Environmental controls of fine-roots decomposition dynamics in a northern temperate forest soil

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1. Introduction

Fine-roots (<2 mm diam.) are considered important sources of soil C and N in forest ecosystems, however the primary factors that control fine-root C and N mineralization rates in temperate forest soils are not well understood. Changes in forest productivity are thought to reduce the inputs of above and belowground C to soils, limiting belowground C storage (Crow et al. 2009). In addition, expected increases in atmospheric N deposition have the potential to induce changes in litter decomposition (Knorr et al. 2005, Fornara & Tilman 2012). We conducted a 2-year field study to examine the influence of long-term litter inputs and N additions on *Acer rubrum* (red maple) fine root C and N dynamics in a temperate forest soil, and answer the following specific questions:

How do litter inputs and N additions affect the:

- Retention and stabilization of fine root C and N in soils?
- Losses of fine root C as CO_2 ?
- Vertical transport of fine root C as dissolved organic C (DOC)?

Approach: we followed the fate of ^{13}C and ^{15}N from $^{13}C/^{15}N$ dual labeled red maple root litter in soils, respired-CO_2 fluxes, and DOC.

2. Two-year field study

Experimental manipulation field site:
Long-term Detritus Inputs and Removal Treatment (DIRT), initiated in 2004, University of Michigan Biological Station, Pellston, MI

In 2009, red maples (*Acer rubrum*) were enriched with $^{13}CO_2$ and $^{15}NH_4Cl$ and $K^{15}NO_3$ in a temperature-controlled chamber located in the greenhouse facility at Queens College.

Table 1. Isotopic and elemental composition of red maple root litter

Litter	C	N	C:N ratio	^{13}C	^{15}N
	(g kg^{-1})	(g kg^{-1})		atom %	atom %
Fine roots	50.4	1.2	43.7	5.2	11.5

In 2010, fine-roots (1 g C and 0.02 g N) were applied to the top 1-4 cm of mesocosms (PVC, 10 cm diameter) installed in the top 20 cm of soils within the following DIRT treatments:

Added N: soils received N additions as NH_4Cl , 30 kg N ha^{-1} yr^{-1} (n = 3).

No belowground inputs: roots were excluded by trenching (n = 3).

No above and belowground: aboveground litter were removed using a mesh screen to collect the falling litter; roots were excluded by trenching (n = 3).

Control: no removal of litter inputs or additional N added (n = 3).

Zero-tension lysimeters installed underneath soil mesocosms to collect gravimetric soil water

Control treatment

No above and belowground treatment

Recovery of root ^{13}C and ^{15}N in soil mesocosms:
Intact soil mesocosms with or without applied $^{13}C/^{15}N$ labeled roots were excavated 1 and 2 years following the application. Soil sub-samples were analyzed for C and N elemental and isotopic enrichment by depth (0-10 and 10-20 cm) and size fraction (> and < 2 mm).

Soil CO_2 efflux:
Soil-respired CO_2 fluxes and $\delta^{13}C$ signature of CO_2 were determined 8, 248, 288, 339, and 701 d after the application of $^{13}C/^{15}N$ labeled root litter.

DOC in soil leachate:
Gravimetric soil water was collected after a single rain event at day 368, and DOC was measured for C elemental and isotopic enrichment.

