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Enzyme properties down the soil profile - A matter of substrate quality in rhizosphere and detritusphere

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ABSTRACT

The decomposition of soil organic matter depends strongly on its availability to microorganisms and their enzymes. The rhizosphere and detritusphere are microbial hot spots due to additional substrate input, leading to high abundance, specific species diversity and functional diversity of microbial communities. However, rhizosphere and detritusphere differ in substrate quality, localization, and duration of input. We hypothesized that the contrasting substrate availability between rhizosphere and detritusphere affects the activity of microorganisms and associated enzymes. Organic carbon (C) from the rhizosphere and detritusphere decreases with soil depth and, consequently, microbial hot spots become rarer and competition for C and nutrients increases. In deeper soil (>40 cm depth) the amount and quality of substrates is expected to decrease and, therefore, the effect of contrasting substrate input to disappear. Plant N uptake is expected to reduce N availability in the rhizosphere of maize compared to the detritusphere and bare fallow. These hypotheses were tested in a factorial field experiment with 1) maize-planted, 2) maize litter-amended, and 3) bare sites. Enzyme kinetic parameters (V_{max}, K_m, K_a), extractable organic C and microbial biomass C were compared in soil affected by rhizosphere and detritusphere throughout the profile to 70 cm depth, to assess microbial C and nutrient limitations. A decrease in enzyme activity with depth due to resource scarcity and lower substrate quality appeared in planted and litter-amended soil. N limitation in planted soil increased the activity and substrate affinity of proteolytic enzymes to provide for microbial N demand through SOM decomposition. This was in line with lower V_{max} ratios (V_{max} for C-cycling enzymes divided by V_{max} for N-cycling enzymes) in planted relative to litter-amended topsoil. The catalytic efficiency of enzymes decreased 2- to 20-fold from top- (<40 cm) to subsoil (>40 cm), irrespective of the substrate input. Substrate quality in the rhizosphere and detritusphere affected enzyme activities only in the topsoil, whereas a sharp decline of C input with depth led to similar activities in the subsoil. Most of the enzyme indexes reflected shifts in allocation of C and nutrients in the rhizosphere and detritusphere. The presented results underline the role of microorganisms as critical links in the C and nutrient transfers in the rhizosphere and detritusphere.

1. Introduction

Enzymes in soil catalyze nearly all important transformations in the carbon (C), nitrogen (N), phosphorus (P) and sulfur (S) cycles (Aon et al., 2001; Wallenstein and Burns, 2011). Decomposition of organics is strongly dependent on microbes and enzymes, which are especially abundant in the rhizosphere and detritusphere – two main microbial hot spot environments in soil. The rhizosphere is characterized by high density and quality of substrates for microorganisms (Garbeva et al., 2008; Marschner et al., 2012, 2001), and plants provide a variety of C and energy sources from their roots

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