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The contribution of diffusion processes and leaf temperature variations to the spatial distribution of leaf water isotopes.

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The analysis of leaf water isotopes can provide insight into the movement of water in the plant-atmosphere system at a number of levels. During transpiration the isotopic composition of leaf water (the ^{18}O/^{16}O ratio, or $\delta^{18}\mathrm{O}_{lw}$) becomes enriched, as light water molecules tend to evaporate more rapidly. The extent of isotopic enrichment at the evaporation site depends mainly on leaf temperate and air humidity, and the impact of this localized enrichment on bulk leaf water depends on the interplay between the advection of initially unenriched source water in the transpiration stream and the back-diffusion of enriched water through the mesophyll and vein compartments. Hence the spatial distribution of $\delta^{18}\mathrm{O}_{lw}$ will depend on factors affecting the relative strength of the advection and diffusion processes, such as resistances, gradients, flow paths and distances. Analysis of the isotopic composition of leaf water can therefore be used to develop and test models of water movement through leaves. Furthermore, the transpiration flux from these enriched leaf water pools contributes to variations in isotopic composition of ecosystem water vapour, and combining isotopic measurements with appropriate models are necessary for interpreting fluctuations in atmospheric signals and partitioning biosphere-atmosphere evapotranspiration exchange into soil and plant water flux contributions.

In this study, we followed the change over time in the $\delta^{18}\mathrm{O}_{lw}$ of corn leaf sections in plants grown under controlled conditions during a transition from steady-state transpiration in the light to minimal transpiration under dark conditions. The observed $\delta^{18}\mathrm{O}_{lw}$ patterns were then interpreted using a transient advection-diffusion model of leaf water isotopic enrichment that incorporates both longitudinal and radial diffusion dimensions. Transverse leaf sections were sampled for isotopic analysis in the light and over the course of hours following transfer to dark conditions. Progressive enrichment was observed along the leaf from base to tip, typically reaching a maximum enrichment of 6-10‰ at about 60% of the total leaf length in the leaf lamina. Separated leaf midrib veins also displayed a longitudinal enrichment of 2-7‰Ẇhen a constant humidity was maintained between light and dark periods, the spatial patterns of $\delta^{18}\mathrm{O}_{lw}$ in the lamina mesophyll did not change significantly, but there was a tendency for a shift back towards a lower base-to-tip gradient in the midrib water over time, increasing the midrib-lamina difference. The model was able to successfully reproduce the isotopic distribution along the leaf segments, with leaf temperature and mesophyll tortuosity being key parameters for accurate simulations. Spatial variations of leaf temperature along the leaf blade caused by leaf angle distribution and local microclimate were also critical, which has implications for studies at larger scales.