Physiological response of canopy red spruce to an experimental extreme drought

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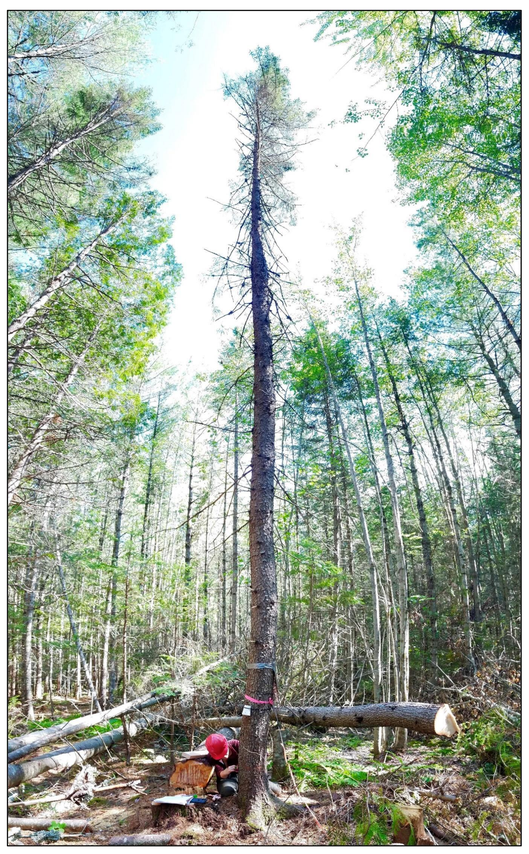
Background

- Drought frequency and severity are projected to increase for the northeastern US. However, it is still unclear how mesic forest trees in this region will respond to novel future climate conditions.
- Experimentally manipulating soil moisture for canopy trees is logistically difficult, making it challenging to predict how novel future droughts will impact tree growth and survival. Therefore, we severed functional sapwood to simulate extreme drought.

Study Objectives

1) Quantify how sapwood severing induced extreme drought conditions through reductions in sap flow
2) Measure physiological responses after water stress was induced, quantifying any evidence of drought resistance strategies.



Methods

- We severed the functional xylem in eight suppressed red spruce trees.
- Over the next four months we intensively monitored the impacts of this drought on water relations, photosynthesis, and growth.
- Due to larger than anticipated variations in bark thickness, two of the four trees in the sapwood severing treatment still had partial sapwood remaining unintentionally.
- Therefore, our focal trees are split into three groups: total sapwood severed (TOT; n = 2), partial sapwood severed (PAR; n = 2), and control (CON: n = 4, Figure 1).

