

## High-resolution carbon and oxygen isotope profiles of tropical and temperate liana species

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### Introduction

Previous studies on high-resolution isotope measurements in wood have found a remarkable annual cyclicity in the isotope profile and this for temperate as well as tropical tree species (Schleser et al. 1999, Helle and Schleser 2004, Helle et al. 2004, Verheyden et al. 2004). The presence of this annual cyclicity offers great potential for tropical dendrochronology in general. Indeed, if these results can be confirmed in other tropical tree species, the annual isotope signal can be used to identify annual tree ring boundaries in trees that do not produce anatomical tree ring boundaries (a problem commonly encountered in tropical trees) (Verheyden et al. 2004). However, the high-resolution isotope profiles could not entirely be explained by changes in environmental conditions. Previous investigations suggested that the isotope signal is probably the result of a post-photosynthetic signal on which the environmental signal is superimposed (Helle and Schleser 2004, Verheyden et al. 2004). In this context, the post-photosynthetic signal is defined as the signal resulting from additional fractionations occurring after leaf sugar synthesis, such as fractionations involved in the storage and remobilization of starches. If high-resolution isotope profiles are to be used for dendrochronological purposes, two fundamental questions need to be answered: 1) is the annual cyclicity in the isotope profile a universal pattern and 2) can the environmental signal be separated from the post-photosynthetic signal(s)?

In this study, the high-resolution stable carbon and oxygen isotope profiles of three liana species were investigated to contribute to the growing knowledge on changes in the intra-annual isotopic composition of tree rings. More specifically, the aim of this study was to 1) investigate whether there is a periodicity in the high-resolution stable isotope profiles in tropical and temperate liana species, 2) compare the isotope profiles of a tropical evergreen, a temperate evergreen and a temperate deciduous species, 3) compare the oxygen and carbon isotope profiles.

### Materials and Methods

Three liana species were investigated: the temperate evergreen *Hedera helix* (Fam. Araliaceae), the temperate deciduous *Clematis vitalba* (Fam. Ranunculaceae) and the tropical evergreen *Tetracera alnifolia* (Fam. Dilleniaceae). *H. helix* and *C. vitalba* were collected on 14 November 2004 in Zavelenberg, Sint-Agatha-Berchem, Belgium. *T. alnifolia* was collected

in 1989 from the Kouilou region, Republic of Congo. All samples are now part of the Royal Museum for Central Africa, Tervuren, Belgium. From each sample, a series of tangential wood slices of 20 to 40  $\mu\text{m}$  thickness were obtained for isotope measurements using a fixed-blade sledge microtome (Polycut E, LEICA Microsystems, Bensheim, Germany). No cellulose extraction of the samples was performed, since many studies have reported a constant offset between the isotopic composition of bulk wood and cellulose (e.g. Livingston and Spittlehouse, 1996, Saurer et al., 2000, Helle and Schleser, 2004).

## Results and Discussion

### *Hedera helix*

Both, the stable carbon and oxygen isotope profiles of *H. helix* show an annual cyclicity (Fig. 1). The lowest  $\delta^{13}\text{C}$  value occurs at the tree ring boundary, after which a gradual increase takes place. The decrease in  $\delta^{13}\text{C}$  begins in the late stage of the growth ring formation (at approximately 2/3 of the ring width). The  $\delta^{18}\text{O}$  also shows a lowest value at the tree ring boundary, however, the highest value precedes the maximum of the  $\delta^{13}\text{C}$  value. In the year 2003,  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  show higher values than in the two other years (Fig. 1). These higher values are most likely caused by the severe drought that occurred in that year (Trigo et al., 2005). Furthermore, it is interesting to note that the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  pattern look very similar in 2002 and 2003, which indicates that both signals detain similar information during this time period, however the signals differ in 2004.

