Transient increases in fine root biomass and endomycorrhizal colonisation under throughfall exclusion

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1 Introduction

Temperate deciduous forests are experiencing more frequent, severe **droughts**, affecting soil moisture.

Fine root mass and fungal endophyte colonisation are key belowground functional parameters controlling stand water and nutrient acquisition.

Sugar maple is a dominant mesic species whose drought response may shape ecosystem processes of eastern North American hardwood forests.

2 Objectives

Aim: assess effects of multi-year soil water deficits on the depth distribution of **fine root mass density** and **fungal endophyte colonisation (AMF/FRE + DSE):**

1. During treatment with throughfall exclusion.
2. The following growing season (legacy effect).

Endomycorrhizae: AMF = arbuscular mycorrhizal fungi + FRE = fine root endophytes; DSE = dark septate endophytes.

3 Methodology

Design: two sites, 20 × 20 m control and throughfall-exclusion plots, each with two subplots (**Kenauk**: 45°45'N, 74°56'W).

Treatment: ~75% throughfall interception during the growing seasons from 2021 to 2024; relative extractable water (REW) calculated from soil volumetric water content (VWC) at 12 cm:

REW = VWC relative to soil wilting point and field capacity

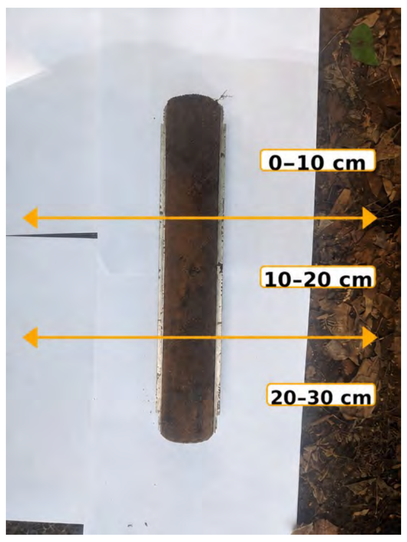
Throughfall-exclusion treatment using semi-transparent tarpaulins.

Sampling:
30 cm mineral-soil cores taken in 2024 and post-exclusion in 2025;

depths: 0-10, 10-20 and 20-30 cm;

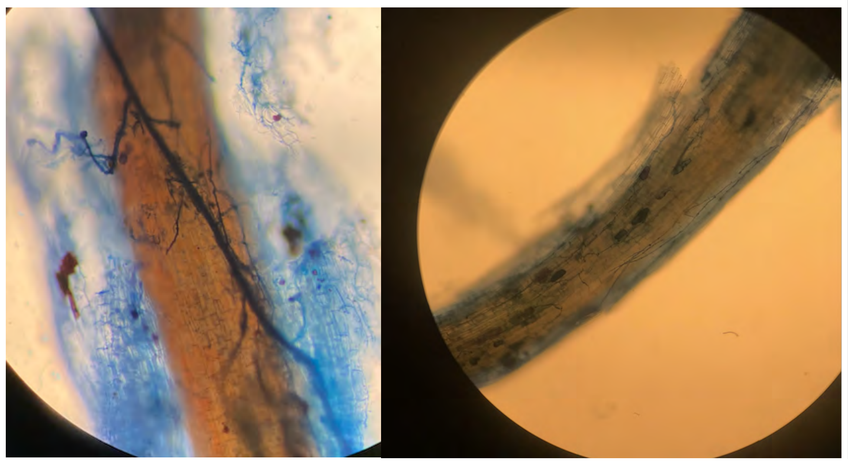
fine roots = 0-2 mm;