3. The exclusion of above and belowground inputs increased the retention of root litter N in soils

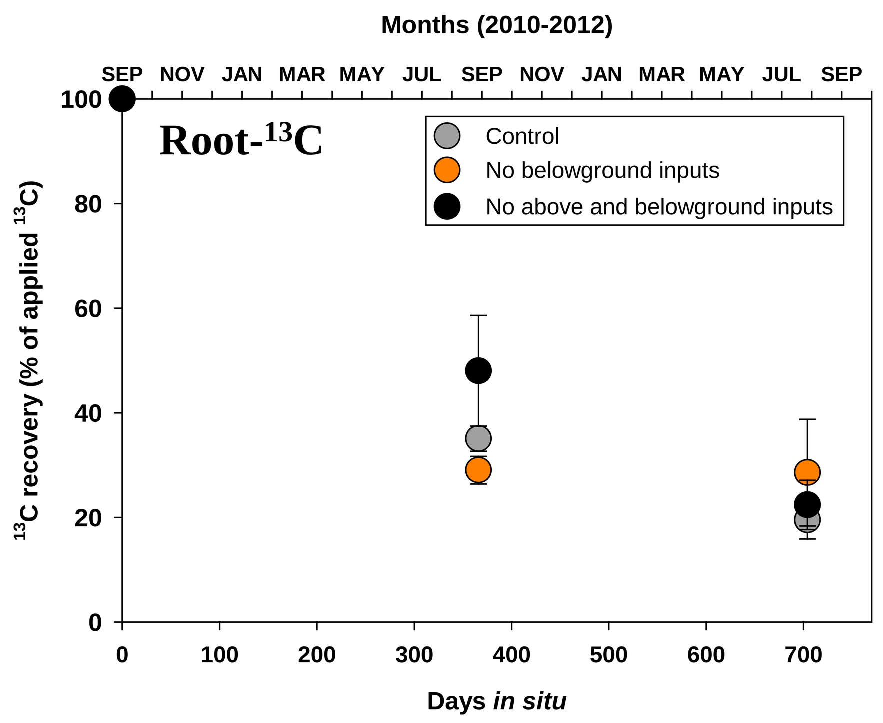

Figure 1. Total root litter ^{13}C retained in soil mesocosms after 1 (366 days) and 2 years (704 days) *in situ* within litter manipulation treatments.

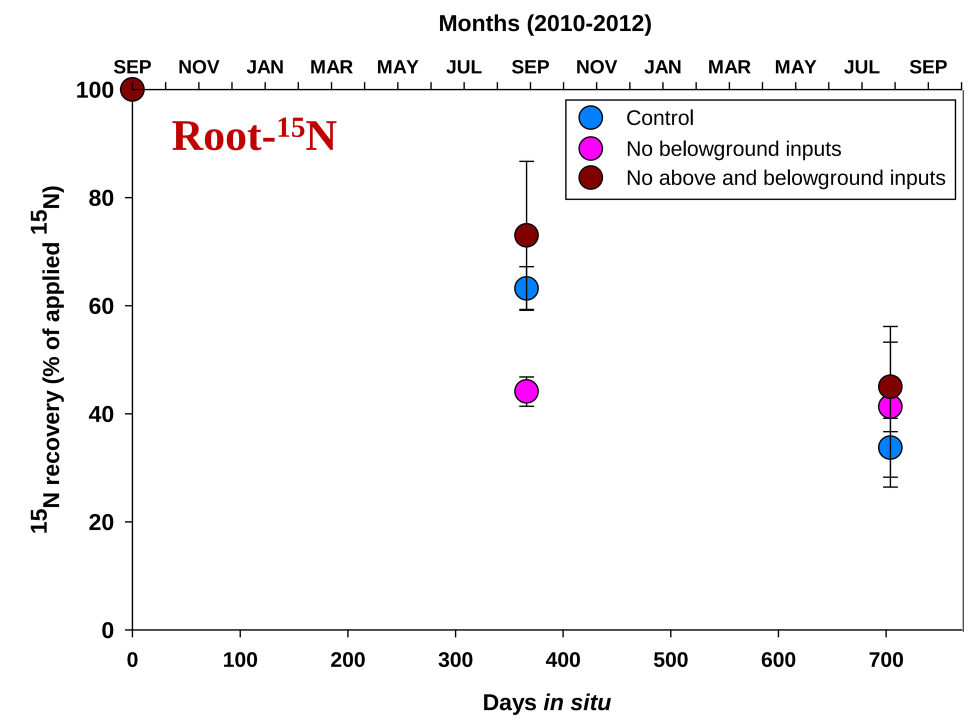

Figure 2. Total root litter ^{15}N retained in soil mesocosms after 1 (366 days) and 2 years (704 days) *in situ* within litter manipulation treatments.