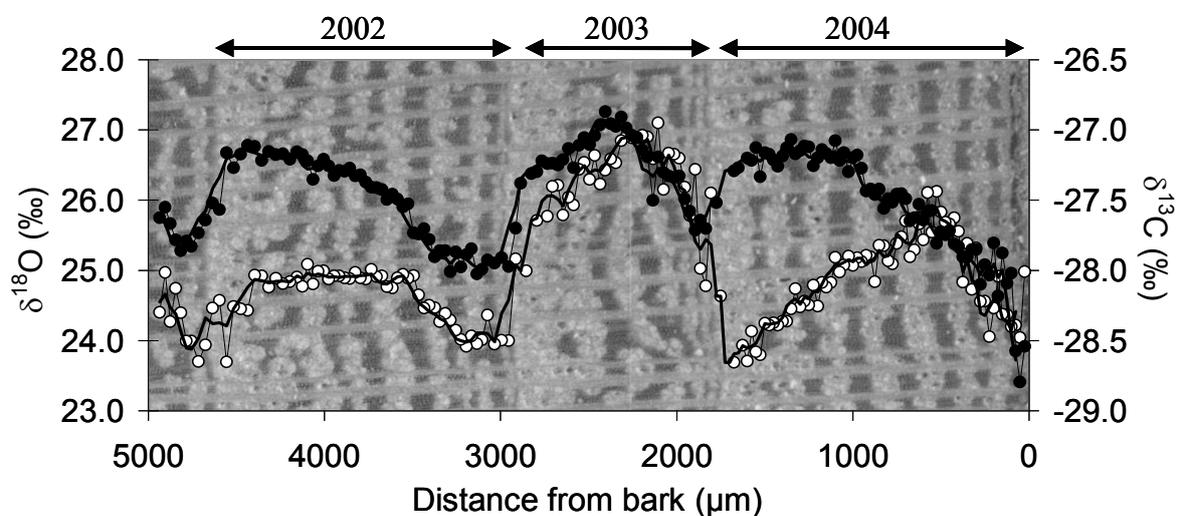


Figure 1: High-resolution stable oxygen (solid symbols) and carbon (open symbols) isotope profiles of *Hedera helix*.

### *Clematis vitalba*

Similar to the profiles of *H. helix*, the  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  profiles of *C. vitalba* also show an annual cyclicity (Fig. 2). However, the annual  $\delta^{13}\text{C}$  signal is strongly influenced by the 2003 drought, which probably also affected the year 2004. The  $\delta^{13}\text{C}$  pattern under more 'normal' environmental conditions is therefore, implied from the year 2002. The  $\delta^{13}\text{C}$  pattern of *C. vitalba* differs from *H. helix* in that the highest value and the consequent decrease in  $\delta^{13}\text{C}$  occurs in the earlywood and therefore, in an early stage of the growth ring formation, while a

more or less stable value is obtained in the latewood. Interestingly, this pattern has also been observed in *Quercus* spp. (Helle and Schleser, 2004). Both *C. vitalba* and *Quercus* spp. are ring porous and characterized by an abrupt difference between small vessels in the latewood and large vessels in the earlywood. Ring porous species are known to use stored carbohydrates to develop their earlywood vessels, prior to leaf emergence and therefore, prior to the production of new photosynthetic material (Aloni, 2004). This affects the  $\delta^{13}\text{C}$  profile in particular, as indicated by the high  $\delta^{13}\text{C}$  value in the earlywood of 2004, but not the  $\delta^{18}\text{O}$  profile, which is consistent with the results from Hill et al. (1995). Indeed, these authors found that the  $\delta^{13}\text{C}$  value of the earlywood was influenced by the previous year carbohydrates, while the  $\delta^{18}\text{O}$  value was not, due to exchange with current-year xylem water. The similarity in the isotope profiles of *C. vitalba* and *Quercus* spp. offers additional evidence that the shape of the  $\delta^{13}\text{C}$  profile is probably mainly controlled by post-photosynthetic processes. The  $\delta^{18}\text{O}$  signal has a lowest value in the vicinity of the tree ring boundary, while the highest value occurs in the latewood and therefore, is considerably different from the  $\delta^{13}\text{C}$  profile (Fig. 2).

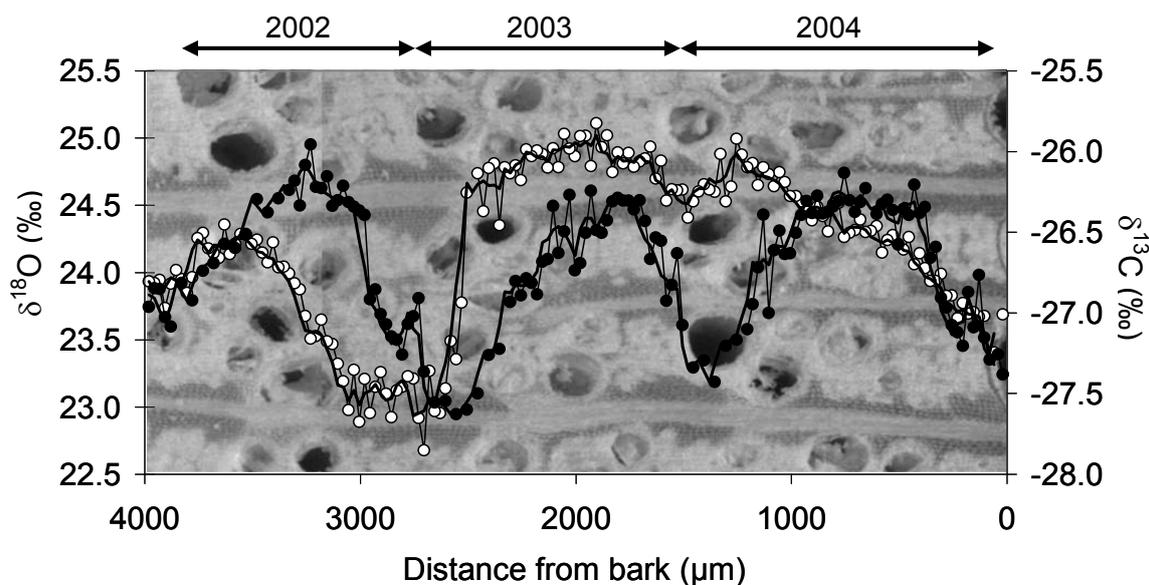


Figure 2: High-resolution stable oxygen (solid symbols) and carbon (open symbols) isotope profiles of *Clematis vitalba*.

