Utilization of Organic Nitrogen by Arbuscular Mycorrhizal Hyphae in Soil - Zooming into the Hyphosphere Microbiome

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Nitrogen (N) availability often limits growth and yield of crop plants. This is also why the utilization of synthetic N fertilizers (among other measures) during 20th century lead to unprecedented increases (multiplications) in yields, but also to great dependency of global agricultural production on fossil energy, and to widespread degradation of soil quality. To sustain primary production of agricultural systems in the future, it is important to re-design many aspects of agricultural land management, aiming at improving soil quality and fostering recycling of resources, particularly organic N in forms of green and farmyard manure, sewage sludge and various kinds of compost.

Arbuscular mycorrhizal (AM) fungi (recruiting from Glomeromycotina and Mucoromycotina) accompany plants since the beginning of their colonization of terrestrial environments, establishing intimate relationship with their roots, rhizoids and/or thalli, and being heavily implicated in plant acquisition of phosphorus (P) and micronutrients, and in plant carbon economy. They colonize roots of nearly three quarters of all plant species currently on Earth, including most of the agricultural crop plants (particularly cereals and most legumes) By extending their hyphae far away from the P depletion zone established around the roots, the AM hyphae greatly increase the volume of soil from which the plant acquire soil nutrients. The AM fungal hyphae also interact with soil particles, promoting soil aggregate stability and soil hydraulic properties, and with other soil microorganisms, while foraging for resources they require.

Particularly, the AM fungi need lots of mineral N to build their own biomass – for which purpose their genome contains genes coding for both ammonia and nitrate transporters, facilitating uptake of these N forms to the hyphae from the soil solution. Multiple studies also reported transport of N from the soil via AM fungal hyphae to their host plants, which may be important for plant N acquisition under some situations. Yet the AM fungi are apparently incapable of efficient biodegradation of biopolymers on their own. To utilize organic N, the AM fungi obviously have to build alliance with other saprotrophic microbes in soil, which are capable of organic N degradation (or at least cleaving the ammonia groups off from the organic moiety). Exact identities of such microbes and/or food chain members involved in release of N from organic sources and increasing mineral N availability to AM hyphae remains unclear as yet, however.

Our recent research showed consistent stimulation of AM hyphal proliferation in soil patches enriched with various organic N sources (plant litter, chitin, proteins) and efficient transport of N originating from such sources back to the host plant (*Andropogon gerardii*). Heterogeneous microbial communities are likely involved in primary degradation of the biopolymers, but there are strong indications that soil protists are the key functional group to liberate the N (originally supplied as soil organic amendment) from the microbial biomass and make it available as free ammonia ions to the AM fungal hyphae. Through efficient uptake of ammonia ions from the soil solution, the AM fungal hyphae indirectly suppress growth/activity of soil ammonia oxidizers and thus the entire nitrification pathway. The AM fungi could thus become an important component of future agricultural production systems, not only with respect to efficient P uptake by the plants, but also as facilitators of organic N recycling.