Fine Root Dynamics Under Elevated CO_2

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INTRODUCTION

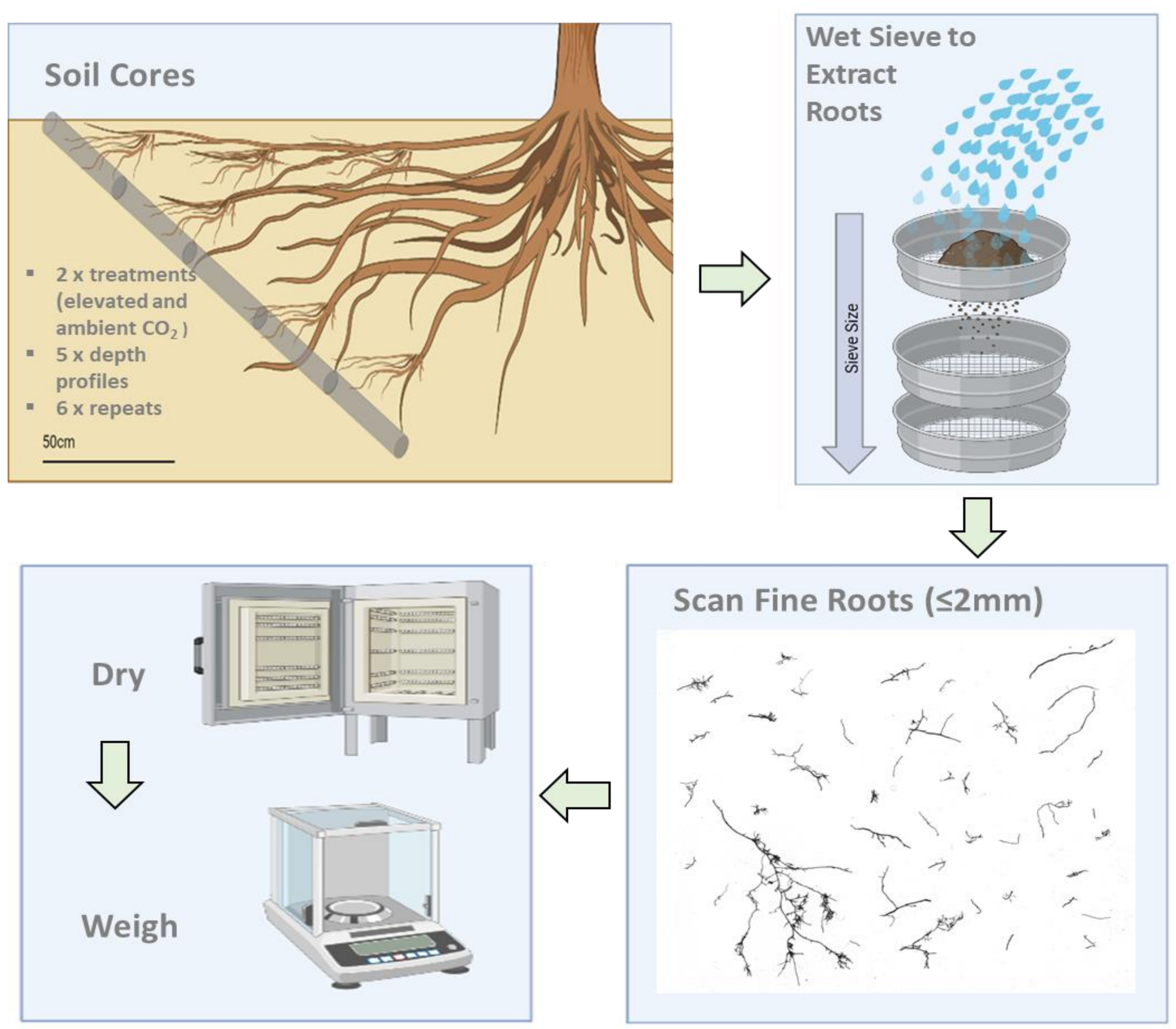
Evidence suggests that forests can **sequester more carbon** under elevated CO_2 as a result of **photosynthetic enhancement** [1]. However, it remains largely unclear **where** and for **how long** this **carbon is stored**. To sustain photosynthetic enhancement under elevated CO_2, trees are likely to require **higher intake of water and nutrients** from the soil, which should **stimulate root growth**. Understanding the fine root dynamics of mature forests in a natural ecosystem in response to eCO_2 is vital for **projecting the future of the terrestrial biosphere in the global carbon cycle** .