#### *Tetracera alnifolia*

Similar to the temperate liana species, the isotope signal in this tropical species also shows considerable variation in the high-resolution profile (Fig. 3), with peak amplitudes (2 ‰) exceeding those observed in the temperate liana species (1.5 ‰). However, the isotopic composition of *T. alnifolia* was measured over a larger wood section (by a factor of about 3) as compared to the temperate liana species.

Although the *T. alnifolia* sample originated from a region with a distinct dry season of four months, no distinct growth ring boundaries could be identified, nor does the  $\delta^{13}\text{C}$  profile present the typical periodicity observed in other temperate and tropical trees (e.g. Helle and Schleser 2004, Helle et al. 2004, Verheyden et al. 2004). Due to the absence of distinct

growth ring boundaries, we can at this moment, not confirm whether the observed peaks are annual, nor can we exclude the possibility that the peaks reflect severe droughts which are known to occur in the region sporadically. Comparison of the peaks with particular anatomical features (Fig. 3) reveals only partial association of peaks with indistinct anatomical structures in the wood. These results illustrate that the use of high-resolution profiles for identification of growth ring boundaries in tropical woody plants is not straightforward and needs to be further confirmed in different species.

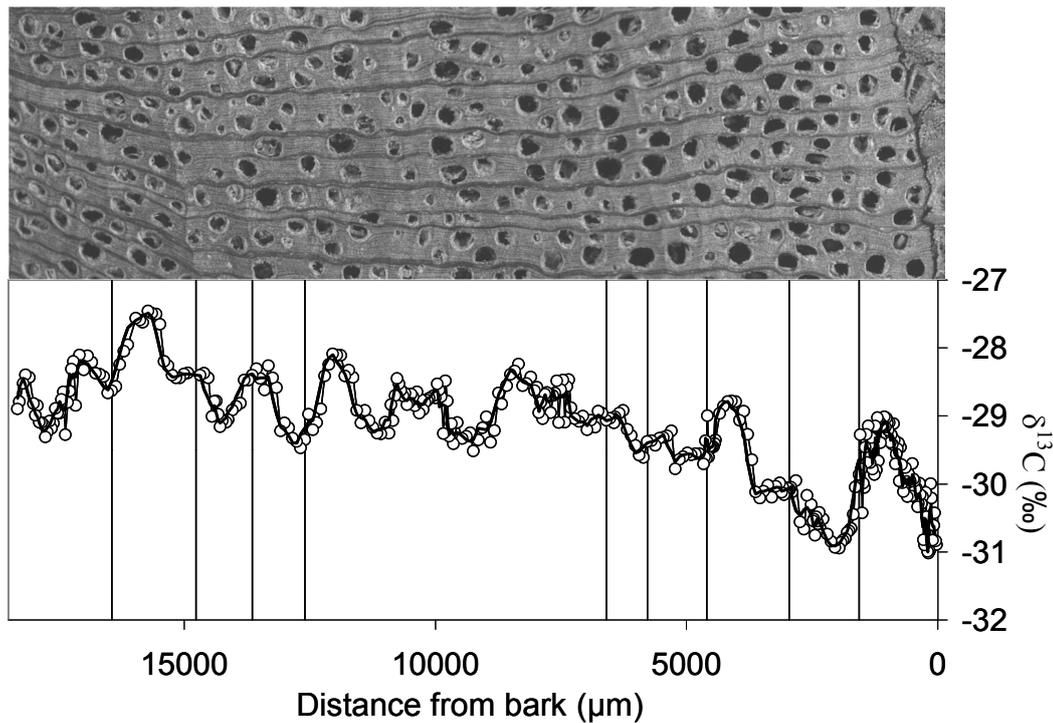


Figure 3: High-resolution stable carbon isotope profiles of *Tetracera alnifolia*. Vertical lines indicate position of observed indistinct anatomical features.

### Conclusions

The results from this study add evidence for the presence of an annual cyclicity in the isotope profiles of temperate woody plants. Although the annual cyclicity could not be proven in the evergreen tropical liana species, the considerable variation in the high-resolution isotope profile is remarkable for this species which shows relatively little variation in wood anatomical features. Furthermore, the results obtained here suggest that the shape of the profiles are species specific, but that they can be classified according to similarities in the pattern. Comparison of the profiles of different species, can then further give insight in the processes involved in the shaping of the profile as was observed here for *C. vitalba* and *Quercus* spp. Finally, the study clearly showed that, unlike the results obtained in other studies (Barbour et al. 2002, Verheyden et al. 2004), the  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  values do not give similar signals in the two temperate liana species, pointing to different causes of their formation.

## Acknowledgements

The authors would like to thank Dr. S. Godefroid from the Vrije Universiteit Brussel for collecting the temperate liana samples, W. Laumer, M. Schrimpf and G. Reiss of the Forschungszentrum Jülich, Germany, for their assistance during this work.

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