



## Letter to the Editor

## Why we need to restrict the use of “rhizodeposition” and the Janzen and Bruinsma equation

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<sup>15</sup>N  
<sup>13</sup>C  
 Plant  
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## Dear Editor

In 2010, a good number of papers have, like preceding years, dealt with rhizodeposition. Unfortunately the term “rhizodeposition” has not yet found a common definition. In a 2010-paper like [zu Schweinsberg-Mickan et al. \(2010\)](#) rhizodeposition describes deposition of C or N from root exudates, sloughed off root cells, mucilage, and root hair covering a time scale up to a few weeks. However, in papers like [Dahlin and Stenberg \(2010\)](#), and [Scandellari et al. \(2010\)](#) rhizodeposition in addition includes root system turnover covering longer time scales.

In all the 2010-papers mentioned and in many preceding papers, isotopic tracers (e.g. <sup>13</sup>C or <sup>15</sup>N) were used to study the soil percentage of C or N derived from rhizodeposition (%Cdfr or %Ndfr). The rhizodeposition (%Cdfr or %Ndfr) was calculated using the equation ([Janzen and Bruinsma, 1989](#)):

$$\%Cdfr \text{ or } \%Ndfr = \frac{{}^{13}\text{C} \text{ or } {}^{15}\text{N} \text{ atom\% excess in soil}}{{}^{13}\text{C} \text{ or } {}^{15}\text{N} \text{ atom\% excess in root}} \times 100$$

where atom% excess are calculated as the atom% in the enriched sample minus the atom% in an unlabeled control sample. The basic assumptions when using the equation are that the added tracer is evenly distributed in the root system, the N deposited has the same enrichment as the roots, and the tracer content of the roots is constant over the growth period of the plants ([Jones et al., 2009](#); [Mayer et al., 2003](#)). These assumptions imply that any process leading to a changing tracer enrichment in the whole root system or processes that lead to uneven tracer distributions within the root system, i.e. a lower or higher atom% excess in root, without a simultaneous deposition of tracer to the soil, and thus an increase in soil atom% excess, disqualifies the use of this commonly used equation for calculating rhizodeposition.

I will give a few examples to illustrate situations where rhizodeposition estimates may be biased due to changing root enrichment not associated with deposition of tracer to the soil. Furthermore these examples underline that the longer the duration of the

experiment, the larger the potential uncertainties of rhizodeposition estimates when using the Janzen and Bruinsma equation.

- (i) Root growth after initiation of continuous labeling can lead to an uneven distribution of tracer in the root system, unless C or N tracer is added at the same rate as C and N in general is incorporated into the root tissue; the latter in practice only achievable when using enriched or depleted CO<sub>2</sub> for C labeling. In addition, when using pulse labeling, root growth after the pulse will dilute the enrichment of the root system. This will, all other equal, result in false higher estimates of rhizodeposition, because of lower enrichment in the root tissue. Exemplifying the latter is the study of [Wichern et al. \(2007\)](#), where peas were pulse labeled at different growth stages and the rhizodeposition determined at pea maturity. Given continued growth of the pea root system from the first pulse labeling at the three leaf stage until, at least, the second labeling at the five and eight leaf stage, it is evident that the enrichment of the early labeled roots would have been diluted compared to the later labeled roots. This leads to an overestimation of the rhizodeposition from the early labeled pea root, because the enrichment of the roots is diluted, and not necessarily, as should be the case, due to a higher deposition of tracer to the soil. The major problem being that it is impossible to distinguish what really happened.
- (ii) Reallocation of tracer from the root system to e.g. re-growth of shoot biomass or grain filling will deplete root C and N in particular, without this change in root enrichment is reflected in an increase of tracer in soil. Given that as much as 40–45% of the N in roots can be used for shoot re-growth after cutting white clover ([Dahlin and Martensson, 2008](#)), reallocation of tracer from the root to the shoot could change the root enrichment resulting in biased rhizodeposition estimates. This would occur if the proportion of C or N tracer reallocated was different from total C or N reallocated e.g. due to higher remobilization of recently formed storage C or N, or due to isotope discrimination in the root. An example of a study where tracer reallocation could have been a problem is the study by [Rasmussen et al. \(2007\)](#) where grass or white clover was pulse labeled and the rhizodeposition determined after three months. During these three months the grass-white clover mixtures were harvested three times resulting in two re-growth periods, which, as I happily stated in the paper, resulted in a reallocation of <sup>15</sup>N to the new shoot material. Thus, the rhizodeposition estimates (Ndfr) given in the paper could be biased; at least it is clear that <sup>15</sup>N-tracer was removed from the root system without a simultaneous deposition of <sup>15</sup>N to the soil.

(iii) In studies of long duration both root growth and reallocation of tracer most likely takes place, and additionally leaf senescence might result in tracer deposition directly to the soil. Furthermore, turnover of a major part of the original root system mean that the basic assumptions for using the Janzen and Bruinsma equation is not fulfilled. Exemplifying this is the study of Høgh-Jensen and Schjoerring (2001) where clovers or grass were multiple-pulse labeled over two growing seasons and the rhizodeposition determined at the end of the second growing season. Over the two growing season the plants were cut seven times resulting in six re-growth periods where added tracer most likely was reallocated from root to shoot. During the two growing seasons major parts of the clover and grass root systems were most likely turned over and replaced by new root growth. Therefore, roots sampled after the second growing season was probably to a greater extent a reflection of tracer added in the second growing season than an equal reflection of both growing seasons. Since the latter is the basic assumption for using the Janzen and Bruinsma equation, the rhizodeposition estimates is probably overestimated.

In all three above mentioned studies, rhizodeposition could instead have been estimated using a tracer mass balance approach. Although there would be losses of tracers from the systems, in particular when working with C, a tracer mass balance would make it possible to see how large a proportion of the recovered tracer was present in soil pools compared to that recovered in root and shoot. Thereby it would be possible to estimate the net C or N deposition to the soil from the living plant based on plant biomass C or N yields. This both by comparing soil and root tracer content, but also soil and total plant tracer content; the former resembling Janzen and Bruinsma based estimates, and the latter additionally relating tracer deposition to the overall plant growth. Furthermore, a tracer mass balance approach would work both for pulse and continuous labeling, and would not require the same degree of homogeneous enrichment of the plant tissue as is required for the Janzen and Bruinsma equation, as the tracer mass balance is based on total tracer contents in soil and root, and not on specific tracer enrichments. In fact, a tracer mass balance approach would allow us to use inhomogeneous distribution of tracer, e.g. from pulse labeling, to quantify and qualify when the labeled plant material add C or N to the soil; This being particularly interesting in field settings or in experiments of longer duration where homogeneous labeling can hardly be achieved.

Wichern et al. (2008) excellently reviewed the usage of rhizodeposition and concluded that “fine roots, root fragments, and decaying roots” should be included by the term. In contrast, Frank and Groffman (2009) clearly separate root turnover and rhizodeposition, defining the latter as “exudates, secretions, lysates, sloughed

cells, and mucilages”. In my view the term rhizodeposition should describe processes related to the living root. In practice it is inherently difficult to separate exudations etc. from turnover of the finest root parts. Therefore, an operational definition of rhizodeposition would include C or N from turnover of root hairs, fine roots and minor root fragments, but exclude C or N from turnover of decaying roots and larger parts of the root system; as the latter imply that this plant tissue is no longer living plant tissue. If such a definition is coupled to a restricted use of the Janzen and Bruinsma equation, i.e. to shorter term studies, it would most likely lead to lesser uncertainties in rhizodeposition estimates.

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