FERTILIZATION AND THROUGHFALL REDUCTION EFFECTS ON SOIL CO_2 EFFLUX AND LITTER DECOMPOSITION AS MEDIATED BY EXTRACELLULAR ENZYME ACTIVITY

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Background

- Soils contain the largest pool of organic carbon (C) in the terrestrial biosphere.
- Forest fertilization and altered precipitation regimes are expected to influence decomposition dynamics and soil CO_2 efflux, thereby ultimately affecting the net ecosystem C balance.
- Decomposition of organic matter is mediated by microbial extracellular enzymes. Enzyme production and activity is dependent on microbial community composition, forest nutrient management, and physical and chemical soil properties. As such, enzyme activity assays are widely used as sensitive indicators of environmental change in forest ecosystems.

Research Questions and Methods

Research Questions

1. How do the interactive effects of fertilization and throughfall reduction alter soil extracellular enzyme activity and litter quality?
2. What are the relationships among enzyme activity, litter quality, and total, mineral, and litter CO_2 efflux?

Site Characteristics

Soils: Littlejoe & Spears Mountain Series (Fine, mixed, subactive, mesic Typic Hapludults)
Treatment plot: 108'×108' (0.27 ac); Measurement plot: 68'×68' (0.11 ac)
Stand prior to treatment: Age 9, loblolly pine, 330 stems/ac, SI_{25} 68'

Experimental Design

Randomized Complete Block Design; 2×2 Factorial of treatments; 4 Blocks (Figure 1)

PINEMAP Tier III Treatments

1) Control 2) Fertilization (lbs/ac): 200 N, 25 P, 50 K + Micros (B, S, Mn, Cu, Zn)
3) 30% Throughfall Exclusion 4) Fertilization and Throughfall Exclusion

Figure 1. This research site is located in an 11-year-old loblolly pine stand (A) in the Appomattox Buckingham State Forest, VA with fertilization, throughfall exclusion treatments (B,C).

Measurements and Analysis

CO_2 Efflux

CO_2 efflux measurements from total, mineral, and litter components were made in July, 2014 using a LI-6200 closed dynamic system.

Litter Quality

Lignin concentration was determined using sulfuric acid hydrolysis (NREL procedure), and total C and N percents were determined using an elemental analyzer.

Extracellular Enzyme Activity

Potential extracellular enzyme activity of nine key enzymatic reactions (Table 1) in the litter (Oi) and mineral soil (0-10cm) were assayed using fluorometric and colorimetric analysis.

ID	Enzyme	Process
NAG	N-acetyl-β-glucosaminidase	N-mineralization
LAP	leucine aminopeptidase	N-mineralization
POX	Polyphenol Oxidase	N-mineralization; lignin degradation
PER	Peroxidase	Lignin degradation
BG	β-glucosidase	C-mineralization; sugar degradation
CHB	β-D-cellubiosidase	C-mineralization; cellulose degradation
AG	α-glucosidase	C-mineralization; sugar degradation
XYL	β-xylocidase	C-mineralization
AP	Phosphatase	P-mineralization

Table 1. Key enzymatic reactions that degrade cellulose, lignin, hydrolyze reservoirs of organic N, and mineralize P.

Results

CO_2 Efflux Components

- Fertilization reduced mineral CO_2 efflux, but did not effect litter CO_2 efflux (Figure 2).
- Throughfall reduction reduced total and litter CO_2 efflux (Figure 2).

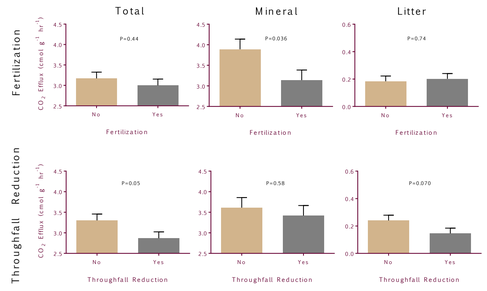

Figure 2. Fertilization and throughfall reduction treatment effects observed in total, mineral, and litter CO_2 efflux.

Litter Extracellular Enzyme Activity

Main Effects

- Fertilization and throughfall reduction treatments increased C-mineralization enzyme activity in litter (Figure 3).

