Root exudates as pathway for nitrogen transfer from a tropical leguminous tree

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1. Introduction

N_2-fixing plants may contribute N to associated plants, and thus compensate for the use of chemical fertilisers in agricultural systems.

In the tropics, the N_2-fixing plant in the association is usually a woody species, and leaf litter or prunings are considered as the main pathway of N release to the system.

Recent research in other natural and man-made ecosystems has provided evidence on the role of below-ground processes in N transfer. Possible mechanisms include root and nodule decomposition (Sierra et al. 2002; Nygren et al. 2000), root exudates (Paynel et al. 2001; Sierra et al. 2007), and common mycorrhizal networks (He et al. 2003). These pathways still remain relatively poorly understood.

We studied (i) the extent of root exudation on a tropical leguminous tree *Gliricidia sepium*, and (ii) transfer of N via exudates from the tree to a fodder grass *Dichantium aristatum* in a glasshouse experiment.

2. Material & Methods

Study site: a glasshouse study at the Antillean research centre of INRA, Guadeloupe, Lesser Antilles
Plant material: N_2-fixing tree *Gliricidia sepium,* and C4 fodder grass *Dichantium aristatum* (N receiver).
Soil: Vertisol with 80% of clay, collected from a *G. sepium – D. aristatum* agroforestry plot and sieved for removing plant roots
Methodology: Hydroponics cultivation and leaf feeding of ^{15}N

Trees established from cuttings were transferred to hydroponic tanks, and 30 mg of ^{15}N was applied on tree leaves in the form of 99% ^{15}N-enriched KNO_3.

During the following 10 weeks, water solution in tanks was changed weekly and used for irrigation of grass grown in separate pots. The root exudates of 3 trees were collected solely for analysis of ^{15}N.

Half of the grass pots were treated biweekly with fungicide *Iprodione* to reduce arbuscular mycorrhizal colonisation and to study the role of mycorrhizal fungi in nutrient uptake.

Grass shoots were sampled for ^{15}N analysis immediately before, and 4, 7 and 10 weeks after the initiation of irrigation with exudates. At the end of the experiment, tree and grass were harvested and analysed for N & ^{15}N content by compartments. Mycorrhizal colonisation was determined from plant roots using the method described in McGonigle et al. (1990).

Upper photo: *Gliricidia sepium* in hydroponic tanks
Lower photo: Pots of *Dichantium aristatum*
Photos by J. Sierra

3. Results & Discussion

During the 10-week experiment, trees exuded 1.3% (0.23 mg) of the foliarly-fed ^{15}N. Exudation of N equalled 1.7% (38 mg) of the total N in tree at the end of the experiment (fig. A).

The average amount of daily exuded N was similar to that measured in *G. sepium* by Sierra et al. (2007), but exudation as percentage of total N in tree was only half of what they observed.

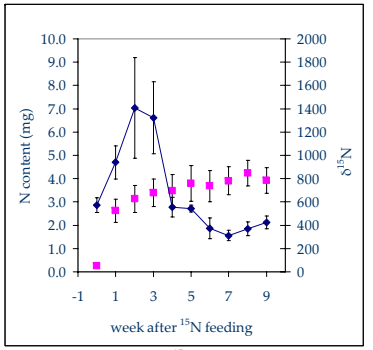
Of the total ^{15}N in grass at the end of the experiment, 1% originated from the exudates added in grass pots in irrigation water. Grass absorbed only 6% of the total ^{15}N in exudates. The results suggest a significant immobilisation of N by soil microorganisms.

Grass total and root $\delta^{15}N$ correlated with $\delta^{15}N$ of exudates (P= 0.066 to 0.034; *fig. C*). ^{15}N content of grass did not correlate with ^{15}N content of exudates. This lack of correlation was probably due to the immobilisation of N and thus the small amounts of ^{15}N transferred. As the ^{15}N enrichment of exudates was high, the effect of even small transfer showed in $\delta^{15}N$ of grass.

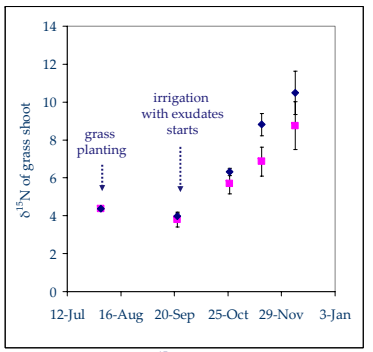
Fungicide application did not reduce mycorrhizal colonisation within-root. However, fungicide-treated grass had
- lower N and ^{15}N concentration
- higher total and root weight
- higher shoot ^{15}N enrichment

The results imply a reduction in external mycorrhizal mycelia, which are more vulnerable than mycorrhizal organs inside plant roots. Non-fungicide treated grass seemed to benefit clearly from the mycorrhizal association in terms of N yield, but had to invest photosynthetic products for maintaining the symbiosis. Additional N in exudates was more readily available for the fungicide-treated grass than N in soil.

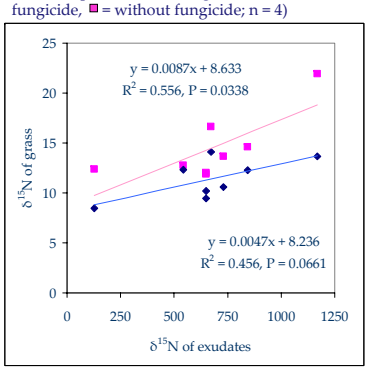
Trees suffered visibly from defoliation. On average, only 32% of the leaf-fed ^{15}N was recovered from trees at the end of the experiment. Tree compartments were unevenly enriched with ^{15}N, enrichment being highest in leaves and smallest in exudates.



A. N content (◆) and $\delta^{15}N$ (■) in exudates (n = 3)



B. Development of $\delta^{15}N$ in grass (◆ = with fungicide, ■ = without fungicide; n = 4)



C. Correlation between $\delta^{15}N$ in exudates and in grass (■ = grass root, ◆ = grass total; n = 8)

4. Conclusions

In this experimental setup root exudates did not contribute substantially to ^{15}N content in grass, indicating negligible transfer of N in general. Possible explanations for these results include

(i) Low levels of root exudation due to tree sufferance.

(ii) Immobilisation of ^{15}N by soil micro-organisms, as exudates were applied on soil surface in irrigation water. In natural systems, root exudates are released in rhizosphere where they can be readily absorbed by associated plants. Therefore N immobilisation by soil biological activity is likely smaller, and more N from exudation is available for plant uptake.

The extremely high level of immobilisation observed in this study suggests, however, that the role of exudation in interplant N transfer may be curtailed by competition with soil microorganisms. The substantial below-ground N transfer observed in several studies probably results largely from other, more direct transfer mechanisms, such as mycorrhizal networks.

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