RESEARCH QUESTIONS

This ongoing study (2022-2026) at BIFoR FACE aims to answer the following research questions;

1. What is the impact of eCO_2 on root biomass and SRL?
2. What is the impact of eCO_2 on root growth, mortality and turnover rates?
3. What is the impact of eCO_2 on root depth distribution?

METHOD: SOIL CORES



RESULTS

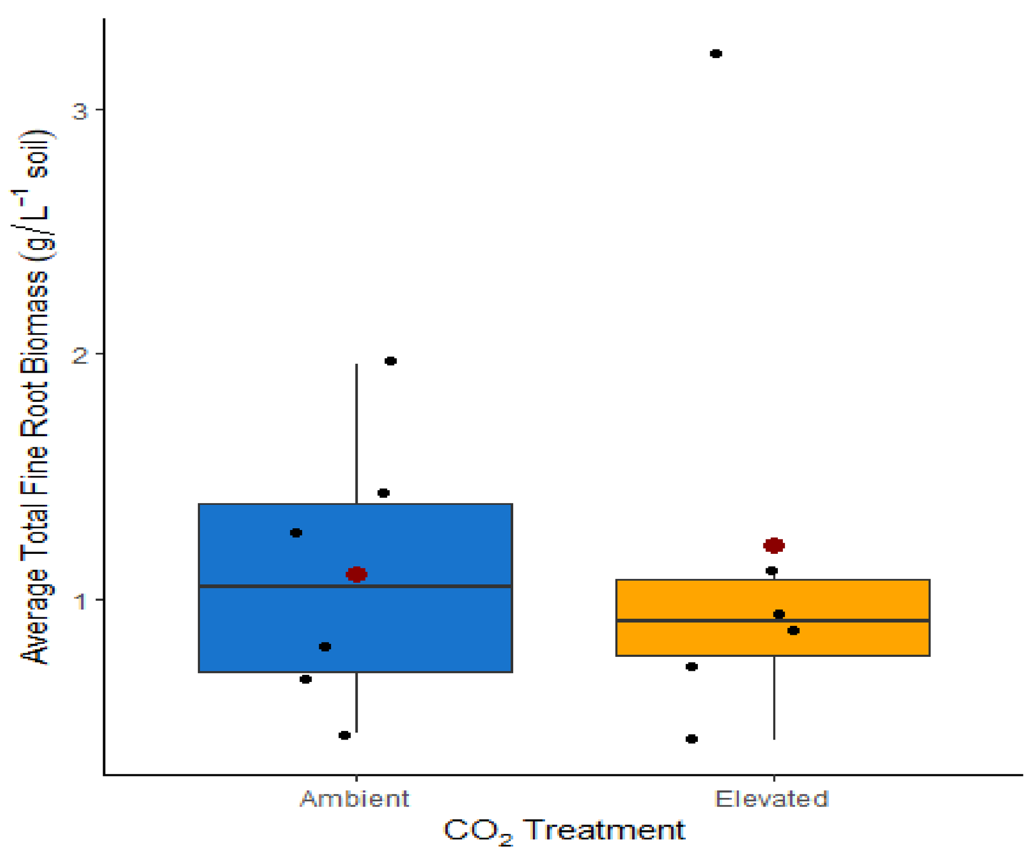


Figure. 1: Average total fine root biomass (g/L -1 soil) of cores to a depth of 1m under ambient and elevated CO_2 (+150ppm) treatments.