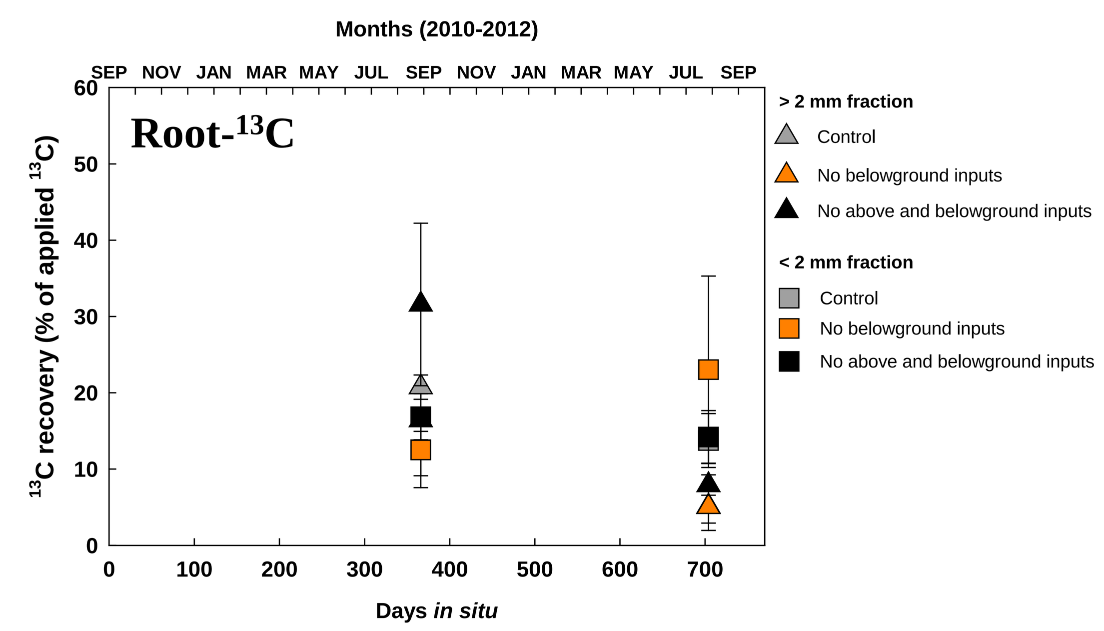

Figure 3. Total root litter ^{13}C retained in soils within **0-10 cm depth** after 1 (366 days) and 2 years (704 days) *in situ* within litter manipulation treatments.

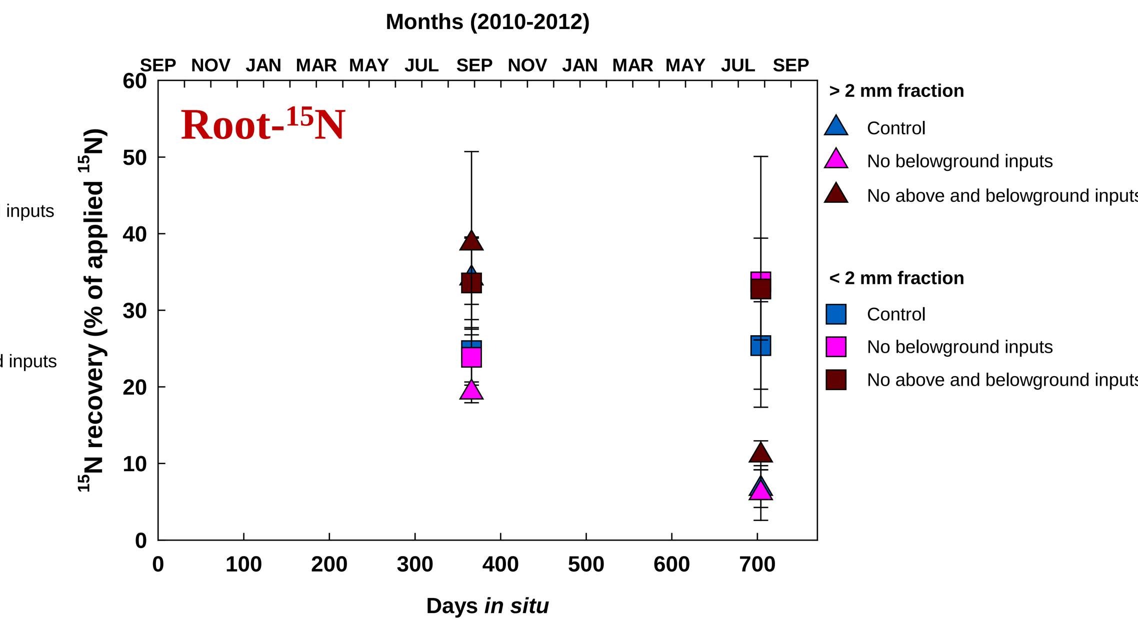

Figure 4. Total root litter ^{15}N retained in soils within **0-10 cm depth** after 1 (366 days) and 2 years (704 days) *in situ* within litter manipulation treatments.

After 2 years *in situ*:

- 19.5 and 33.7% of applied root C and N, respectively, were recovered in control treatments (regular above and belowground litter inputs, Figs. 1 and 2).
- On average, the greatest retention of root C and N occurred in bulk soil (76% of remaining C and 81% of remaining N) within 0-10 cm depth (Figs. 3 and 4)
- The recovery of root C and N was unaffected by treatments with no belowground inputs.

- During the 2-yr study, treatments with no above and belowground inputs increased the retention of root N in soil mesocosms (Fig. 2) and within 0-10 cm depth (Fig. 4) when compared with control treatments.

In year 2, the removal of above and belowground decreased:

- the retention of root C within 10-20 cm depth. However, less than 1 % of added root C and N was recovered within that depth.

