

This Week's Citation Classic

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Smith B N & Epstein S. Two categories of $^{13}\text{C}/^{12}\text{C}$ ratios for higher plants. *Plant Physiol.* 47:380-4, 1971. [Division of Geological Sciences, California Institute of Technology, Pasadena, CA]

$^{13}\text{C}/^{12}\text{C}$ ratios have been determined for plant tissue from 104 species representing 60 families. Higher plants fall into two categories, those with low $\delta^{13}\text{C}$ values (-24 to -34‰) and those with high $\delta^{13}\text{C}$ values (-6 to -19‰). Algae have $\delta^{13}\text{C}$ values of -12 to -23‰. Photosynthetic fractionation leading to such values is discussed. [The *SCI*[®] indicates that this paper has been cited over 155 times since 1971.]

Bruce N. Smith
Department of Botany and
Range Science
Brigham Young University
Provo, UT 84602

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"In 1965 I went to Caltech to work with Sam Epstein as a research fellow in geochemistry. My purpose in going was to learn stable isotope techniques which Epstein pioneered. His help and discussions were essential to the development of the paper. These techniques were in wide use in geology, but had just been introduced to biological systems. I first wanted to work with deuterium to hydrogen (D/H) ratios and collected a number of samples from a marine salt marsh.¹ The D/H ratios of the plants and animals reflected the ground water where they were collected. However, the carbon isotopic ratios ($^{13}\text{C}/^{12}\text{C}$) of plants grown side by side often differed by 10‰! Why should $^{13}\text{C}/^{12}\text{C}$ ratios be so much more variable than D/H ratios in the same material? A careful perusal of the isotopic literature indicated that a few odd carbon values had been reported over the years. I then began collecting

and analyzing all of the identified plant material I could find. Taxonomy was never my strong suit so I wandered through the Los Angeles County Arboretum, the Huntington Memorial Gardens, Rancho Santa Ana Botanical Gardens, University of California at Berkeley Botanical Gardens, etc., collecting small samples from labeled plants. (It wasn't until much later that I discovered herbariums.) I then tried to make some kind of phylogenetic sense out of the data. It seemed that (except for algae and aquatic plants) most plant tissues had $\delta^{13}\text{C}$ values between -23 to -34‰ vs. PDB, while some monocots and dicots had $\delta^{13}\text{C}$ values of -6 to -18‰. Hence, two categories of higher plants.

"While we were doing this work, Kortschak et al.,² and later Hatch et al.,³ published papers indicating that some plants had a different mechanism for fixing CO_2 during photosynthesis than the classical Calvin cycle. The species they listed to our great surprise included those with relatively larger $^{13}\text{C}/^{12}\text{C}$ ratios. Thus, it turned out that isotopic methods were extremely useful for differentiating C_4 from C_3 plants.

"I moved to Austin, Texas in 1968, but for one reason or another the paper wasn't published until 1971. Isn't it interesting that a *Citation Classic* should result from a paper that had a four year interval from first draft to publication? One of the reasons this paper is widely cited is that it was one of the first to identify C_4 photosynthesis by isotopic fractionation. It was also one of the first to list several C_4 species and put them in some sort of taxonomic order."

1. **Smith B N & Epstein S.** Biogeochemistry of the stable isotopes of hydrogen and carbon in salt marsh biota. *Plant Physiol.* 46:738-42, 1970.
2. **Kortschak H P, Hartt C E & Burr G O.** Carbon dioxide fixation in sugarcane leaves. *Plant Physiol.* 40:209-13, 1965.
3. **Hatch M D, Slack S R & Johnson H S.** Further studies on a new pathway of photosynthetic carbon dioxide fixation in sugar cane and its occurrence in other plant species. *Biochemical J.* 102:417-22, 1967.