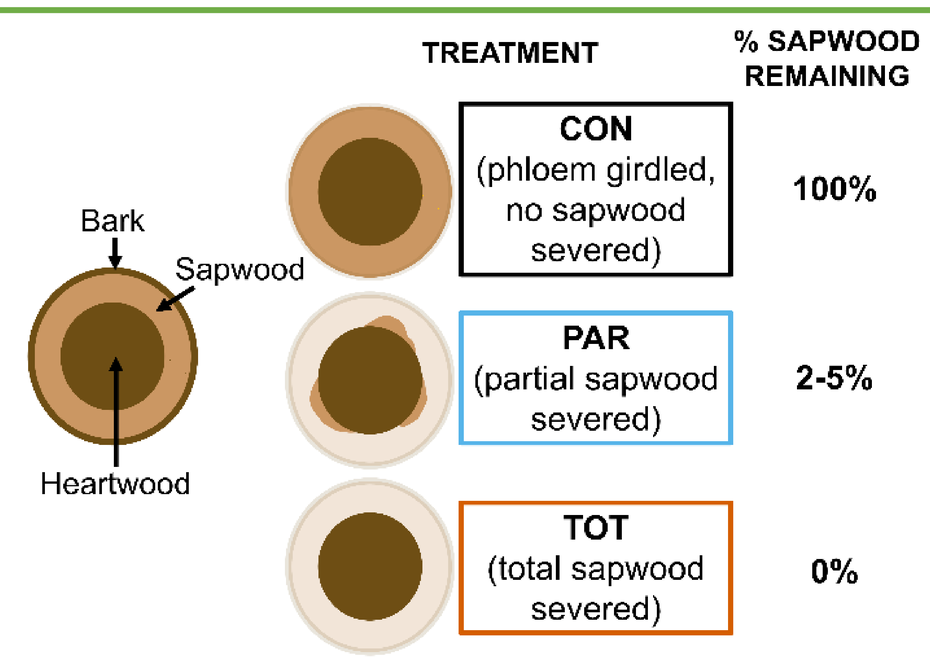


Figure 1. Representative illustrations of the three sapwood severing treatments: phloem girdled control (CON), partial sapwood severed (PAR), and total sapwood severed (TOT).

Results

Only by severing 100% of the sapwood (total sapwood severed, TOT) did we see a complete reduction in daily sap flow (Figure 2a). Interestingly, trees that only had partial sapwood severed (PAR; 2 - 5% sapwood remaining) experienced only 74% sap flow reduction.

