N and P limitation shapes plant-AMF interactions across an aridity gradient

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Arbuscular mycorrhizal fungi (AMF) are important partners in plant nutrition, as they increase the range to scavenge for nutrients and can access resources otherwise occlude for plants. Under water shortage, when mobility of nutrients in soil is limited, AMF are especially important to acquire resources and can modulate plant drought resistance. Strategies of plants to cope with water and nutrient restrictions are shaped by the intensity of aridity. To investigate the effect of aridity on plant-AMF associations regarding drought resistance and plant nutrient acquisition, a 13CO2 pulse labeling was conducted across an aridity gradient. In a semiarid shrubland (66 mm a⁻¹), a Mediterranean woodland (367 mm a⁻¹), and a humid temperate forest (1500 mm a⁻¹), root and soil samples were taken from 0-10 cm and 20-30 cm soil depth before labeling and at 1 day, 3 days, and 14 days after labeling. Carbon (C), nitrogen (N), and phosphorus (P) stocks as well as AMF root colonization, extraradical AMF biomass (phospho- and neutral lipid fatty acids (PLFA and NLFA) 16:1w5c), specific root length (SRL), and root tissue density (RTD) were measured. Plant C investment into AMF and roots was determined by the 13C incorporation in 16:1w5c (PLFA and NLFA) and root tissue, respectively. Soil C:N:P stoichiometry indicated a N and P limitation under humid conditions and a P limitation in the topsoil under Mediterranean conditions. N stocks were highest in the Mediterranean woodland. A strong correlation of the AMF storage compound NLFA 16:1w5c to C:P ratio under semiarid conditions pointed to a P limitation of AMF, likely resulting from low P mobility in dry and alkaline soils. With increasing aridity, the AMF abundance in root
(and soil) decreased from 45% to 20% root area. $^{13}$C incorporation in PLFA 16:1w5c was similar across sites, while relative AMF abundance in topsoil (PLFA 16:1w5c:SOC) was slightly higher under semiarid and humid than under Mediterranean conditions, pointing to the importance of AMF for plant nutrition under nutrient limitation. Additionally, PLFA 16:1w5c contents in soil were higher with lower P availability in each site, underlining the role of AMF to supply P for plants under P deficiency. Under humid conditions (with strong N and P limitation) and semiarid conditions (with strong water limitation), root AMF colonization increased with lower N availability, displaying the role of AMF for plant N nutrition under nutrient and/or water shortage. Under humid and Mediterranean conditions, SRL decreased (0.5 and 0.3 times, respectively) and RTD increased (1.9 and 1.7 times, respectively) with depth, indicating a drought tolerance strategy of plants to sustain water shortage. Under semiarid conditions, SRL increased with depth (2.3 times), while RTD was consistently high, suggesting an increasing proportion of long-living fine roots with depth as scavenging agents for water. These relations point to a drought avoidance strategy of plants as adaptation to long-term water limitation. Under strong nutrient limitation, as under humid and semiarid conditions, AMF are crucial to sustain plant nutrition and to enhance plant resistance to water shortage.