Elevated CO_2 and O_3 Effects on Fine-Root Life Span in Ponderosa Pine

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Abstract

Atmospheric carbon dioxide (CO_2) and ozone (O_3) concentrations are rising, which may have opposing effects on tree C balance and allocation to fine roots. More information is needed on interactive CO_2 and O_3 effects on roots, particularly fine-root life span, a critical demographic parameter and determinant of soil C and N pools and cycling rates. We conducted a study in which ponderosa pine (*Pinus ponderosa*) seedlings were exposed to two levels of CO_2 and O_3 in sun-lit controlled-environment terracosms for three years. Minirhizotrons were used to monitor individual fine roots in three soil horizons every 28 days. Proportional hazards regression was used to analyze effects of CO_2, O_3, diameter, depth, and season of root initiation on fine-root survivorship. More fine roots were produced in the elevated CO_2 treatment than in ambient CO_2. Median life spans varied from 140-448 days depending on the season of root initiation. Elevated CO_2, increasing root diameter, and increasing root depth all significantly increased fine-root survivorship and median life span. Life span was slightly, but not significantly, lower in elevated O_3, and increased O_3 did not reduce the effect of elevated CO_2. These results indicate the potential for elevated CO_2 to increase the number of fine roots and their residence time in the soil, which is also affected by root diameter, root depth, and phenology.

Introduction

- CO_2 and O_3 are generally increasing worldwide
- Leaves are sites of uptake and direct action, but CO_2 and O_3 can affect C assimilation and allocation with consequences for whole plant
- Fine roots are especially important because of:
  - role in water and nutrient uptake
  - significant contribution to NPP and its responses to CO_2 and O_3
- CO_2 and O_3 have potentially offsetting effects of on fine roots (allocation, growth, mortality)
- Fine root life span is an important determinant of soil C pools and cycling rates
- Multi-year studies are needed on CO_2 & O_3 effects on fine root longevity

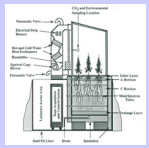
Hypotheses

1. Elevated CO_2 alone will increase life span
2. Elevated O_3 will alone decrease life span
3. Elevated CO_2 and O_3 together will show additive compensatory effects on life span
4. Life span will increase with root diameter, soil depth, and vary with season of root formation

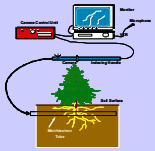
Methods

- 3 year experiment on ponderosa pine seedlings
- Sun-lit controlled environment mesocosms at EPA lab in Corvallis, OR
- 2-way factorial (2 CO_2 x 2 O_3 with 3 replicates)
  - CO_2: ambient (AC), elevated (EC; AC+270 ppm)
  - O_3: low (LO; 0 ppm-h seasonal SUM06) high (HO; 10-26 ppm-h seasonal SUM06)
- Minirhizotron tubes at 4 depths
- Each fine root (≤2 mm diameter) was measured in images recorded every 28 days
- Proportional hazards regression was used to analyze the effects on fine-root life span of:
  - CO_2 and O_3 treatments
  - season of root formation, horizon, diameter

Mesocosm array



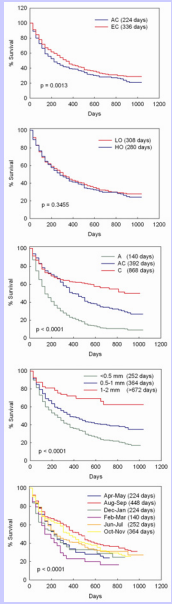
Mesocosm cross-section



Minirhizotron imaging system

Minirhizotron image with roots

Results and Discussion



- 46% more individual roots were produced in elevated CO_2
- Elevated CO_2 significantly increased median life span
- Effect was not due to differences in diameter or depth

- Median life span was 10% longer at low ozone but the difference was not significant
- High ozone treatment may have been too mild for significant effect

- Median life span increased 6-fold with depth
- Possible factors: more stable temperature & moisture, reduced herbivory, lower maintenance respiration in cooler temperatures

- Median life span increased 3-fold over diameter categories
- Possible factors: functional differences, vulnerability to stresses (e.g., parasitism, drought), construction costs, respiration rates, root branch order

- Median life span varied >3-fold over seasonal cohorts
- Late summer/fall cohorts lived longest; winter/early spring cohort had shortest life spans
- Over all cohorts, monthly survival rates were greatest in Jan-Apr, periods of low soil temp. and peak soil moisture

Conclusions

- Elevated CO_2 led to longer-lived fine roots in growing ponderosa pine seedlings, as did increasing depth & diameter
- No compensatory effects of elevated CO_2 and elevated O_3 on root life span were observed
- Fine root C turnover at end of study was lower for EC (290 g/m^2/yr) than for AC (374 g/m^2/yr)
- Thus, elevated CO_2 may lead to increased root C residence time in the soil (at least for tree seedlings)