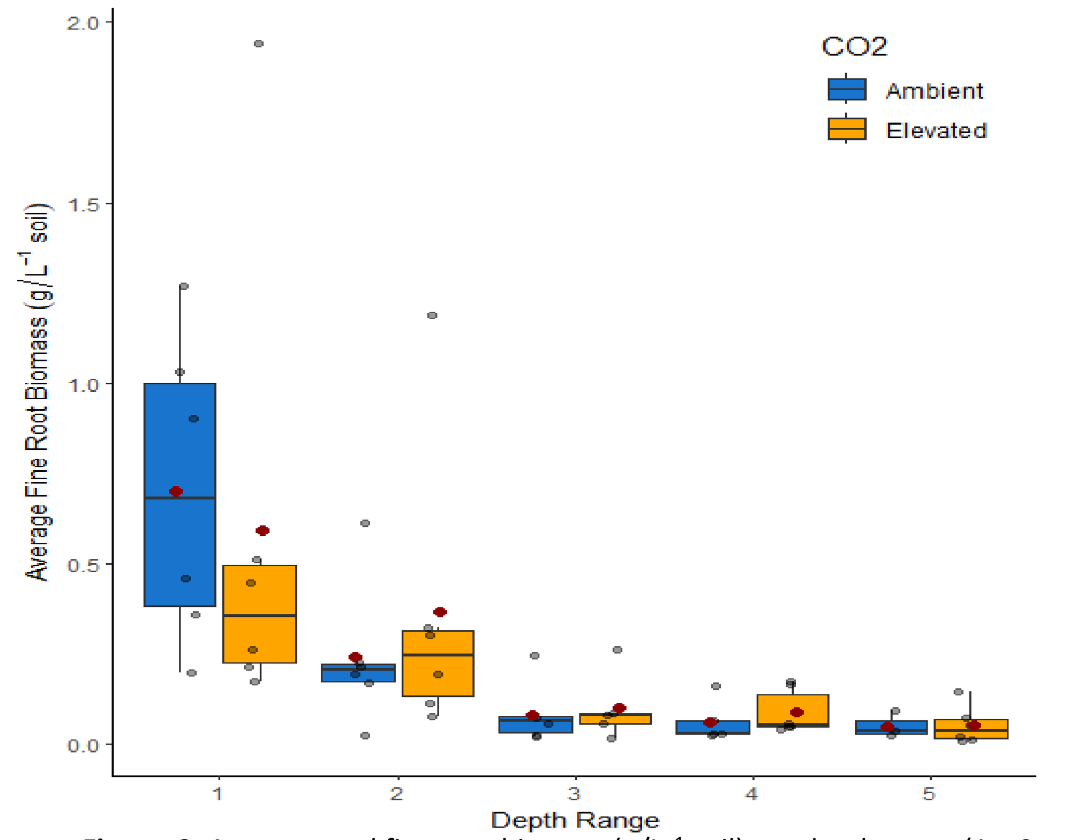


Figure. 2: Average total fine root biomass (g/L -1 soil) per depth range (1 = 0cm - 21.2cm, 2 = 21.2cm - 42.4cm, 3 = 42.4cm – 63.6cm, 4 = 63.6cm – 84.8cm & 5 = 84.8cm – 106cm) for replicates under ambient and elevated CO_2 (+150ppm) treatments. Grey points = individual replicates. Red points = mean.

