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The effect of drought on C and N stable isotopes in different fractions of leaves, stems and roots of sensitive and tolerant beech ecotypes

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ABSTRACT

Beech seedlings from 11 German climatic provenances were exposed to a realistically timed drought treatment in a greenhouse experiment. The stable isotope composition of carbon (C) and nitrogen (N) was analysed in pooled bulk material of roots, stems and leaves, as well as in the aqueous extracts and starch fractions. The $\delta^{13}C$ values increased in bulk samples (BS) of roots, stems and leaves by drought, although no leaf growth occurred during the experimental period. A clear drought effect on $\delta^{13}C$ in aqueous extracts was detected in leaves. In aqueous extracts of stems and roots as well as in starch fractions of all organs, abundance of $\delta^{13}C$ also tended to be increased by drought, but this effect was not statistically significant. For both $\delta^{13}C$ and $\delta^{15}N$, enrichment was observed from the site of uptake/source to the site of use/sink. A gradient for $\delta^{13}C$ in all fractions from leaves (–29.49, –28.89 and –27.85‰) to stems (–28.81, –27.48 and –26.98‰) and to roots (–27.60, –26.37 and –26.48‰) was detected in BS, aqueous extracts and starch, respectively. An opposite gradient for $\delta^{15}N$ was found in BS: 1.59‰, 1.84‰ and 3.05‰ in roots, stems and leaves, respectively. $\delta^{15}N$ was neither affected by drought in the BS nor in aqueous extracts, but an effect of provenance was observed. Particularly in roots and stems, drought-sensitive provenances showed the strongest shifts in $\delta^{13}C$ induced by drought and the lowest $\delta^{15}N$ values. In the present experiment, $\delta^{13}C$ values were more affected by the environmental factor drought, while $\delta^{15}N$ values were more affected by the genetic factor provenance.

Key-words: drought stress, *Fagus sylvatica*, isotope discrimination, provenances.

INTRODUCTION

Climate change models predict that increasing atmospheric CO_2 partial pressure will cause average surface temperatures to increase by 1–3.5 °C in mid-latitude regions during the next 100 years (Saxe, Ellsworth & Heath 1998; UNEP 1999). As a consequence, precipitation and evaporation patterns will change in Europe, and ecosystems will be exposed to more intense drought and heavy rain events in summer (IPCC 1997; UNEP 1999). Changing climatic conditions will become of particular importance for trees because of their long lifespan. Forests will face altered environmental conditions during their lifetime, with likely consequences for species composition and forest management (IPCC 1997; Saxe *et al*. 2001). Natural regeneration of the drought-sensitive European beech (*Fagus sylvatica* L.) – one of the most important deciduous tree species in Central Europe – may be significantly affected by such climate alterations, specially because the area of distribution includes sites with shallow limestone-derived soils with low water storage capacity (e.g. Schwäbische Alb, Fränkische Alb, Schweizer Jura and French Jura). Therefore, projected short summer drought periods caused by global warming may inhibit natural regeneration in critical habitats.

Owing to its sensitivity towards environmental constraints, $\delta^{13}C$ and $\delta^{15}N$ are now widely used to assess the effects of changing climatic condition on plant ecophysiology. However, a question that requires further research is which parts, tissues, chemical fractions or compounds of plants reflect the best particular biotic or abiotic conditions. Bulk materials have been isotopically analysed to provide physiological or environmental insights over the lifespan of the plant part sampled (see in review Adams & Grierson 2001; Evans 2001; Dawson *et al*. 2002). Specific individual compounds or groups of compounds such as water extractable C, cellulose, lipids, sugars and starch have been isotopically analysed to provide information about metabolism integrated over particular time integrals (Picon, Ferhi & Guehl 1997; Gleixner *et al*. 1998; Ghashghaie *et al*. 2001; Ponton *et al*. 2001; Terwilliger *et al*. 2001; Arndt & Wanek 2002; Barbour, Walcroft & Farquhar 2002; Damesin & Lelarge 2003). Leaf material is most commonly studied, but axial tissue has also drawn attention (Picon *et al*. 1997; Ponton *et al*. 2001; Arndt & Wanek 2002; Barbour *et al*. 2002; Damesin & Lelarge 2003; Fotelli *et al*. 2003). Not much is known about environmental effects on stable isotope abundance in the roots (Robinson *et al*. 2000; Emmerton *et al*. 2001; Arndt & Wanek 2002; Fotelli *et al*. 2003). Variations

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