The Enrichment of $^{18}$O in Leaf Water Under Natural Conditions

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Summary. The enrichment of $^{18}$O in the water of transpiring leaves under natural conditions is described. In the first series two, later three species at the same location and at the same time are compared (birch Betula pubescens L., oak Quercus robur Ehrh., larch Larix decidua Mill., and spruce Picea abies Karst). All four show parallel enrichment properties. In addition two beeches (Fagus sylvatica L.) were observed, one at Jülich, the other at the Solling hills. They show a similar $^{18}$O/$^{16}$O ratio fluctuation in their leaves during the time of observation. Three plant communities (beech forest B1, spruce forest F1, and meadow W, sites of the “Solling-Project”, German Research Foundation, part of International Biological Program, at the Solling hills) show a daily course of the $^{18}$O enrichment comparable to each other.

1. Introduction

The leaves of terrestrial plants contain water enriched in $^{18}$O compared to the soil water and to precipitation. This effect is already known for some years [1—4]. The enrichment is caused by the transport of water vapor from the liquid phase of the leaves to the gaseous phase of air humidity. The fact of the enrichment itself does not surprise, if one considers the separation of isotopes during distillation processes and within the natural water cycle [5, 6]. Surprising however is the change of the $^{18}$O/$^{16}$O ratio in leaf water during the day. A rapid increase of the $^{18}$O/$^{16}$O ratio during the morning is followed by a slow decrease during the afternoon and the night. This distinct diurnal fluctuation may be of methodological significance to researchers interested in the biogeochemistry of oxygen, the water turnover of terrestrial plants and the physiology of water transport in plants.

In an earlier paper [2] we emphasized, that the observed $^{18}$O enrichment of the leaf water should be reflected in the photosynthetically evolved oxygen. This fact could be important, if one considers the biogeochemical cycle of oxygen. If the assumption holds true, terrestrial plants produce oxygen of a higher $^{18}$O/$^{16}$O ratio than marine algae or submersed plants do. The measurement of the $^{18}$O/$^{16}$O ratio of
photosynthetic oxygen from terrestrial plants includes difficult technical and biological problems. The main problem is the low amount of oxygen from the plant in comparison to the amount of air oxygen within the experimental set up. Up to now all results published show that algae and submersed plants produce oxygen of the same $^{18}\text{O}/^{16}\text{O}$ ratio as the surrounding water has [7]. This does not imply, that the water must be the primary oxygen source. It may be, that the oxygen during or shortly after its release shows a rapid, may be catalyzed isotope exchange with the surrounding water.

Not only in biogeochemistry but also in ecology the diurnal cycle of the $^{18}\text{O}$ enrichment may be an important fact. If a correlation exists between the $^{18}\text{O}/^{16}\text{O}$ ratio of leaf water and the water turnover or the climate data the oxygen isotope measurement could be a new experimental tool.

The study of leaf water physiology may use the variation of the $^{18}\text{O}/^{16}\text{O}$ ratio as a "natural tracer", since the use of artificially enriched $^{18}\text{O}$ is very expensive, especially if one studies larger plants or plant communities.

Several diurnal variations of the $^{18}\text{O}/^{16}\text{O}$ ratio in leaf water have been published already, but a detailed comparison of species and habitats is still lacking.

2. Material and Methods

2.1 Material

Our first and our second series (series 1 and 2) was intended to compare the $^{18}\text{O}/^{16}\text{O}$ enrichment in leaf water of different species. This is only possible, if one observes trees of similar age at the same place. Under these conditions one may suppose, that the trees depend from the same environmental conditions, especially from the $^{18}\text{O}/^{16}\text{O}$ ratio of soil water and of atmospheric water vapour, as well as from the relative humidity and temperature of the air. We choose trees growing near the border of a small forest at the Nuclear Research Center Jülich, and from these twigs of south-western exposure. The leaves on these twigs got full irradiation without any shading during the whole day. The twigs under observation were 2 m above the soil, which made sampling easier during the night. The meteorological station of the Nuclear Research Center is close to the experimental site (sketch see Fig. 1).

The first series (series 1, September 6–7, 1973) included a small birch (*Betula pubescens* L.) and a small oak (*Quercus robur* Ehrh.), the second series (series 2, April 11–12, 1974) included a birch (*Betula pubescens* L.), a larch (*Larix decidua* Mill.) and a spruce (*Picea abies* Karst). These species represent three different types of trees: broad-leaf trees (oak, birch) a summergreen (larch) and an evergreen (spruce) conifer. Leaf samples were collected each half hour, samples of branches only five times during one series. Air water vapour was trapped at intervals of 1 h. During the first series three samples of roots and soil were taken. Air temperature and relative humidity were registrated beside the trees. The temperature and relative humidity data of the official meteorological station are not identical but very close to our recording.

The next two series (series 3 and 4) compared two beeches (*Fagus sylvatica* L.) at different places. One beech tree at the fringe of an older forest at the Nuclear