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

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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 grown in greenhouse
- Provenances selected to encompass full range of climatic conditions within Douglas-fir's BC distribution (Fig. 1) [3]

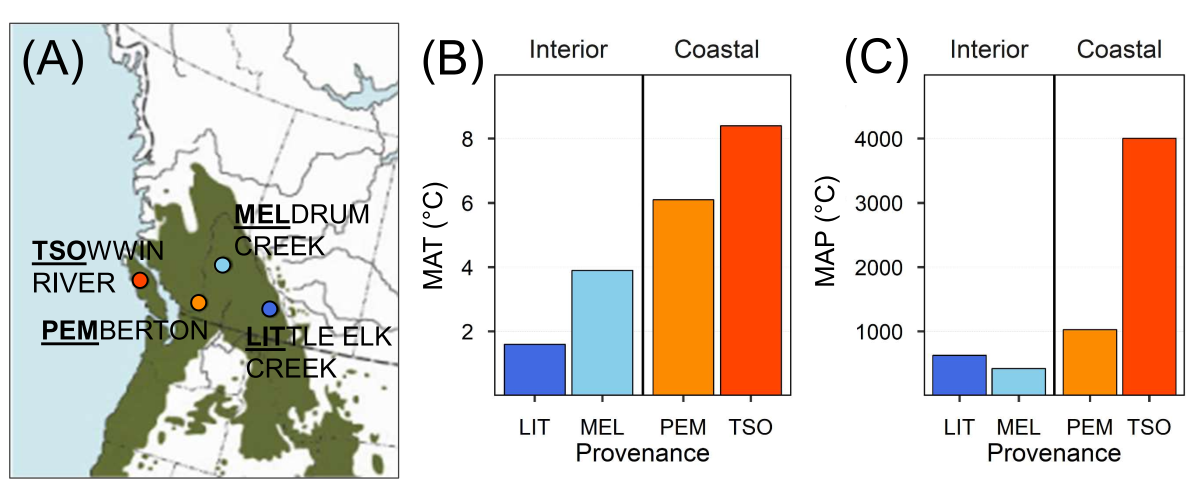

Fig. 1 *Provenance (A) location and (B) mean annual temperature (MAT) and (C) precipitation (MAP) from 1961-1990.*

- 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 historical and projected autumn conditions:
  - 4 °C/-4 °C (short day/low temp; SD/LT)
  - 19 °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 LT_{50} calculated [5]

