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Tree species related functional properties of dissolved and total organic matter in throughfall, stemflow and forest floor solutions

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The amount and chemical nature of water-bound organic matter is a prerequisite for advancing our understanding of the C and nutrient cycling and associated ecosystem processes. While many investigations have addressed the nature and dynamics of DOM in terrestrial ecosystems, only a few have investigated the dynamics and composition of water-bound total OM (TOM) including the particulate organic matter fraction (POM; 0.45 μm < POM < 500 μm). Since water-bound element and nutrient concentrations are conventionally measured after 0.45 μm-filtration, the exclusion of the POM fraction results in misleading inferences and budgeting gaps of nutrient and energy fluxes in terrestrial ecosystems. Furthermore, tree species differ in leaf composition (e.g. nutrient, polyphenols content) and leaf litter quality, which in turn affect a variety of ecosystem processes. Nevertheless, the composition and amount of DOM and TOM derived from living plant material via throughfall (TF), stemflow (SF) and its compositional fate traversing the forest floor (FF) are insufficiently understood. In particular we asked: How do tree species and forest types affect the amount of dissolved and particulate C and N in TF and FF solutions and thus the input into the mineral soil? Do functional properties (e.g. aromaticity) of DOM and TOM differ in TF, SF and FF solutions collected in beech and spruce stands and among different beech stands across Germany?

To monitor (mineral) soil input fluxes of DOM and POM in different spruce and beech forests, we fortnightly sampled TF and FF solution over three years (2010-2012) in the “Hainich-Dün-Exploratory”, Thuringia, Central Germany, which forms part of the DFG SPP 1374 "Exploratories for Large-scale and Long-term Functional Biodiversity Research“. To characterize chemical properties of DOM and TOM, we applied solid-state 13C NMR spectroscopy to TF, SF and FF solutions from three European beech regions across Germany and from Norway spruce sites of the Hainich-Dün-Exploratory.

Fluxes of POC and PN were highly variable between years and added significantly to the annual budgets of DOC and DN in TF and FF solutions especially in beech forests. The non-consideration of these particle-bound element fluxes remarkable underestimates the TOC input to the soil by 30 to 40% and those of TN by 10 to 20%. We therefore emphasize the imperative to include POC and PN fluxes into C and N budgeting of forest ecosystems.

13C NMR spectroscopy revealed remarkable tree-species related differences in the composition of DOM and TOM. Compared to DOM, TOM generally showed higher intensities for the alkyl C region and lower ones for lignin-derived and aromatic C of the aryl C region resulting in lower aromaticity indices and a diminished degree of humification. Differences in the structural composition of DOM and TOM under beech lessened in the order: throughfall > stemflow > forest floor leachate.

Compared to spruce, TF DOM under beech concordantly showed the highest intensities of aromatic and phenolic C and lowest ones of alkyl-C. Phenolic compounds are known for their allelopathic potential successfully impairing competing plants and hence altering ecosystem structure and functions - mechanisms being still imperfectly understood.