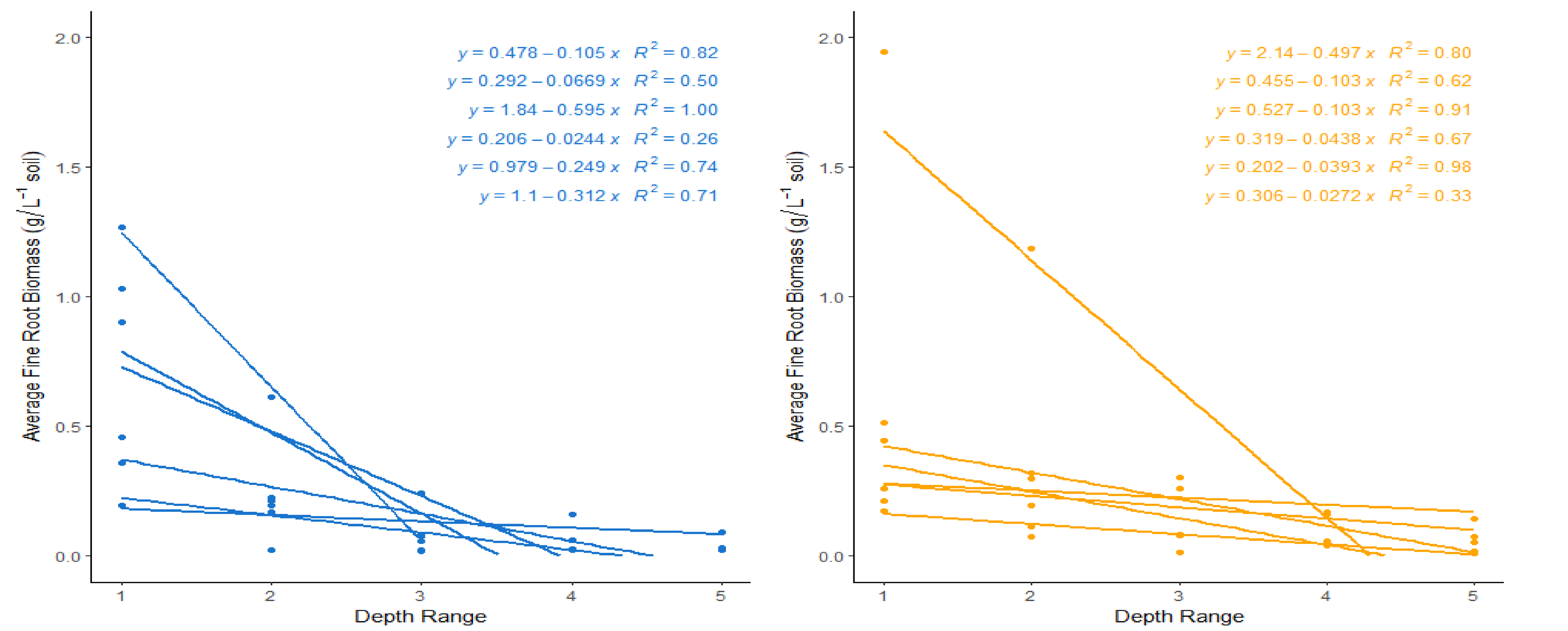


Figure. 3: Fine root biomass (g/L -1) as a function of soil core depth classes (1 = 0cm - 21.2cm, 2 = 21.2cm - 42.4cm, 3 = 42.4cm – 63.6cm, 4 = 63.6cm – 84.8cm, 5 = 84.8cm – 106cm) for replicates under **(A)** ambient CO_2 and **(B)** elevated +150ppm CO_2. Trend lines and equations = linear regression.

Discussion

- Unlike in previous studies [2, 3] the results of this study **cannot fully support the hypothesis that total fine root biomass increases under eCO_2** (Fig. 1).
- However, again unlike similar studies which commonly focus on the first 30cm [2, 3], these cores sampled to a **depth of 1 vertical metre**. Average fine root biomass was **higher under eCO_2 in all depth profiles between 21.2 and 106cm** (Fig. 2).
- Additionally, although both followed the common trend of a negative correlation between average fine root biomass and depth, this correlation was stronger under ambient than elevated CO_2 treatments, meaning that overall, **decline in fine root biomass with depth was less under eCO_2** (Fig. 3).

Conclusions

- These results imply that the **trees may invest in root proliferation in lower depth profiles under eCO_2** to match the increased requirement of water and nutrient uptake and avoid the high levels of competition in the upper soil layers.
- **Soil cores** provide data about **root standing stock** (Fig. 1, 2 and 3).
- However, **minirhizotrons** are required to accurately measure **root growth, mortality and turnover rates.**

NEXT STEPS: MINIRHIZOTRON & AI?

- Minirhizotrons are **cameras** periodically inserted into pre-installed transparent tubes in the soil to photograph root dynamics. This provides **a time series of images** (Fig. 4) from which data on **fine root production, mortality and turnover rates** will be collected.
- Traditionally, the images are analysed using **manual root tracing** software such as Rootfly, a very **time consuming** process with a high potential for **inter-observer bias**.
- We are in the process of trialling the use of Rootpainter – a software which aims to make the benefits of convolutional neural networks (CNNs) and therefore **automated root annotation** more accessible, by combining annotation, training and segmentation with an easy to use, open source user interface.
- This software will be faster and reduce chance of inter-observer bias, but does not differentiate between individual roots as in manual annotation, making **turnover rates difficult to quantify**.

