

The influence of temperature and relative humidity on $\delta^{13}\text{C}$ values of C_3 plants in growth chamber experiments

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Experimental setting and methods

Three different C_3 plant species (*Vicia faba* var. *minor* cv. Fribo, *Eucalyptus globulus* and *Brassica oleracea* var. *medullosa* cv. Grüner Ring) were cultivated under controlled conditions in four growth chambers at the phytotron facility at the GSF (Research Centre for Environment and Health) in Neuherberg (for description of the chambers see Payer et al. 1993). The experimental setting consisted of seven climatic conditions that differed in relative humidity and/ or temperature. The experiments were carried out in two series including the repetition of one climatic condition. Other climatic parameters than relative humidity and temperature (e.g. irrigation and radiation) were kept identical in all chambers.

CO_2 concentrations in each chamber were regularly controlled and air samples were taken for $\delta^{13}\text{C}$ -analyses. Both CO_2 concentration and $\delta^{13}\text{C}$ values of the air did not differ significantly between any of the chambers.

The plants were set to the growth chambers immediately after germination and further cultivated there for 56 days. After that period the plant material was harvested for isotopic analyses of dry organic matter ($\delta^{13}\text{C}$), cellulose nitrate ($\delta^{13}\text{C}$, $\delta^2\text{H}$) and plant water ($\delta^{18}\text{O}$, $\delta^2\text{H}$). Here only results from $\delta^{13}\text{C}$ analyses of cellulose nitrate are discussed. Cellulose nitrate was prepared from dried stem material using standard methods (Epstein et al. 1976). Cellulose nitrate was combusted in vacuo in glass tubes in the presence of copper and copper oxide and the resulting gases were separated cryogenically in a preparation line (Stichler et al. 1982). The purified CO_2 was trapped in an ampoule and isotope ratios were determined with an IR-mass spectrometer (Delta-S, Finnigan MAT, Germany). The analytical error including the preparation of cellulose nitrate was 0.1‰ (one standard deviation).

Results and discussion

The $\delta^{13}\text{C}$ values of cellulose nitrate extracted from the stems differed by up to 4.7‰ (*Brassica*) between plants grown under different climatic conditions. The experiment clearly demonstrated that both temperature and relative humidity had an influence on the stable carbon isotope ratios of the C_3 plants. All examined species showed a similar $\delta^{13}\text{C}$ response: the most negative isotope values were observed within the plants cultivated under high relative humidity and high temperature (climate conditions 3 and 2 in Table 1), the most positive $\delta^{13}\text{C}$ values within those grown under cold and dry conditions (conditions 6, 5 and 4/8).

Table 1. The $\delta^{13}\text{C}$ values of cellulose nitrate extracted from stems of the species cultivated in the experiments under the given climate conditions.

“Climate condition”	Temperature in °C	Rel. humidity in %	$\delta^{13}\text{C}_{\text{Brassica}}$ in ‰	$\delta^{13}\text{C}_{\text{Eucalyptus}}$ in ‰	$\delta^{13}\text{C}_{\text{Vicia}}$ in ‰	
1	24	49	-30.04 ± 0.51	$-29,50 \pm 0,36$	-28,12	±
2	24	68	-31.64 ± 0.73	$-30,78 \pm 0,24$	-28,43	±
3	30	48	-32.30 ± 0.27	$-30,35 \pm 0,36$	-29,83	±
4	18	32	-28.38 ± 0.52	$-28,86 \pm 0,48$	-25,13	±
5	24	21	-27.95 ± 1.24	$-28,11 \pm 0,61$	-25,62	±
6	14	24	-26.93 ± 1.13	$-28,45 \pm 0,10$	-26,11	±
7	14	50	-28.37 ± 0.43	$-28,80 \pm 0,41$	-26,86	±
8	18	32	-27.87 ± 0.72	$-27,91 \pm 0,38$	-25,68	±

