21. The Use of Variation in the Natural Abundance of ^{15}N to Assess Symbiotic Nitrogen Fixation by Woody Plants

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Introduction

Deeply rooted woody plants capable of symbiotic N_2 fixation are often dominant components of plant communities. The importance of symbiotic N_2 fixation to the N economy of these plants and to overall ecosystem productivity is poorly understood. This is a consequence of technical difficulties in detecting and/or measuring N_2 fixation under field conditions using conventional approaches (i.e., acetylene reduction assay). The utility of the natural ^{15}N abundance approach to assess symbiotic N_2 fixation is discussed by Shearer and Kohl in Chapter 20 of this volume. This approach is analogous to isotopic dilution methods widely used in agricultural studies except that it takes advantage of small deviations in the natural ^{15}N abundance of soil from that of the atmosphere and, therefore, does not require isotope application to the soil.

There has been a steady progression in the application of the natural abundance technique to ecological questions. Early studies described the extent of variation in the natural ^{15}N abundance of biological materials including plants, soils, and sediments (Bremner and Tabatabai 1973; Cheng et al. 1965). Most soils were found to have a higher ^{15}N abundance than atmospheric N_2, with $\delta^{15}N$ values ranging from about -5 to 15‰. Observation of significant deviations in the natural ^{15}N abundance of soil from that of the atmosphere led to efforts to detect symbiotic N_2 fixation by isotopic analysis of plant tissues and soils (Delwiche and Steyn 1970; Delwiche et al. 1979; Hogberg 1986; Shearer and

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Kohl 1978; Virginia and Delwiche 1982). These investigators found that the N isotope composition of plants was a function of the relative importance of soil and atmospheric sources of N when certain conditions were met. The ^{15}N abundance of the soil had to be significantly different from that of the atmosphere ($\delta^{15}N = 0$) and isotopic fractionation effects associated with N uptake and plant metabolism could not obscure the identity of the N sources after incorporation into plant tissues. These studies established the conditions under which N_2 fixation could be detected in natural systems using ^{15}N measurements. In a few studies, natural ^{15}N abundance data have been coupled with measurements of plant production and N uptake to quantify inputs of fixed N to ecosystems (Rundel et al. 1982; Shearer et al. 1983).

The objectives of most natural ^{15}N abundance studies are to detect N_2 fixation or to quantify inputs of fixed N to the system. The fractional contribution of fixed N to the plant (FN_{dfa}, or "fixed N derived from atmosphere") can be calculated from an isotope dilution expression, $FN_{dfa} = (\delta^{15}N_0 - \delta^{15}N_t) / (\delta^{15}N_0 - \delta^{15}N_a)$, where $\delta^{15}N_0$ is the ^{15}N abundance of a suitable nonfixing control plant, $\delta^{15}N_t$ is the ^{15}N abundance of the N_2-fixing plant, and $\delta^{15}N_a$ is the ^{15}N abundance of fixed N after it has been incorporated into plant tissue (see Chapter 20 of this volume). The latter information can be obtained by growing the plant in an N-free medium.

This paper will present selected examples of applications of the natural abundance method to ecological studies. The emphasis will be on results from ongoing ecosystem level studies examining the role of woody legumes in N cycling in warm deserts (Rundel et al. 1982; Shearer et al. 1983; Virginia and Jarrell 1983). Data from other systems (tropical forest, chaparral) where significant sustained inputs of N fixed by woody plants may affect ecosystem processes are also discussed to demonstrate the utility of the natural abundance method in a diversity of systems.

Desert Ecosystems

Prosopis-Dominated Ecosystems

Desert ecosystems are frequently dominated by woody legumes, especially in landscape positions where water accumulates in the soil profile. Since 1980 we have been studying N cycling in California Sonoran Desert legume woodlands. We have studied highly productive phreatophytic mesquite *(Prosopis glandulosa)* woodlands utilizing groundwater and mixed legume wash woodlands codominated by fixing *(Psorothamnus spinosus)* and nonfixing *(Cercidium floridum)* trees. The intensively studied mesquite system is located near Harper's Well and has been described in detail (Sharifi et al. 1982; Nilsen et al. 1984; Virginia and Jarrell 1983). The wash woodland ecosystem is located at the University of California Deep Canyon Desert Reserve near Palm Desert. These sites differ greatly in the pattern of soil water availability and provide model systems in which to examine water and nutrient limitations to plant production in deserts.