REFINEMENT OF ISOTOPIC FRACTIONATION IN PLANTS: A NEW INSIGHT INTO PHYSIOLOGICAL RESPONCE TO DRY-WET CONDITIONS

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Introduction

Stable hydrogen (δD) and carbon (δ^{13}C) isotopic compositions of plants and their products (e.g., *n*-alkanes) have long been employed as a potential powerful proxy to reconstruct hydrology (e.g., humidity) in paleoenvironments and paleoecosystems over a wide range of geological timescales. This is based on the stomatal regulation responses to water stresses (i.e., dry vs. wet), resulting in changes in the isotopic fractionations of plants. For instance, the decreasing stomatal conductance (*gs*) of plants in dry conditions leads both high δD and δ^{13}C values through either high evapo-transpiration or lack of CO_2 supply, or both during photosynthesis (e.g., Sachse et al., 2012). Thus, so far, we have simply conducted or interpreted that high and low isotope values mirror dry and wet conditions, respectively.

However, under overwatering conditions (e.g., submerged, waterlogging, etc.), unexplainable high δ^{13}C values were frequently found in both bulk and *n*-alkanes in plants leaves, although the δD values of *n*-alkanes were remained as low as typical wet conditions (e.g., Li and Sugimoto 2017; Chikaraishi and Naraoka 2007). This unusual expression of isotope values in plants under overwatering conditions therefore always leads to confusion and doubtfulness for the interpretion of isotope evidences in the study of paleoenvironments and paleoecosystems, especially for mesic areas, as simply the low δD values of *n*-alkanes indicate wet (or humid) conditions while and high δ^{13}C values indicate dry (or arid) conditions in sedimentary records.

To clarify this unusual expression between δ^{13}C and δD values in plants and associated physiological and environmental factors during carbon fixation, in the present study, we carried out a combined analysis of the δ^{13}C and δ^{15}N values in bulk leaves and of the δ^{13}C and δD values in *n*-alkanes, for the leaves of *Salix* species collected from four different hydrological regimes (i.e., dry, wet, sporadic waterlogging, and long-period waterlogging) in three transects along Indigirka river, Northeastern Siberia.

Results and Discussion

We reveal that the δ^{13}C values of *Salix* vary among the different hydrological status, which can be explained by: (i) the δ^{13}C values are decreased from the dry (far from a river) to the wet (along a river bank) areas, because of the regular stomatal regulations; (ii) the values are once increased in frequently the waterlogged areas owing to stomatal closure; and (iii) the values are however again decreased in prolonged flooding periods, probably owing to the reduction of foliar photosynthetic activity under the long-period of waterlogging. The δ^{13}C values thus have not always a simple linier response in dry-wet conditions, as high values in both dry and sporadic waterlogging but low values in both wet and long-period waterlogging conditions.

On the other hand, the bulk foliar $\delta^{15}N$ values of *Salix* have a different trend with the $\delta^{13}C$ values, with negative values in both dry and wet conditions but positive values in both sporadic and long-period waterlogging conditions. Moreover, the δD values of *n*-alkanes have a simple linier response in dry-wet conditions, while their $\delta^{13}C$ values have almost the same trend to the bulk foliar $\delta^{13}C$ values.

These results demonstrate a clear separation among the four hydrological conditions on the multi-dimensional isotope plots, particularly in a cross-plot of the $\delta^{13}C$ and $\delta^{15}N$ values of bulk leaves (Figure 1). Also, combination analysis of the δD and $\delta^{13}C$ values of *n*-alkanes can distinguish at least the waterlogging from wet and long-period waterlogging conditions. Based on these results, we predict that the multi-dimensional isotope analysis (i.e., not only δD but also $\delta^{13}C$, especially for *n*-alkanes) will be useful to reduce considerably the confusion and doubtfulness in hydrology that is reconstructed by the molecular isotope evidences from sedimentary records.

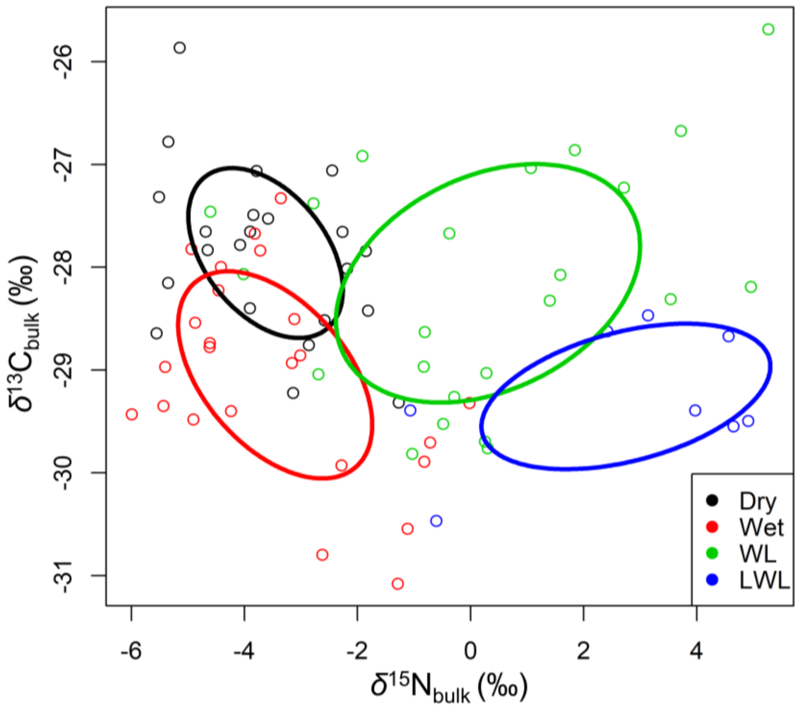

Figure 1 *The bulk $\delta^{13}C$ and $\delta^{15}N$ values in leaves of Salix species collected from four different hydrological regimes (i.e., dry, wet, waterlogging, and long-period waterlogging) in three transects along Indigirka river, Northeastern Siberia. The cycles in black, red, green, and blue represent the water conditions: dry, wet, sporadic waterlogging (WL), and long-period waterlogging (LWL), respectively. The statistical analysis was conducted in R with "Siar".*

References

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