

Do chemical gradients within soil aggregates reflect plant/soil interactions?

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As roots and hyphae often accumulate at the surface of soil aggregates, their formation and turnover might be related to the bioavailability especially of immobile nutrients like phosphorus. Several methods have been developed to obtain specific samples from aggregate surfaces and aggregate cores and thus to investigate differences between aggregate shell and core. However, these methods are often complex and time-consuming; therefore most common methods of soil analysis neglect the distribution of nutrients within aggregates and yield bulk soil concentrations.

We developed a new sequential aggregate peeling method to analyze the distribution of different nutrients within soil aggregates (4–20 mm) from four forest sites (Germany) differing in concentrations of easily available mineral P. Aggregates from three soil depths (Ah, BwAh, Bw) were isolated, air-dried, and peeled with a sieving machine performing four sieving levels with increasing sieving intensity. This procedure was repeated in quadruplicate, and fractions of the same sample and sieving level were pooled. Carbon and N concentration, citric acid-extractable PO₄ and P, as well as total element concentrations (P, K, Mg, Ca, Al, Fe) were analyzed. Additionally, synchrotron-based P K-edge XANES spectroscopy was applied on selected samples to detect P speciation changes within the aggregates.

The results reveal for most samples a significantly higher C and N concentration at the surface compared to the interior of the aggregates. Carbon and N gradients get more pronounced with increasing soil depth and decreasing P status of study sites. This might be explained by lower aggregate turnover rates of subsoil horizons and intense bioturbation on P-rich sites. This assumption is also confirmed by concentrations of citric acid-extractable PO₄ and P: gradients within aggregates are getting more pronounced with increasing soil depth and decreasing P status. However, the direction of these gradients is site-specific: On P-rich study sites the results reveal a significant depletion of citric acid-extractable PO₄ and P on aggregate surfaces in subsoil horizons, while at the other study sites a slight enrichment at the aggregate surfaces could be observed.

Total P concentrations show no distinct gradients within topsoil aggregates, but a slight P enrichment at the surface of subsoil aggregates at the P-rich site. A strong correlation with the total Al concentrations may indicate a P speciation change within aggregates (e.g., due to acidification processes). These results were also confirmed by P K-edge XANES spectra of aggregate core and shell samples of the P-rich site: In the aggregate shells of topsoil as well as subsoil aggregates, organic P forms are most dominant (82 and 80 %, respectively) than in the aggregate interior (54 and 66%, respectively). Moreover, P in the shell seems to be completely associated to Al, whereas some of the P in the aggregate interior is bound to Fe and/or Ca.

Overall, our results show that plant/soil interactions impact on small-scale distribution and bioavailability of nutrients by root uptake and root-induced aggregate engineering.