centre, Castello d'Agogna (Pavia, Italy). Intact soil aggregates were air-dried, embedded in epoxy resin and then cut and polished in order to obtain a surface with low topography. Reflected-light microscopy was used (mm to μm scale) to visualize the aggregate architecture and to identify root channels in the embedded aggregate. In the next step, scanning electron microscopy (SEM) was applied to obtain images of high resolution and to define distinctive spots for subsequent NanoSIMS analyses.

Using the Cameca NanoSIMS 50L at TU München, we simultaneously detected $^{12}C^-$, $^{12}C^{14}N^-$, $^{28}Si^-$, $^{32}S^-$, $^{27}Al^{16}O^-$ and $^{56}Fe^{16}O^-$ at several areas around root channels in order to distinguish between organic material and different mineral particles (e.g. oxides, clay minerals). Beside single 40 x 40 μm sized spots, mosaics of 20 x 20 μm sized images were combined to investigate the region from the surface of the root channels into the soil matrix. The image data of all detected secondary ions was analysed using line scans and designation of regions of interest (ROI) to evaluate relative occurrences and spatial distributions.

The results revealed that the oxic zone around rice roots can be subdivided in distinctive sub-zones. We identified a distinctive zone of approx. 20 μm around the root channels, where exclusively oxide-associated organic matter occurred. This zone can be clearly distinguished from a clay mineral-dominated zone. In addition, oxide-incrusted root cells revealed coexisting regions of Fe (hydr)oxides and Al–organic complexes.