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More than a source of "stable C": Unraveling the unexplored potential of microbial necromass as dynamic nutrient reservoir for ecosystems

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The high relevance of microbial necromass as source of long-term stable C has become evident in the past decade. However, microbial cell death releases nutrient-rich organic matter (OM) with unique properties: 1) Its narrow C:N:P stoichiometry makes it a valuable nutrient source. 2) Its location in patchy microbial hotspots makes it easily exploitable once the hotspot is reached by roots. 3) Its structural location embedded in biofilms or hyphal structures minimizes the risk of nutrient-leaching. 4) Depending on C availability and microbial growth dynamics, microbial necromass is a continuously renewing pool with seasonal dynamic. 5) The binding forms of nutrients cover a wide range of molecular compounds from easily available forms (free amino acids, free nucleotides) to medium (peptides, DNA, RNA, phospholipids) and complex forms (e.g. chitin or peptidoglycane). Such a wide compositional range provides a set of successively exploitable nutrients depending on the ecosystems' nutrient limitation status. Although systematic studies are still lacking, such properties suggest a key role of microbial necromass for ecosystem nutrition.

To identify the significance of necromass P and N for plant nutrition in forest ecosystems we established a series of experiments with soils from four contrasting beech forests sites. The use of T-shaped pots allowed to create i) an intact rhizosphere and ii) a hyphosphere by using PTFE gauze not permeable by plant roots but by mycorrhizal hyphae. Thus, beech P and N uptake directly via roots incl. mycorrhizal associations or via mycorrhizal association only could be distinguished. 14C-, 15N-, and 33P-labelled microbial necromass was applied on both ends of the side compartments of the T-shaped pots. Gradients of necromass OM depolymerizing exoenzymes (phosphatases, chitinases, etc.) were analyzed along the lateral axis from the beech stem to the necromass hotspot.

Generally, the hyphosphere alone was as potent as the combination of roots and their mycorrhizal partners in mobilizing necromass nutrients and providing them for plant nutrition demonstrating the key role of ectomycorrhizal fungi in necromass nutrient utilization in forests. Uptake of microbial necromass-derived P by beech trees increased with decreasing soil P availability, suggesting a higher relevance of microbial necromass-derived nutrients in ecosystems with closed nutrient (re-)cycling. In these ecosystems, the activity of exoenzyms releasing necromass nutrients (e.g. chitinase or phosphatase) was factor 2 to 20 higher in close proximity to the necromass hotspot compared to the middle soil compartments. This shows that triggering the activity of necromass decomposing enzymes is a key trait of the rhizo-hyphosphere of trees to access the necromass nutrient reservoir, especially in recycling ecosystems.

Our results reveal that forest ecosystems have defined strategies to exploit the intermediate nutrient reservoir of the microbial necromass by the interaction of roots, mycorrhiza and activation of microbial functions. This suggests that the role of microbial necromass as dynamic nutrient reservoir for ecosystem nutrition was strongly underestimated up to now and that the ecosystem's demand on exploiting this nutrient reservoir can be a triggering factor for its potential to function as C sink in soils.