Three climatic conditions had identical temperature (24°C) but differing relative humidity (climate conditions 1,2,5), three other conditions had almost the same relative humidity (~50%) but different temperatures (climate conditions 1,3,7). The $\delta^{13}\text{C}$ values were approximately linearly correlated with temperature as well as with relative humidity (see Fig. 1 and 2). Both increasing temperature and increasing relative humidity resulted in decreasing $\delta^{13}\text{C}$ values. The negative correlation coefficients between $\delta^{13}\text{C}$ values and temperature found in the experiment are in contrast to a variety of field studies, in which positive correlations with temperature were observed, but are in agreement with various experimental results (see e.g. review of Schleser et al. 1999). The discrepancy with field studies may be explained by the intercorrelations of climate parameters under natural conditions. The $\delta^{13}\text{C}$ signal in plant material is a composite signal that reflects humidity and temperature conditions as well as water availability and radiation status

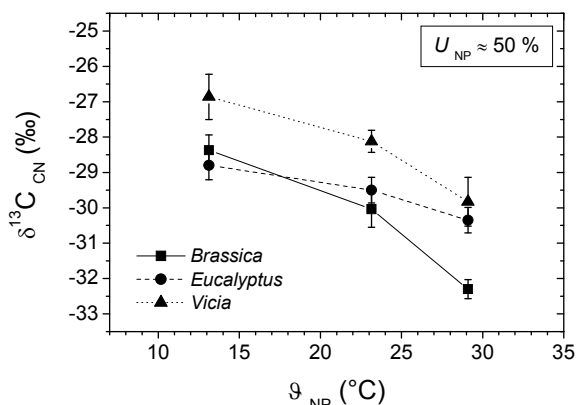


Fig. 1. $\delta^{13}\text{C}$ values of stem cellulose nitrate of plants cultivated under the same relative humidity (~50%) but with different temperature (mean values of five individuals and standard deviation of the mean for each data point).

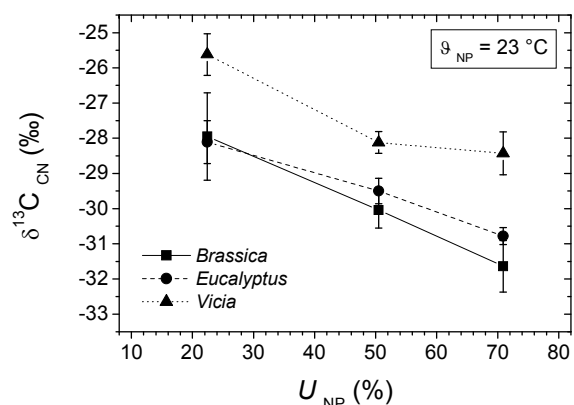


Fig. 2. $\delta^{13}\text{C}$ values of stem cellulose nitrate of plants cultivated under the same temperature (23°C) but with different relative humidity (mean values of five individuals and standard deviation for each data point).

The climate mode and the “ $\delta^{13}\text{C}$ sensitivity” to each of these parameters should determine the $\delta^{13}\text{C}$ value in the end. An example of the effect of water availability on the $\delta^{13}\text{C}$ values of plants is provided by an experiment with *Vicia faba* carried out by Lipp et al. (1997). The plants were cultivated under two different irrigation levels with other climatic parameters being identical. In that experiment the plants with drought stress had 1.5 to 3.0‰ more positive $\delta^{13}\text{C}$ values than those supplied with high irrigation (Mayr et al. in press).

Relative humidity and temperature are generally negatively correlated with each other in Middle European summer climate. Provided that full-grown trees have similar $\delta^{13}\text{C}$ responses to relative humidity and temperature as the plants used in the experiment, both parameters should weaken or even cancel each other out in their influence on $\delta^{13}\text{C}$ values. This may explain, why $\delta^{13}\text{C}$ values of tree rings are often best correlated with another climate parameter, namely with summer precipitation sum, especially at relatively dry Mid-European sites (Saurer et al. 1995, Mayr et al. in press).

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