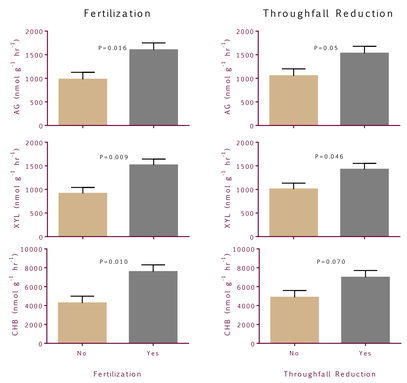

Figure 3. Main treatment effects observed in litter enzyme activity in fertilized and throughfall reduction treatments.

Interactions

- Fertilization×throughfall reduction resulted in increased C-mineralization enzyme activity (Figure 4A) but reduced N-mineralization activity in litter (Figure 4B).

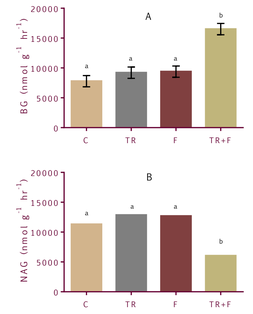

Figure 4. Control (C), throughfall reduction (TR), fertilization (F), and throughfall reduction and fertilization (TR+F) effects observed in C-mineralizing enzyme activity (A) and N-mineralizing enzyme activity (B). Letters denote significant differences at P<0.05.

Mineral Soil Extracellular Enzyme Activity

- Fertilization decreased P- and N-mineralization enzyme activities in soil.

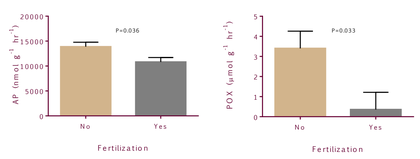

Figure 5. Main treatment effects observed in N- and P-mineralizing soil enzyme activity

- Fertilization and throughfall reduction decreased N-mineralization enzyme activities in soil.

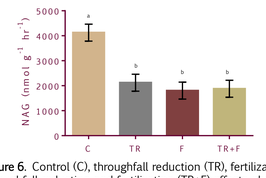

Figure 6. Control (C), throughfall reduction (TR), fertilization (F), and throughfall reduction and fertilization (TR+F) effects observed in N-mineralizing enzyme activity. Letters denote significant differences at P<0.05.

Litter Quality

- Fertilization decreased litter C:N and Lignin:N, while throughfall reduction increased C:N and lignin:N.

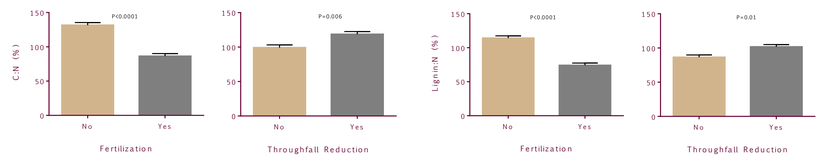

Figure 7. Fertilization and throughfall reduction treatment effects observed in litter C:N, and lignin:N.

Discussion

Soil CO_2 Efflux

- Fertilization reduced total and mineral soil CO_2 efflux, but had no impact on litter CO_2 efflux, suggesting that a fertilization effect is limited to soil only.
- Throughfall reduction decreased total and litter CO_2 efflux, but had no impact on mineral soil CO_2 efflux, suggesting that a throughfall reduction effect is limited to litter only.

Extracellular Enzyme Activity

- Fertilization increased activity of C-mineralizing enzymes in leaf litter and decreased the activity of N- and P-mineralizing enzymes in mineral soil. This suggests that fertilization may reduce microbial nutrient limitations, allowing them to reallocate resources to obtain C from leaf litter, potentially accelerating decomposition and nutrient cycling. This decreased activity could also be reflected in the decreased CO_2 efflux in mineral soil due to fertilization.
- Throughfall reduction also resulted in increased C-mineralizing enzyme activity. This response may be a result of the increased litter C:N and lignin:N in the throughfall reduction treatment.

Summary

- Fertilization caused a shift in extracellular enzyme activity from mineral soil N- and P-mineralizing enzyme activity to litter C-mineralizing activity. This shift could accelerate decomposition rates in fertilized loblolly pine systems and decrease C loss from mineral soil.
- Increased litter decomposition could, in the short-term, reduce C sequestration in loblolly pine plantations, but in the long-term, enhance nutrient availability and improve soil productivity.
- Results from this study could be used to infer shifts in decomposition dynamics and microbial nutrient demand in response to forest management and environmental change.

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