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Microbial respiration and kinetics of extracellular enzymes activities through rhizosphere and detritusphere at agricultural site

Sebastian Löppmann, Evgenia Blagodatskaya, and Yakov Kuzyakov
Dept. of Soil Science of Temperate Ecosystems, Georg-August University Göttingen, Germany

Rhizosphere and detritusphere are soil microsites with very high resource availability for microorganisms affecting their biomass, composition and functions. In the rhizosphere low molecular compounds occur with root exudates and low available polymeric compounds, as belowground plant senescence. In detritusphere the substrate for decomposition is mainly a polymeric material of low availability. We hypothesized that microorganisms adapted to contrasting quality and availability of substrates in the rhizosphere and detritusphere are strongly different in affinity of hydrolytic enzymes responsible for decomposition of organic compounds. According to common ecological principles easily available substrates are quickly consumed by microorganisms with enzymes of low substrate affinity (i.e. r-strategists). The slow-growing K-strategists with enzymes of high substrate affinity are better adapted for growth on substrates of low availability.

Estimation of affinity of enzyme systems to the substrate is based on Michaelis-Menten kinetics, reflecting the dependency of decomposition rates on substrate amount. As enzymes-mediated reactions are substrate-dependent, we further hypothesized that the largest differences in hydrolytic activity between the rhizosphere and detritusphere occur at substrate saturation and that these differences are smoothed with increasing limitation of substrate. Affected by substrate limitation, microbial species follow a certain adaptation strategy. To achieve different depth gradients of substrate availability 12 plots on an agricultural field were established in the north-west of Göttingen, Germany: 1) 4 plots planted with maize, reflecting lower substrate availability with depth; 2) 4 unplanted plots with maize litter input (0.8 kg m^{-2} dry maize residues), corresponding to detritusphere; 3) 4 bare fallow plots as control. Maize litter was grubbed homogenously into the soil at the first 5 cm to ensure comparable conditions for the herbivore and detritivore communities in the soil. The kinetics (K_m and V_{max}) of four extracellular hydrolytic enzymes responsible for C- and phosphorous-cycle (β-glucosidase, β-xylosidase, β-cellobiohydrolase and acid phosphatase), microbial biomass, basal respiration (BR) and substrate-induced respiration (SIR) were measured in rhizosphere, detritusphere and control from 0 – 10 and 10 – 20 cm. The metabolic quotient (q_{CO2}) was calculated as specific indicator for efficiency of microbial substrate utilization.

We observed clear differences in enzymes activities at low and high concentrations of substrate. At substrate saturation enzyme activity rates of were significantly higher in rooted plots compared to litter amended plots, whereas at lower concentration no treatment effect could be found. The BR, SIR and q_{CO2} values were significantly higher at 0 – 10 cm of the planted treatment compared to litter and control plots, revealing a significantly higher respiration at lower efficiency of microbial substrate utilization in the rhizosphere.

The Michaelis-Menten constant (K_m) decreased with depth, especially for β-glucosidase, acid phosphatase and β-xylosidase, indicating higher substrate affinity of microorganisms in deeper soil and therefore different enzyme systems functioning. The substrate affinity factor (V_{max}/K_m) increased 2-fold with depth for various enzymes, reflecting a switch of predominantly occurring microbial strategies. V_{max}/K_m ratio indicated relative domination of zymogenous microbial communities (r-strategists) in 0 – 10 cm depth as compared with 10 – 20 cm depth where the K-strategists dominated.