Fine root mass density = Root dry mass / Soil dry mass × Soil bulk density

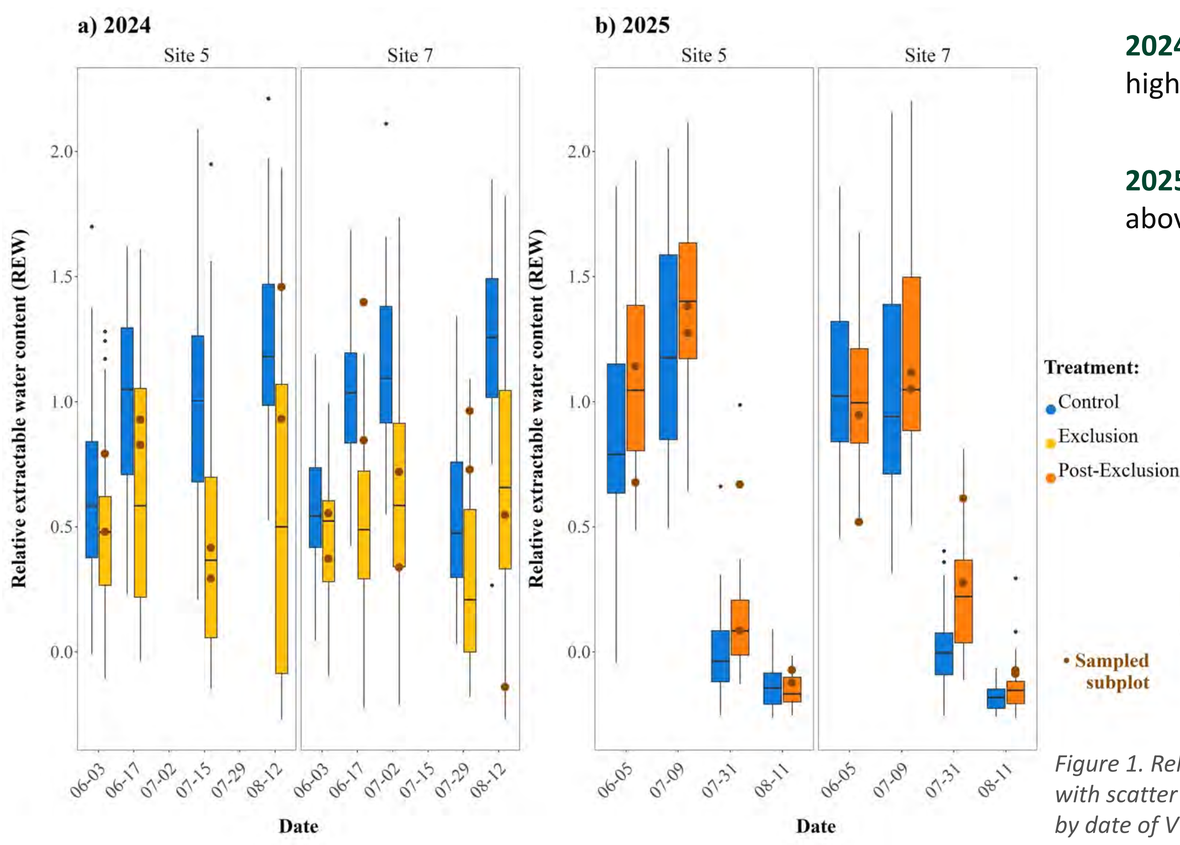


Example of soil core sample.

Fungal endophytes: ***Cleared and stained fine roots*** *showing intraradical hyphae and vesicle-like structures used to score endomycorrhizal (AMF/FRE) colonisation by* ***gridline intersections*** *(100x per sample). DSE not shown.*



Result I – exclusion induced moderate soil moisture deficits in 2024



2024: control plots had consistently higher REW than exclusion plots.

2025: Both remained remained well above 0.5 before sampling (July).

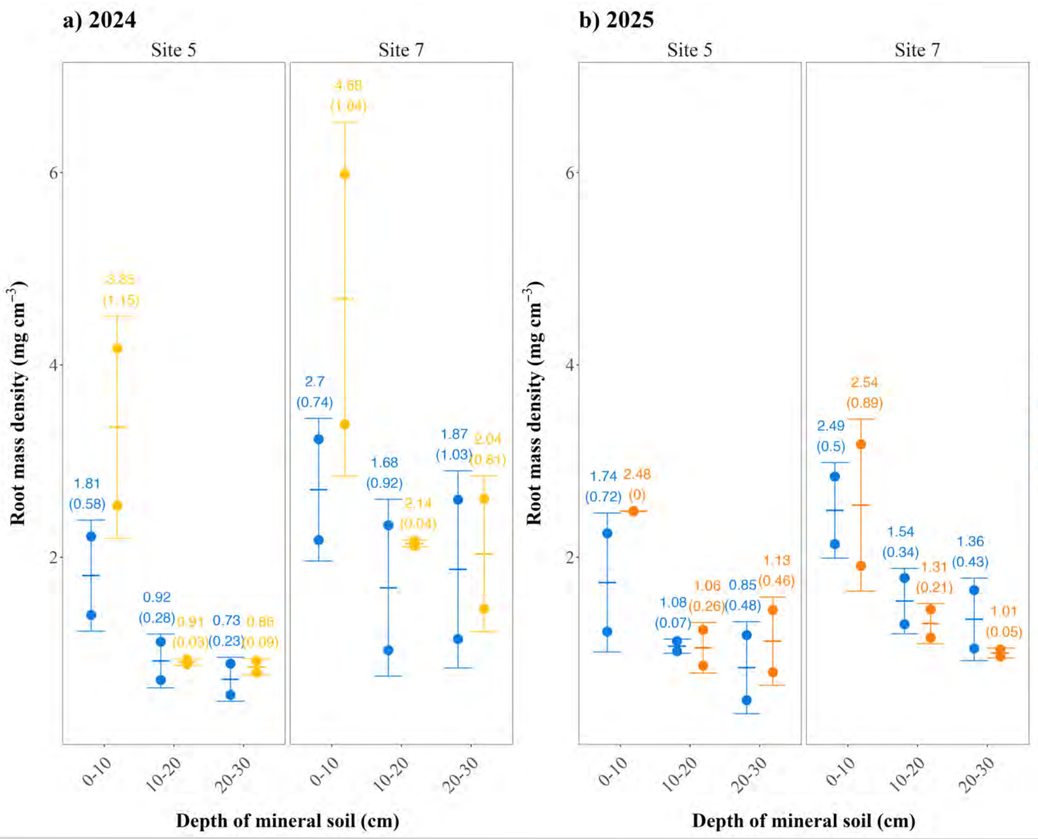
REW ≈ 1 → max plant available water

REW ≈ 0 → no plant available water

Several sampled subplots reached conditions nearing the wilting point in 2024.