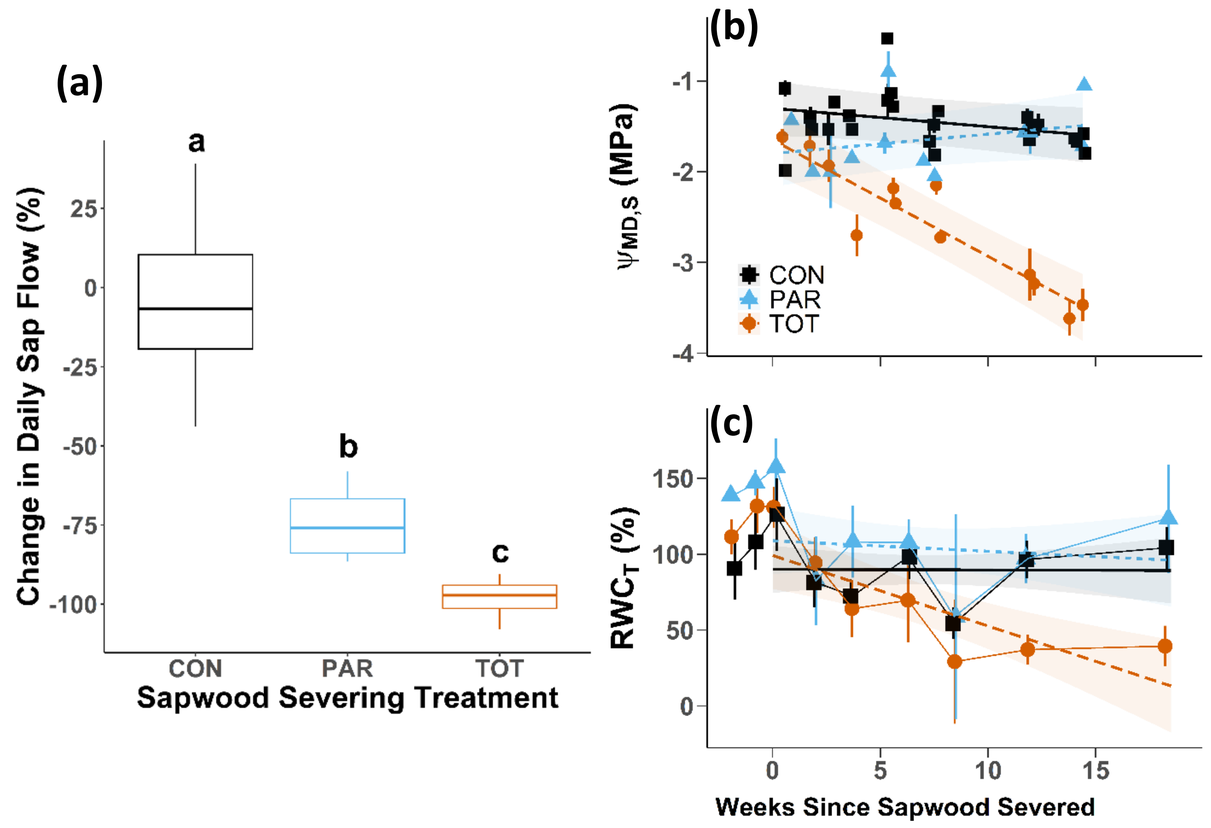


Figure 2. (a) Percent change in daily sap flow of CON, PAR, and TOT trees after treatment initiation (statistical significance denoted by letters, $p<0.05$). (b) Shoot midday water potential ($\psi_{MD,S}$) for each focal tree and (c) average relative water content of trunk-wood (RWC_T) (n=8, ± two standard errors). Statistically significant linear mixed-effects models are overlayed with 95% confidence intervals shown as the shaded region.

Total sapwood severing (TOT trees) resulted in gradual water stress (Figure 2b-c) but did not reach substantial physiological water stress until ~12 weeks after treatment initiation. PAR never experienced significant water stress.

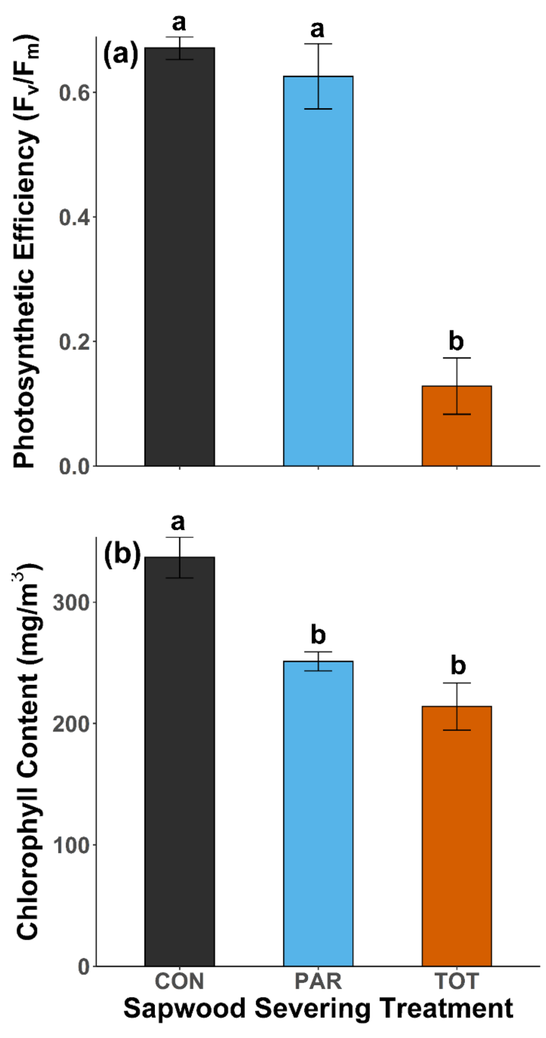


Figure 3. (a) Photosynthetic efficiency (F_v/F_m) and (b) chlorophyll content (mg/m^3) for each sapwood severing treatment 18 weeks post treatment (statistical significance denoted by letters, $p<0.05$).

TOT trees reduced stomatal conductance by 6.8x compared to PAR and CON trees, in order to conserve water in response to the experimental drought.

Despite extreme drought stress, TOT trees did not experience damage to photosystems or reduced chlorophyll content in leaves until 18 weeks after treatment initiation (Figure 3). At 18 weeks, PAR trees also showed reduced chlorophyll content in needles, suggesting that the reduced sap flow was beginning to have negative effects.

Conclusions

These results indicate that red spruce demonstrates resistance to extreme drought induced by sapwood severing, but that stomatal closure to conserve water will likely result in reduced carbon sequestration and growth in the drought year and future years.

Acknowledgments

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