4. The addition of nitrogen to soils affected the retention of root litter N

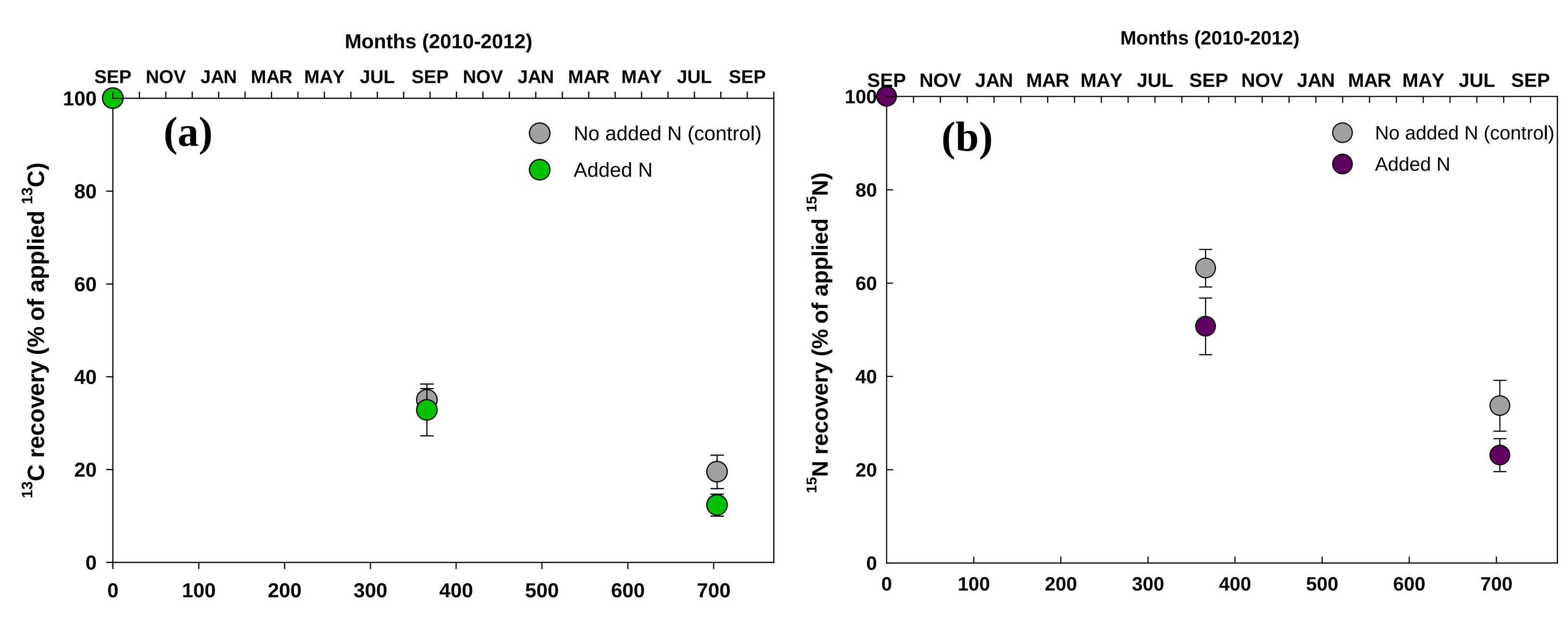

Figure 5. Total root litter **(a)** ^{13}C and **(b)** ^{15}N retained in **soil mesocosms** after 1 (366 days) and 2 years (704 days) *in situ* within treatments with or without nitrogen additions

- Treatments that received nitrogen additions had significantly less root N retained in the mesocosms than treatments without nitrogen additions (Fig. 5a).
- Recovery of root C in soil mesocosms was unaffected by nitrogen additions treatment (Fig. 5b).

