Changes in fine-root quantity and quality with elevated CO_2: Implications for decomposition and N cycling

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INTRODUCTION

- Half of forest NPP is partitioned to fine roots, and fine roots represent a significant deposition of C and N to the soil as they decompose.
- Elevated CO_2 is predicted to increase fine-root production as N becomes limiting. Increased fine-root biomass could either stimulate microbial decomposition and increase plant-available N, or increase microbial N immobilization of plant-released chemicals.
- Potential decreases in root litter quality under elevated CO_2 will interact with increased root volume to affect microbial decomposition, though this depends on total amounts of C and N input belowground.
- Elevated CO_2 has increased fine-root (< 1 mm diameter) production and proliferation at depth in ORNL FACE since 2000 (Norby et al. 2004, Figure 1a,b). Partitioning of extra C fixed under elevated CO_2 to the fine-root pool will decrease long-term plant C storage because the fine-root population turns over quickly (<1 year) at ORNL FACE.
- Conversely, soil C storage may increase if fine-root decomposition does not increase on par with production. The additional N immobilized in fine-root detritus may result in a decline in soil N available for forest uptake, and thus reduce forest production in response to elevated CO_2.

METHODS

▪We examined the effects of fine-root quality and quantity on root decomposition in a common garden experiment in the ORNL FACE site (Figure 1a). Roots were collected in 5 cm diameter by 30 cm deep cores from each FACE ring in June, July, and September 2005.

▪Root length and diameter were determined on an Epson Scanner with *WinRhizo* root scanning software at 400 dpi. Subsamples were taken for chemical analysis.

▪Initial volumes of field-moist fine roots from each shallow core (0-15 cm) were mixed with a fine glass bead substrate (600 µm), and wrapped in a water-permeable membrane (pore size 30 µm). The decomposition cores were placed in the soil profile within the ORNL FACE plantation, but outside of the rings, in late December, 2005 (Figure 1c).

▪Decomposition cores were collected four times over a period of 188 days, with one remaining collection at 300 days, for a total of five collections. Percent volume loss and changes in chemistry were determined for each core.

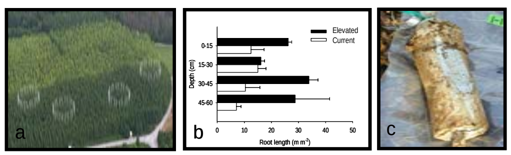

Figure 1: (a) ORNL FACE sweetgum plantation, (b) Fine-root production and proliferation at depth have continually increased in response to elevated CO_2 at ORNL FACE, and (c) A decomposition core retrieved in February 2006.

DISCUSSION

▪Changes in root morphology and chemistry with CO_2 enrichment and with soil depth may affect C and N cycling belowground at ORNL FACE (Figures 2, 3). Though litter quality was decreased under elevated CO_2 (as mediated by changes in diameter and depth), the total input of N belowground was increased.

▪To date, decomposition has not differed between roots from elevated and current CO_2 plots (Figure 4). Thus, more root mass would remain as organic detritus in the elevated CO_2 plots. This conclusion is based solely on root quality; changes in the amount of soil organic matter and the microbial community with elevated CO_2 are also expected to have a significant impact on decomposition rates.

▪Fragmentation of larger diameter (>0.5 mm) roots initially drove losses in root volume. This process is assumed in most decomposition studies, but rarely observed experimentally. Fragmentation increased fine-root surface area to volume ratios, perhaps making it easier for the microbial community to access remaining detritus.

▪N was initially immobilized in all of the decomposition cores (Figure 5), though the proportion did not appear to differ between elevated and current CO_2 cores. Thus, more N will be immobilized in the elevated CO_2 plots because root volume has increased, potentially resulting in declining soil N availability, and a negative feedback to forest production.

FUTURE RESEARCH

▪The effects of initial fine-root quality and quantity on decomposition will be quantified by regressing the rate residuals for roots produced under either current or elevated CO_2 against initial parameters such as root C:N, length and surface area.

▪Changes in fine-root chemistry, decomposition and N dynamics will be synthesized with minirhizotron data and used to inform the belowground N budget at ORNL FACE.

▪We will begin a reciprocal-transplant experiment this fall to determine the interactive effects of the soil microbial community and fine-root quality on fine-root decomposition rates.

▪We are currently examining the effects of CO_2-mediated increases in root production and proliferation on gross N immobilization throughout the soil profile (to 60 cm depth) at ORNL FACE.

ACKNOWLEDGEMENTS

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RESULTS

Figure 2:

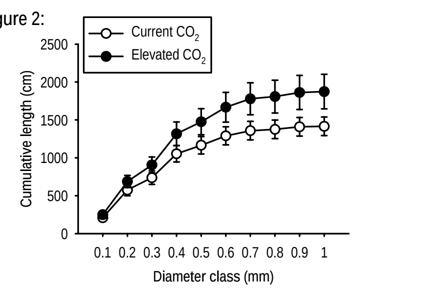


Figure 3:

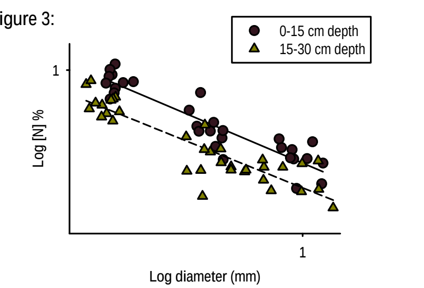


Figure 4:

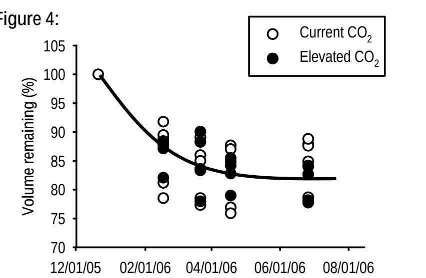
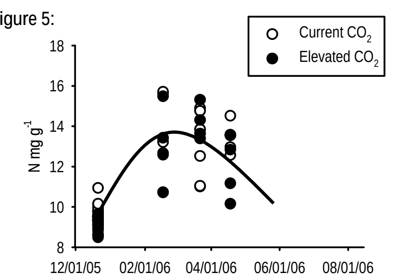


Figure 5:



QUANTITY

CO_2 enrichment increased fine root length and average diameter.

QUALITY

Across both treatments, fine root [N] was inversely related to root diameter, and root [N] decreased with depth.

DECOMPOSITION DYNAMICS

Volume loss happened quickly, but the [CO_2] at which roots were grown has had no effect on decomposition thus far.

N IMMOBILIZATION AND RELEASE

N was initially immobilized as fine roots were decomposed.