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The effect of local ectomycorrhizal nitrogen supply on allocation of recent photosynthates within the mycorrhizosphere

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Understanding allocation patterns of carbon (C) released by plants into their soil environment is vital for understanding global C cycling. Plants release photosynthetically acquired C not only to the rhizosphere and respective soil bacteria, but also to associated mycorrhizal fungi. Mycorrhizal fungi extend further into the adjacent soil, mining for essential nutrients like nitrogen (N) and phosphorous (P), with a dramatically increased surface area compared to plant roots. Symbiotically, plants receive these nutrients in exchange for C. A reciprocal control on exchange rates has been shown in arbuscular mycorrhizal systems, but the situation remains equivocal for the ectomycorrhizal (EM) symbiosis. Furthermore, the symbiosis may conceptually be extended to interactions between mycorrhizal fungal hyphae and soil bacteria. For example, a transfer of plant-derived C from hyphae to surrounding soil microbial communities has been suggested, with however only limited experimental evidence. We hypothesized that (i) reciprocal reward within the EM symbiosis may be observed at the level of root system architecture, i.e. that plants allocate C preferentially to parts of their root system that receive more N by EM fungi, (ii) that EM fungi allocate recent photosynthates to soil bacteria, and (iii) that this C allocation is influenced by N availability.

We conducted a split-root experiment with ectomycorrhizal beech (*Fagus sylvatica*) trees. Young trees were collected in the Wienerwald near Vienna. Each plant was transferred to a 'split-root'-box, dividing its root system into two parts, with each part growing into one of two disconnected soil compartments. Each of the two soil compartments was connected to a separated litter compartment by a mesh (35 μm) penetrable only for fungal hyphae, but not for roots. Stable isotope tracing was used for determining the fate of nutrients and photosynthates in this system, by applying ^{15}N labelled ammonium and amino acids to only one of the two litter compartments, while exposing aboveground plants to a $^{13}CO_2$ enriched atmosphere. Subsequently, we used EA-IRMS to trace isotopic signals in bulk components, and GC-MS/GC-IRMS for PLFA quantification.

Our results show a rapid transport of ^{15}N to plants via EM hyphae, and photosynthetically fixed ^{13}C toward hyphal tips, with already significant enrichments 17 hours after $^{13}CO_2$ labelling and 40 hours after ^{15}N addition. No plant control for reciprocal C-N exchange at the bulk root scale was found. We argue that investigations at smaller scales are required, as regression analysis shows a trend towards reciprocal exchange ($R^2 = 0.32$, $p < 0.001$) when separating roots into branches. Furthermore, we found significant enrichment of ^{13}C in bacteria-specific PLFAs in the hyphae-exclusive litter compartment. This indicates a rapid allocation of recent photosynthates to remote soil bacteria through EM hyphae.