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Isotopic heterogeneity in woody stems revealed by a new water extraction technique

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Recent field studies, and also controlled experiments with potted plants, have revealed isotopic offsets between bulk water from plant twigs or stems and any mixture of potential water sources, questioning the use of water stable isotopes to trace the origin of water used by plants. Observed isotopic offsets between bulk stem water and its potential water sources suggest that either isotopic fractionation is occurring at the soil-root interface and/or during plant internal water transport and redistribution. In the latter case, plant internal water storage and xylem vessels should deploy different isotopic compositions. To test this hypothesis, we extracted water from xylem vessels separately from other stem water pools, using a novel technique based on the flow-rotor method known as Cavitron. This method consists in spinning 40 cm-long stems to create a preset negative pressure at the center of the stem, down to –8 MPa. Xylem emboli expand from the center of the stem and the centrifuge force water to move along the axis of the xylem vessels and finally, out of the stem. Expelled water is collected in a cuvette and stored within minutes for subsequent isotopic determination. The cavitated stem was then use to extract the remaining water pool (extra-xylem) through cryogenic vacuum distillation. We systematically applied this method during a growing season in a beech forest (Fagus sylvatica), along with cryogenic extractions of bulk stem water from different intact segments of the same branches used for the Cavitron. Soil water, groundwater and streamwater were also collected and measured for the entire growing season. In order to have a better understanding of the information provided by the Cavitron water extraction method, we also conducted a manipulative experiment. Stems of F. sylvatica, Quercus robur and Pinus pinaster collected from the field were exposed to a second cycle of extraction, by refilling the cavitated stems with artificially enriched water of known isotopic composition. The results from both the field campaigns and from the manipulative experiment revealed that there is isotopic heterogeneity within woody stems, in all 3 tree species. The physiological and ecohydrological significance of the mechanisms behind this isotopic heterogeneity will be discussed in the context of the isotopic offsets between bulk stem water and subsurface water pools.