5. Losses of root litter C as DOC and CO_2

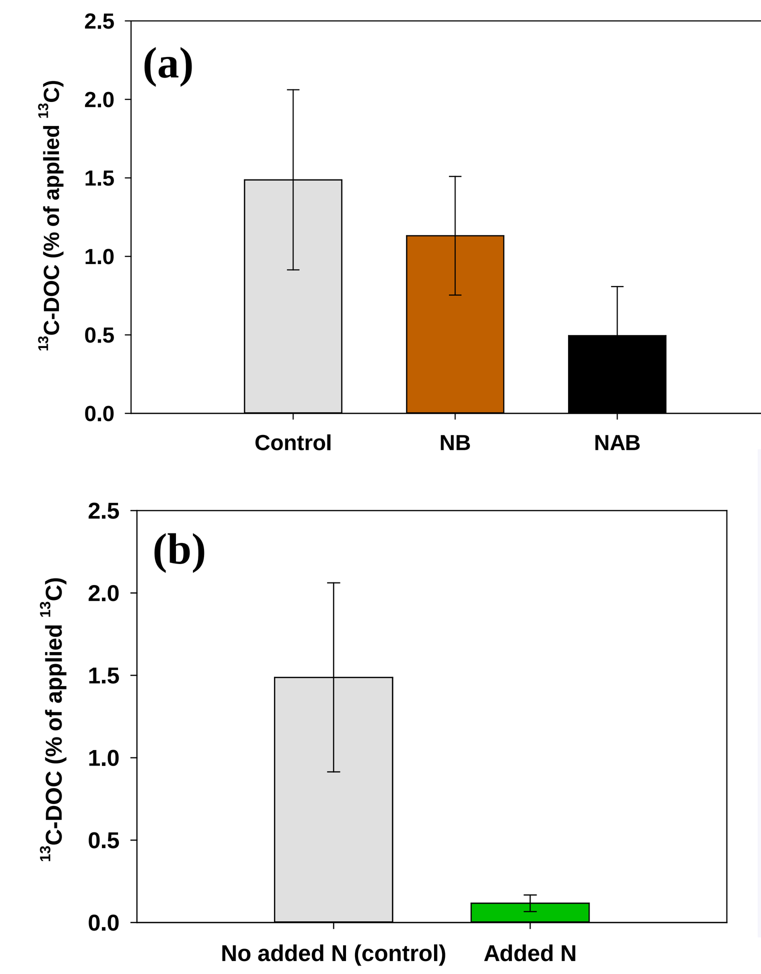

Figure 6. Losses of **root C as DOC** at day 368 within **(a)** litter manipulation and **(b)** N addition treatments. **NB, no belowground; NAB, no above and belowground**

Losses of root C as DOC in treatments with no litter inputs (Fig 6a), and with added N (Fig 6b) were lower than in control treatments, however, differences were not statistically significant.

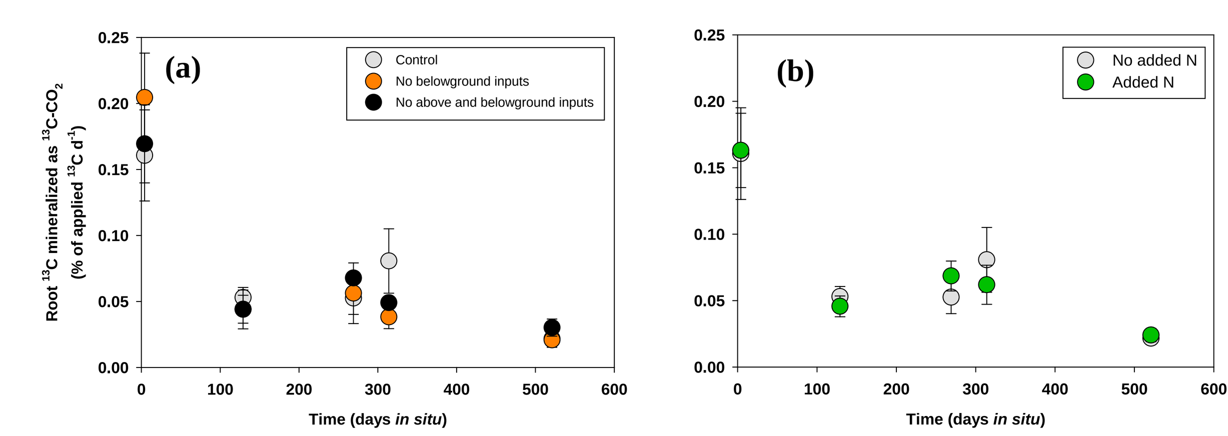

Figure 7. $^{13}CO_2$ **mineralization** rates from applied root C during the 2-yr study in **(a)** litter manipulation and **(b)** nitrogen additions treatments

Rates of root C losses as soil-respired CO_2 were unaffected by in treatments with no litter inputs (Fig. 7a) and added N (Fig. 7b) during the 2-yr study.

6. Conclusions

Overall, the retention of root litter C and N in our study was lower than that reported for a temperate forest in Sierra Nevada, CA (Bird and Torn, 2006) and mountain grasslands in Spain (Garcia-Pausas et al. (2012).

There was a significant vertical loss of root-C as DOC in our study site.

Eight years of litter manipulation and N additions had no effects on the losses of root C as either CO_2 or DOC.

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