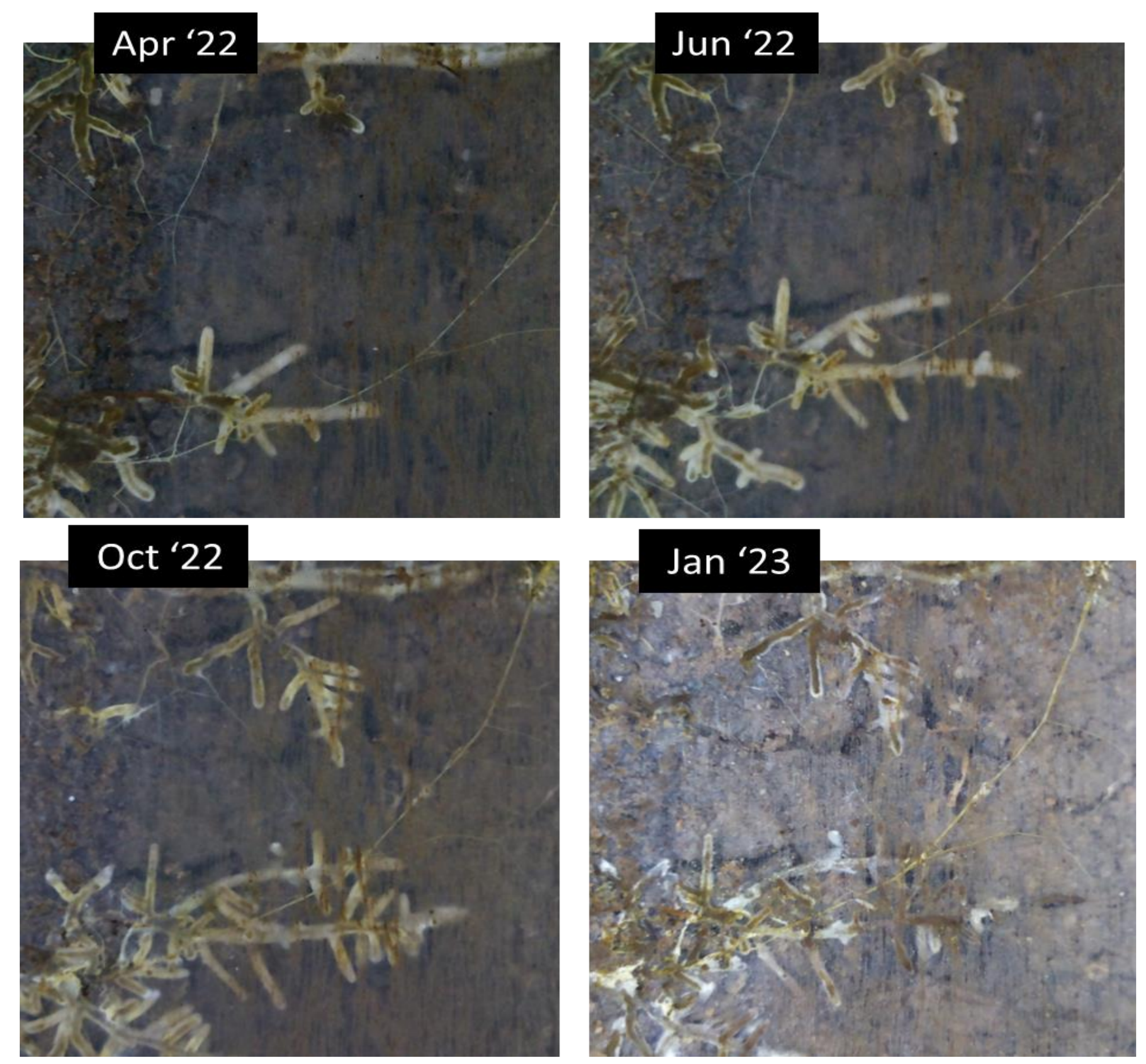


Figure 4: A time series of images taken using a minirhizotron camera.

References

1. Gardner et al., 2022, "Is photosynthetic enhancement sustained through three years of elevated CO2 exposure in 175-year-old Quercus robur?", Tree Physiology, 2022, 42(1):130-44.
2. Norby et al., 2004, "Fine-root production dominates response of a deciduous forest to atmospheric CO2 enrichment". Proceedings of the national Academy of Sciences, 2004, 29;101(26):9689-93.
3. Ziegler et al., 2023, "Quantification and uncertainty of root growth stimulation by elevated CO2 in a mature temperate deciduous forest." Science of The Total Environment, 1;854:158661.

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