Figure 1. Relative extractable water (REW) at 12 cm with scatter dots showing REW of sampled subplots by date of VWC measurements.

Result II – 2024: fine root mass density at 0-10 cm was 80% greater under exclusion 2025: post-exclusion returned to control levels



2024: fine root mass was **80% (95% CI [14, 186]) greater** under exclusion at a soil depth of 0-10 cm.

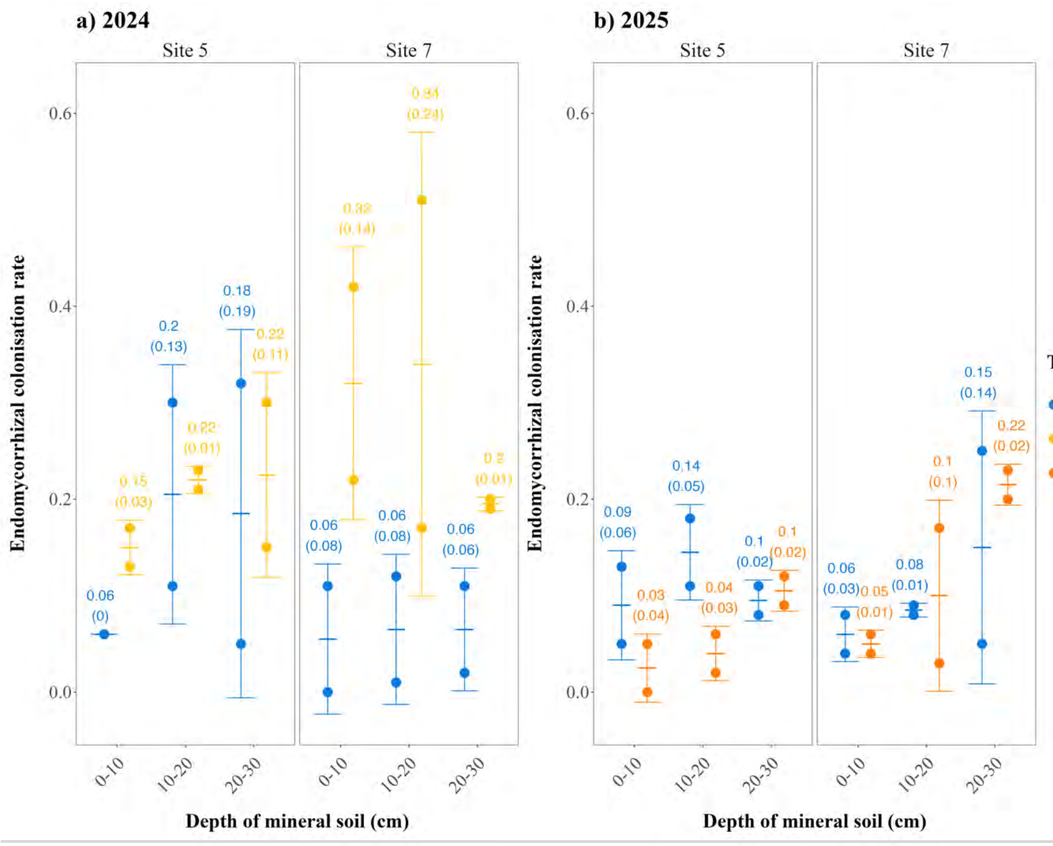
2025 (legacy): returned to control levels **(-1.36 mg cm^{-3} [-2.72, -0.01])** at 0-10 cm.

Stand response reflects low-cost topsoil exploration, where fine roots and immobile nutrients (P) are concentrated.

***Depth :** fine root mass was **79% [14, 182] greater** at 0-10 than 10-20 cm.

Figure 2. Scatter plot of each subplot's fine root mass density with the mean and standard deviation by depth and treatment in July 2024 and 2025.

Result III – 2024: endomycorrhizal colonisation at 0-10 cm was 5× higher under exclusion 2025: post-exclusion returned to control levels



2024: estimated mean colonisation rate was **25% [14, 40] under exclusion vs. 5% [2, 13] in controls** at 0-10 cm.

2025 (legacy): returned to control levels **(-0.22% [-0.40, -0.03])** at 0-10 cm.

Increased hyphal colonisation may expand absorptive surface and increase water/nutrient acquisition of fine roots.

***DSE:** colonisation rate was very low and **half of subplots had no colonised roots**.

Figure 3. Scatter plot of each subplot's endomycorrhizal (AMF/FRE) colonisation rate with the mean and standard deviation by depth and treatment in July 2024 and 2025.

5 Conclusion – topsoil drought response and no short-term legacy effect

2024: Sugar maple stands had a **transient, topsoil drought-response** to soil moisture deficit, rather than deeper soil foraging.

2025: Results indicate rapid turnover and **active regulation** of metabolically costly and plastic fine root-mycorrhizae structures when **soil water availability recovers**.