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Fungi as Ecosystem Engineers in the Soil Pore Space

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Soils are characterized by their largely varying microhabitats that determine their microbial communities and functions such as nutrient cycling. Microbes, and especially fungi, do not only react to those microhabitats but also contribute to shaping them.

We used transparent, microstructured chips simulating the internal pore space of soils, to microscopically study fungal mycelia at the hyphal scale. We investigated the variety of fungal morphologies in maze structures, and hyphal interactions with their biotic and abiotic microenvironments. We studied both a variety of laboratory strains including an arbuscular mycorrhizal fungus and natural soil inocula, and we quantified their growth strategies in different microstructures and their interactions with bacteria, protists and soil mineral particles.

We could observe how the rigid hyphae of fungi opened up passages through chip- or soil solids and aggregates, increasing the spatial availability of the pore space. They, on the other hand, also filled up pores and pore necks with their biomass, creatingbarriers for both organisms, flow of water and sedimentation of matter, and thus changing the pore size distribution and -connectivity. Hyphae also increased the wettability of pores, which led to a higher connectivity of water films across air pockets and thus benefiting the dispersal of water-dwelling microorganisms, a phenomenon earlier termed “fungal highways”. We found the abundance of both bacteria and protists strongly increased in pore spaces containing hyphae in comparison to those without, dispersal events via fungal hyphae that happened frequently and were quantifiable in the high internal replication of our chip’s pore space channels. This allowed us to conclude on a high relevance of this mode of dispersal in soils with intermediate moisture. Fungal hyphae had thus a strong and obvious effect on their surrounding microenvironments and organisms.

We consider the study of microbial behaviour and interactions at the cellular scale in microhabitats to be essential for a better understanding of soil functions, and to gain mechanistic insight into phenomena observable at macroscale.