Carbon isotope ratio in street tree leaves: An indicator for the environmental assessment of the atmosphere

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When plants fix atmospheric CO_2 according to the process of photosynthesis, carbon isotope fractionation associated with carboxylation and diffusion occurs. Therefore, plants are enriched in ^{12}C relative to the atmosphere. The isotopic discrimination between plants and atmospheric CO_2 is shown in the following equation (after Farquhar *et al.*, 1989), written as:

$$\delta^{13}C_p = \delta^{13}C_a - (4.4 + 22.6 \times C_i/C_a)$$

where $\delta^{13}C_p$, is the isotope ratio of plants, $\delta^{13}C_a$ the isotope ratio of atmospheric CO_2, C_i the internal gas-phase concentration Of CO_2, and C_a the external CO_2 concentration. When isotope discrimination between plants and atmospheric CO_2 is established, the leaf carbon isotope ratio depends on that of the CO_2 in the air. The C_i/C_a ratios of plants, however, change according to the long-term water stress. For example, the ratios vary from 0.64 to 0.40 for *Zelkowa serrata* due to soil water content (Takahashi, 1995). Leaves exhibit more positive $\delta^{13}C$ values under stressed conditions, values changing by as much as 5.4‰. When there is no stress on urban street trees, the concentration and origin of atmospheric CO_2 can be estimated from the relationship between the ratios of leaves and CO_2 in the air. *Z. serrata* leaves from street trees in Toyama City were collected during September 1996, and the associated carbon isotope ratios were measured.

TABLE 1. Carbon isotope ratios, and the carbon and nitrogen content of *Zelkowa* leaves along Sakuradori Steet in Toyama City during September 1996

Sample no.	Carbon wt.%	Nitrogen wt.%	$\delta^{13}C$
ZS-01	46	2.1	−31.6
ZS-02	47	1.8	−32.4
ZS-03	45	1.7	−31.4
ZS-04	44	2.1	−31.7
ZS-05	47	1.8	−32.0
ZS-06	47	1.9	−32.0
ZS-07	47	2.1	−30.1
ZS-08	47	2.1	−32.2
ZS-09	42	1.6	−29.7
ZS-10	47	1.9	−31.2
ZS-11	49	1.8	−30.0
ZS-12	41	2.1	−30.5
ZS-14	47	2.1	−30.8
ZS-15	43	1.8	−32.4
ZS-16	46	1.8	−30.8

The concentrations of atmospheric CO_2 collected at street crossings were measured by an FID gas chromatograph. The carbon isotope ratios Of CO_2 in the Toyama City air were obtained from the street crossing values according to the relationship between the carbon isotope ratio and the concentration of atmospheric CO_2 as discussed by Kitano (1988). The *Z. serrata* leaf carbon isotope ratios were obtained in order to judge the stress due to water availability. This resulted in an averaged $\delta^{13}C$ value of −30.5‰. Since the leaf $\delta^{13}C$ values of trees along Sakuradori Street ranged from −32.4‰ to −29.9‰, there was no stress associated with the street plants. In this case, the *Z. serrata* leaf $\delta^{13}C$ value should have been constant, but the present value varied. At the sampling point of present study, there were no differences in meteorological conditions, such as relative humidity and light intensity, that would have caused the change in the isotope ratio. Variations in $\delta^{13}C$ values of *Z. serrata* depend on those of the CO_2 in the air and reflect the change in the atmospheric CO_2. Assuming that the correlation of the $\delta^{13}C$ value for plants versus those of atmospheric CO_2 has been established,the $\delta^{13}C$ values Of CO_2, except for those at street crossings, were estimated to range from −13.5‰ to −11.0‰. The CO_2 concentration at each street crossing increased as the traffic increased. That is, as the $\delta^{13}C$ values of atmospheric CO_2 became more negative, the street tree leaves exhibited more negative $\delta^{13}C$ values. Therefore, since the atmospheric CO_2 content can be estimated by measuring leaf $\delta^{13}C$ values, the traffic along each street was presumed. Assuming that the street trees were under no stress, such as water deficiency, the behaviour of urban atmospheric CO_2 can be clarified from the examination of the leaf $\delta^{13}C$ values for all city street trees. From the *Zelkowa* leaf nitrogen content, it was determined that all of these plants were nutritionally deficient. Since the stress due to nutrition deficiency, however, did not affect the leaf $\delta^{13}C$ values (Takahashi, 1995), it was not responsible for the variation in isotope ratios. Therefore, the variations were due to variations in atmospheric CO_2.

References

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