Partitioning of N in field pea as determined by shoot and atmospheric ^{15}N labeling

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Introduction

- Accurate assessment of the N economy of pulse crops requires a full accounting of total plant N, and specifically, of N acquired by symbiotic N fixation that remains in the field following seed harvest.
- N released from roots during crop growth may be a significant contributor to the total plant N balance.
- ^{15}N labeling techniques have been developed to quantify N rhizodeposition, which otherwise would be missed if only roots are sampled at crop maturity.
- Shoot ^{15}N-labeling techniques are relatively simple to implement, but cannot directly assess N fixation nor the contribution of fixed N to soil—conversely, atmospheric $^{15}N_2$ labeling techniques can directly assess N fixation, but are more expensive and technically challenging to implement.

Objectives

- Determine the relative distribution of ^{15}N in above- and belowground plant components of field pea (*Pisum sativum*) using the cotton-wick shoot ^{15}N labeling and continuous atmospheric $^{15}N_2$ labeling approaches
- Quantify pea N rhizodeposition in soils at different growth stages in pea

Field pea N rhizodeposition: ^{15}N-urea shoot labeling

Fig. 1. ^{15}N shoot labeling

- ^{15}N labeling began at 4 leaves unfolded for all plants using the cotton-wick labeling method.
- ^{15}N labeled urea (99.2 atom% ^{15}N) was wicked into the plant via a cotton string threaded into the stem of the plant (Fig. 1).
- N derived from rhizodeposition (NdfR) was quantified by multiplying %NdfR by the total N (mg plant^{-1}) in rhizosphere and bulk soils, where:

  %NdfR =atom% ^{15}N excess soil/atom% ^{15}N excess root x 100

- Preferential ^{15}N enrichment of aboveground plant parts resulted in differential distribution of ^{15}N compared to total plant N (Fig. 2).
- ^{15}N distribution in the soil increased as the plant matured, likely due to the release of ^{15}N to the soil during decomposition of the older ^{15}N labeled roots (Fig. 2).
- Cumulative N rhizodeposition increased with plant development; however, its contribution to total plant N decreased from 20 to 7.5%, from the vegetative stage to maturity, in conjunction with an increase in N transfer to aboveground components, particularly grain.
- Belowground N (roots and rhizodeposits) comprised 29, 21, and 11% of total plant N at the vegetative stage, flowering, and maturity, with NdfR representing 59 to 68% of total belowground N.
- Harvested grain removed 84% of total plant N from the soil system, with roots and rhizodeposits comprising 63% of the remaining crop residue N—these results highlight the importance of accounting for roots and rhizodeposits in the total N budget of pulses.

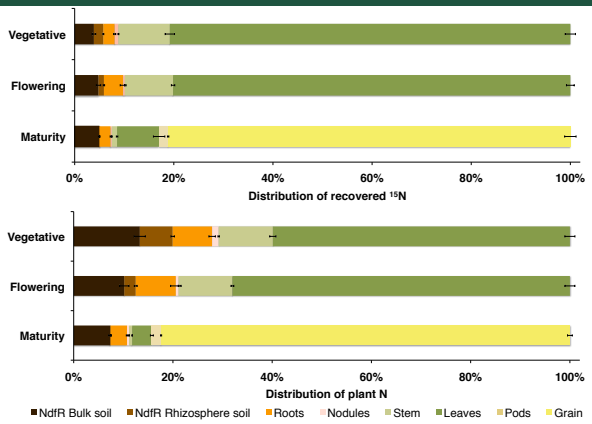

Fig. 2. Distribution of ^{15}N (top) and plant-derived N (bottom) in soil and plant components of pea supplied with ^{15}N urea using the cotton wick shoot labeling method (n=9; bars=SE).

Field pea N fixation: continuous $^{15}N_2$ atmospheric labeling

Fig. 3. $^{15}N_2$ atmospheric labeling system.

- Pea roots and nodules were exposed to $^{15}N_2$ by injecting the gas directly into the soil atmosphere (Fig. 3). The control consisted of plants grown under ambient conditions.

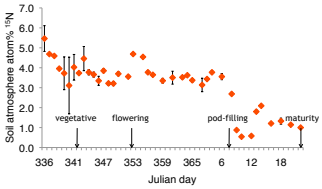

Fig. 4. ^{15}N enrichment of the soil atmosphere of pea over time.

- Leaks in the system (Fig. 4) and low nodulation contributed to the low ^{15}N enrichment in plant parts and rhizosphere soil (Fig. 5).

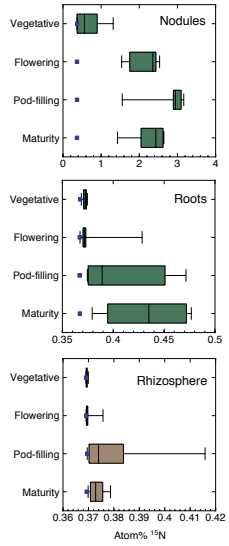

Fig. 5. ^{15}N enrichment of belowground plant parts and rhizosphere soil of pea supplied with ^{15}N. ■ indicates ^{15}N natural abundance of the controls.

- N fixation was active between flowering and maturity (as indicated by the ^{15}N enrichment of the nodules) (Fig 5).
- Whereas a high proportion of ^{15}N was distributed in nodules, the low proportion of total plant N allocated to nodules indicates that the soil was the major source of plant N in this experiment (Fig. 6).
- Despite low nodulation, ^{15}N enrichment in rhizosphere soil was detected in some plants with increased development (Fig. 5) and was related to nodule number and nodule and root ^{15}N enrichment (Fig. 7), suggesting that under high rates of symbiotic N fixation, release of fixed N to soil may be substantial, particularly at pod-filling.

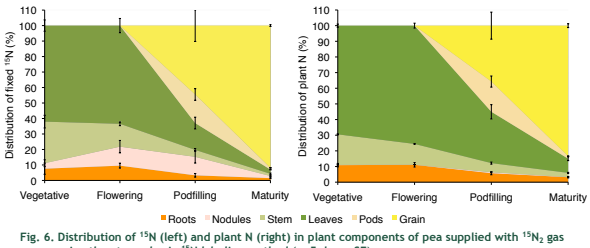

Fig. 6. Distribution of ^{15}N (left) and plant N (right) in plant components of pea supplied with $^{15}N_2$ gas using the atmospheric ^{15}N labeling method (n=5; bars=SE).

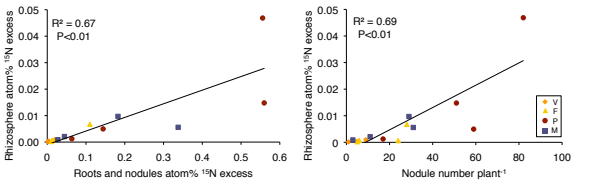

Fig. 7. Effect of root and nodule ^{15}N enrichment (left) and nodule number (right) on ^{15}N enrichment in the pea rhizosphere.

Conclusion

- The release of fixed N to soil through rhizodeposition was minimal due to the unexpectedly low nodulation in the $^{15}N_2$ labeling experiment. Nevertheless, ^{15}N was detected in the rhizosphere soils of plants with higher nodulation, indicating that under higher rates of N fixation, input of fixed N to soil will be significant. Indeed, results from shoot ^{15}N labeling showed that total rhizodeposition comprised the majority of crop residue N remaining in soil after grain harvest, highlighting its importance to the total N budget of pulses.

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