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'Biological noise' and (paleo)hydrological information in leaf wax lipid D/H ratios – insights from transect studies and greenhouse experiments

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Leaf wax lipid D/H ratios (expressed as δD values) are increasingly being employed as paleohydrological proxies and are usually interpreted solely as recorders of changes in precipitation D/H ratios. However, leaf wax lipid δD values of modern plants show complex relationships with source water δD. It has been hypothesized that soil and leaf water isotope enrichment due to evaporation and plant transpiration also affect leaf wax lipid δD values. Additionally, plant physiological properties that change in response to environmental variables may affect the H isotope composition of leaf wax lipids. Furthermore, the exact (seasonal) timing of leaf wax lipid synthesis and possible wax removal and replacement are unknown but necessary to predict the integration time of the recorded environmental signal. Hence, the lack of a mechanistic understanding of the processes potentially influencing leaf wax lipid δD values apart from precipitation δD currently prevents the application of biomarker D/H ratios as a quantitative paleohydrological proxy.

To better understand how the major environmental parameters and plant physiological processes influence the δD values of terrestrial biomarkers we performed various experiments, where we studied modern plants over a seasonal cycle, along steep environmental gradients and conducted greenhouse experiments. Together our results suggest that leaf water enrichment is at least partly responsible for the observed seasonal variability in leaf wax n-alkane δD values. In greenhouse as well as field grown plants we found significant differences in the δD values of leaf wax n-alkanes from leaves of different leaf generations, while within one leaf generation values did not change significantly. We suggest that in these grasses and deciduous trees leaf wax n-alkane synthesis occurs mainly in a short period after leaf emergence, hence 'locking-in' the hydrological signal of this brief period. Plants grown along an altitudinal gradient on the Big Island of Hawaii exhibited variability in n-alkane δD values, which could not be explained by either differences in the δD values of precipitation, leaf water or soil water isotope enrichment. We suggest that temperature and/or the amount of global radiation may have an impact on the biosynthetic isotope fractionation between biosynthetic source water (leaf water) and leaf wax n-alkanes.
Depending on local site- and plant-specific characteristics these factors can introduce substantial variability or 'biological noise', not necessarily related to hydrological variability. However, over large spatial (and presumably temporal) scales hydrological variables are the major drivers of leaf wax lipid δD values. Such an improved understanding of the potential variables affecting leaf wax lipid δD values has now to be synthesized into mechanistic models which can provide a framework for a robust and quantitative paleohydrological interpretation of sedimentary leaf wax lipid δD values.