A paradox: When arbuscular mycorrhizal fungi become limiting in plant phosphate acquisition

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Arbuscular mycorrhizal (AM) fungi are mostly highly beneficial to P uptake and growth of plants in low P soils, but there are also many reports on mycorrhiza-induced growth depressions, e.g. in grasses. Such observations have been explained by the classical carbon drain theory, where the fungus turns into a functional parasite when it supplies negligible amounts of P to plants. A novel hypothesis suggests that growth depressions are instead caused by P limitation. Suppressed growth also occurs in some seedlings, which link into a pre-established mycorrhizal network. That is in poor agreement with the conventional dogma on mycorrhizal networks as nutrient sources for establishing seedlings. This talk will report on experiments designed to gain a better understanding of the mechanisms behind the apparent paradoxes in mycorrhizal functioning. Two phosphate (Pi) uptake routes are present in AM plants: the mycorrhizal pathway and the direct pathway. The mycorrhizal pathway can be dominating even when Pi uptake and plant growth is unaffected and this implies that the direct Pi uptake is reduced. We use the non-responsive' model grass, Brachypodium distachyon to investigate the hypothesis that growth-suppressed mycorrhizal plants will become P limited when the reduction in direct Pi uptake is not fully compensated by the 'hidden' Pi uptake via the mycorrhizal pathway. We aim to identify key components in the interplay between the two pathways and investigate the potential of increasing the direct Pi uptake in mycorrhizal plants through manipulation of key signaling components. Performance of seedlings of tomato and B. distachyon was studied in compartmented growth units containing pre-established mycorrhizal plants and their extraradical mycelium (ERM). Growth and nutrient uptake was reduced in seedlings linking into the ERM. Treatments including excision of 'donor' shoots and of ERM connections between 'donor' and seedlings led to the conclusion that network P predominantly ended up in the large plant and was poorly available to the seedling. It appears that P in the ERM is translocated towards the main carbon source of the fungus. Unraveling the mechanisms behind unexpected P deficiency in AM plants may open new perspectives for use of mycorrhizas in agroecosystems. Firstly, the Pi uptake efficiency of crops might be improved if a high activity of the direct uptake pathway in mycorrhizal plants is maintained, thereby making the two pathways additive instead of complementary. This may become real if key regulatory components in the interplay between the pathways are identified and used in plant breeding. Secondly, initial network-induced repression of the seedling may turn into increased fitness when the large plant is removed and the nutrient pool in the mycelium gets readily available. This would be the case in intercropping systems with time-displaced harvest of the species involved.

Keywords: growth depressions, phosphate transporters, seedlings, mycorrhizal network