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Drought as a modifier of interaction between adult beech and spruce - impacts on tree water use, C budgets and biotic interactions above- and belowground

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Understanding biotic interactions among tree species with their microbial associates under drought will be crucial for silviculture in meeting ecological challenges of the future. This contribution gives an overview on a project integrating a throughfall-exclusion experiment (TEE) on adult trees with a natural precipitation gradient (PGR) in central European forests. Focus is on drought affecting species interaction above and belowground, including associated ectomycorrhizal (ECM) communities. Study objects are pure and mixed forests dominated by adult European beech and Norway spruce trees (c. 70-years old). At the throughfall-exclusion experiment (TEE), trees are readily accessible via scaffolding and canopy crane (Kranzberg Forest, southern Germany). Effects of experimentally induced, repeated summer drought are assessed with roughly 100 trees assigned to a total of 12 plots (Kranzberg forest ROOF experiment, kroof.wzw.tum.de). The summer drought treatment started in 2014 and was repeated in 2015 and 2106. The focus on species interaction is intensified by a parallel study along a natural precipitation gradient with plot triplets of monocultures and mixed cultures of European beech and Norway spruce at each of the five study sites. Complementary resource use, effects of competitive vs. facilitation and related changes in ECM communities are exemplified for the two tree species of contrasting foliage (i.e. deciduous vs. evergreen) and stomatal sensitivity to drought (i.e. an-isohydric vs. isohydric behavior).
At the TEE site, precipitation throughfall was completely excluded from early spring to late fall (i.e. March to November), resulting in pre-dawn leaf water potentials of both beech and spruce as low as -2.5 MPa. Despite significant reductions in growth and rate of photosynthesis by up to 80% under drought, NSC budget of trees was hardly affected. Moreover, phloem functionality, tested as phloem transport velocity through 13C-labeling of recent photoassimilates, remained unaffected. The link between photosynthesis and stem cellulose (DBH) was assessed based on natural abundance of delta13C and delta18O. Under drought, mixing of recent photoassimilates with older carbohydrates during phloem transport significantly affected isotopic signatures of transported sucrose, diminishing the impact of drought. A quantitative relationship of this mixing effect (i.e. uncoupling of photosynthetic fractionation at the leaf level and isotopic signatures in stem cellulose) was established. Belowground, a distinct decline in fine root biomass, in particular in spruce, was observed. Along that line, repeated summer drought affected species composition of associated ECM fungi in both species. In particular, changes of ECM exploration types (i.e. contact/short-distance vs. long distance) may be related to C shortage of trees.
Along the natural precipitation gradient (PGR), basal area increment of tree stems (DBH) was related to 13C discrimination in tree rings. Carbon isotope signatures proved to be a more sensible indicator of tree responses to drought that BAI. Sensitivity of trees was significantly affected by growth conditions, i.e. growth in mono- vs. mixed culture. Higher drought resistance was displayed by spruce on drier sites (i.e. habituation effect) and, conversely, by beech on moist sites, in particular when grown in mixture with spruce.