Autumn warming delays downregulation of photosynthesis and does not increase risk of freezing damage in interior and coastal Douglas-fir seedlings

Devin Noordermeer1, 2, *, Vera Velasco1, Ingo Ensminger1, 2

1 Department of Biology, University of Toronto Mississauga, Mississauga ON, CA; 2 Graduate Program in Cell and Systems Biology, University of Toronto, Toronto ON, CA; * devin.noordermeer@utoronto.ca

INTRODUCTION

- Climate change will result in asynchronous phasing between the temperature and photoperiod signals that conifers rely upon for cold hardening in autumn [1].
- Cold hardening involves downregulation of photosynthesis and transition from dynamic to sustained nonphotochemical quenching (NPQ) via xanthophyll pigment changes [2].
- Understanding how autumn warming will affect cold hardening in Douglas-fir (Pseudotsuga menziesii) is essential to improve future breeding outcomes in British Columbia (BC), Canada.

OBJECTIVES

1. Characterize the intraspecific variation in the photosynthetic and photoprotective mechanisms of cold hardening
2. Determine the plasticity of cold hardening in response to autumn warming

HYPOTHESES

- Autumn warming will:
  1. Delay downregulation of photosynthesis (and therefore prolong carbon uptake period)
  2. Delay the transition to sustained nonphotochemical quenching
  3. Impair the development of freezing tolerance

METHODS

- Seedlings of two interior (LIT, MEL) and two coastal (PEM, TSO) provenances selected to encompass full range of climatic conditions within Douglas-fir’s BC distribution (Fig. 1) [3]
- Seedlings transferred to growth chambers and acclimated for 42 d to historical summer conditions: 16 h photoperiod and 22 °C/13 °C (long day/summer temp; LD/ST)
- Photoperiod shifted to 8 h and seedlings acclimated for 42 d to projected autumn conditions:
  - 4 °C/14 °C (short day/low temp; SD/LT)
  - 18 °C/11 °C (short day/high temp; SD/HT)
- Gas exchange and chlorophyll fluorescence measured via GFS-3000
- Photosynthetic pigment quantities analyzed via HPLC [4]
- Freezing tolerance assessed via chlorophyll fluorescence after exposing needles to 0°C to -40°C at 5°C intervals; vulnerability curves constructed and LT50 calculated [5]

RESULTS

- Hypothesis 1: Delayed photosynthetic downregulation and transition to sustained NPQ

- Hypothesis 2: Delayed xanthophyll pigment changes

- Hypothesis 3: Impaired freezing tolerance

REFERENCES

[1] McMahon et al. (2010), PNAS 107(8), 3611–3615

ACKNOWLEDGEMENTS

Study funding provided under the CoAdapTree Project by Genome Canada, Genome British Columbia, NSERC, and 15 other sponsors (https://coadaptree.forestry.uta.ca/sponsors/)

CONCLUSIONS

- Results suggest photoperiod alone is causal seasonal signal for development of freezing tolerance in Douglas-fir
- Intraspecific variation: interior provenances (LIT, MEL) developed greater freezing tolerance
- All provenances exposed to autumn photoperiod (SD) developed freezing tolerance sufficient for projected winter temperatures
- Prolonged carbon uptake period under future climate for Douglas-fir
- Potential future research: does this translate into increased growth?