DELAYED PHOTOSYNTHETIC DOWNREGULATION

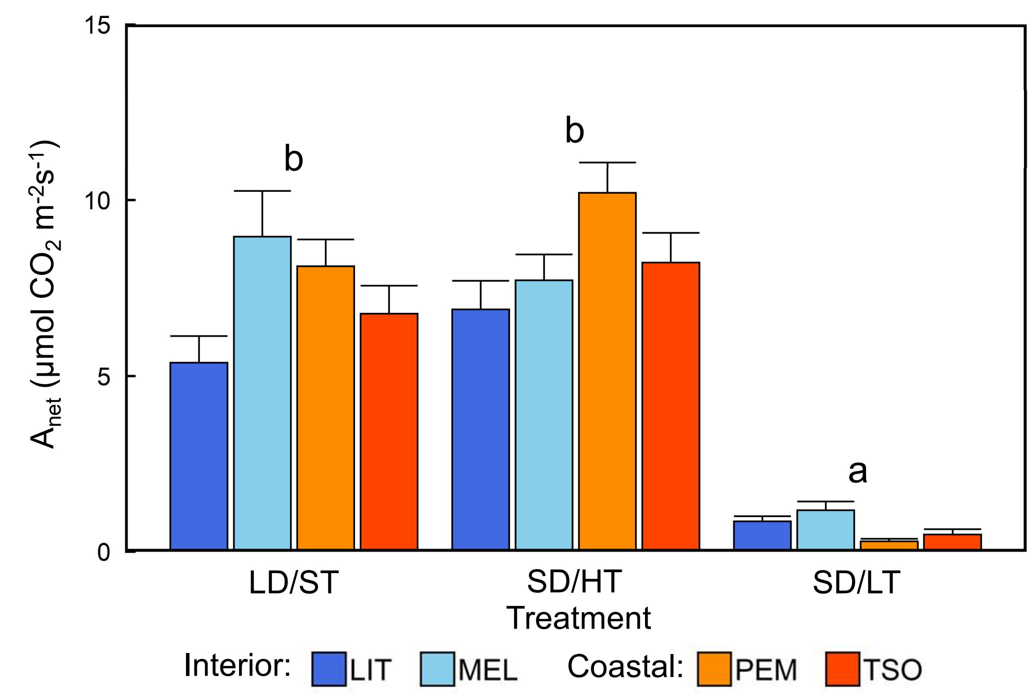

Fig. 2 *Changes in CO_2 assimilation rate in response to short day/high temperature (SD/HT) and short day/low temperature (SD/LT). Data shows mean ± SE, n = 10. Letters indicate statistically different groups ($p < 0.05$) as determined by LSD test.*

DELAYED XANTHOPHYLL PIGMENT CHANGES

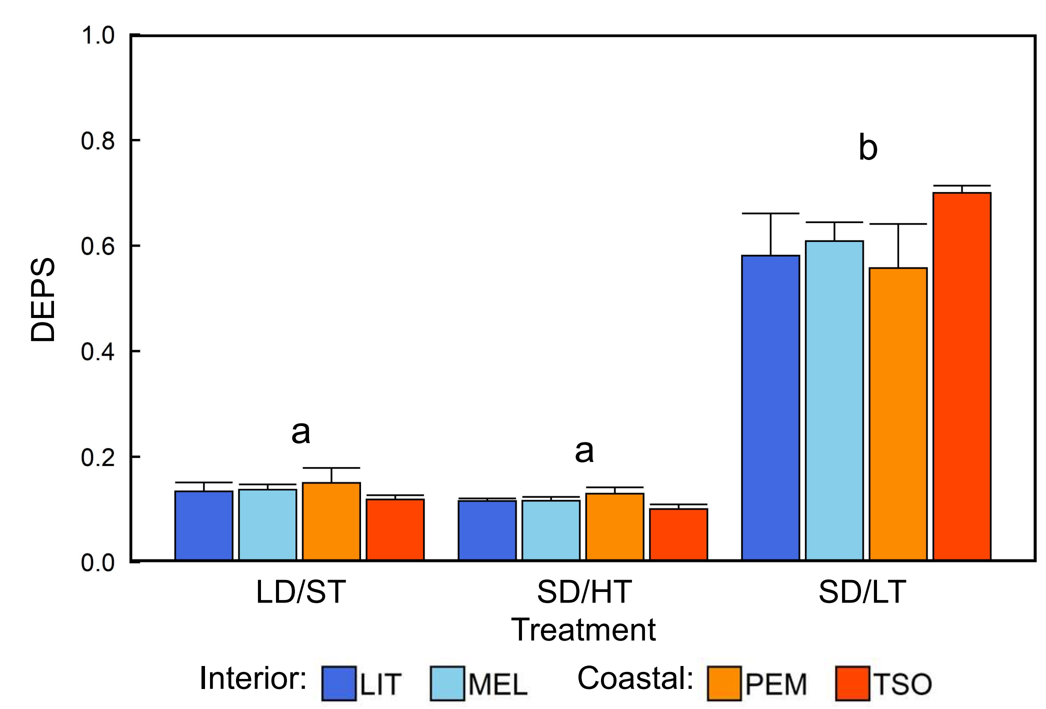

Fig. 3 *Changes in de-epoxidation state (DEPS) of xanthophyll cycle pigments in response to short day/high temperature (SD/HT) and short day/low temperature (SD/LT). Data shows mean ± SE, n = 5. Letters indicate statistically different groups ($p < 0.05$) as determined by LSD test.*

DELAYED TRANSITION TO SUSTAINED NPQ

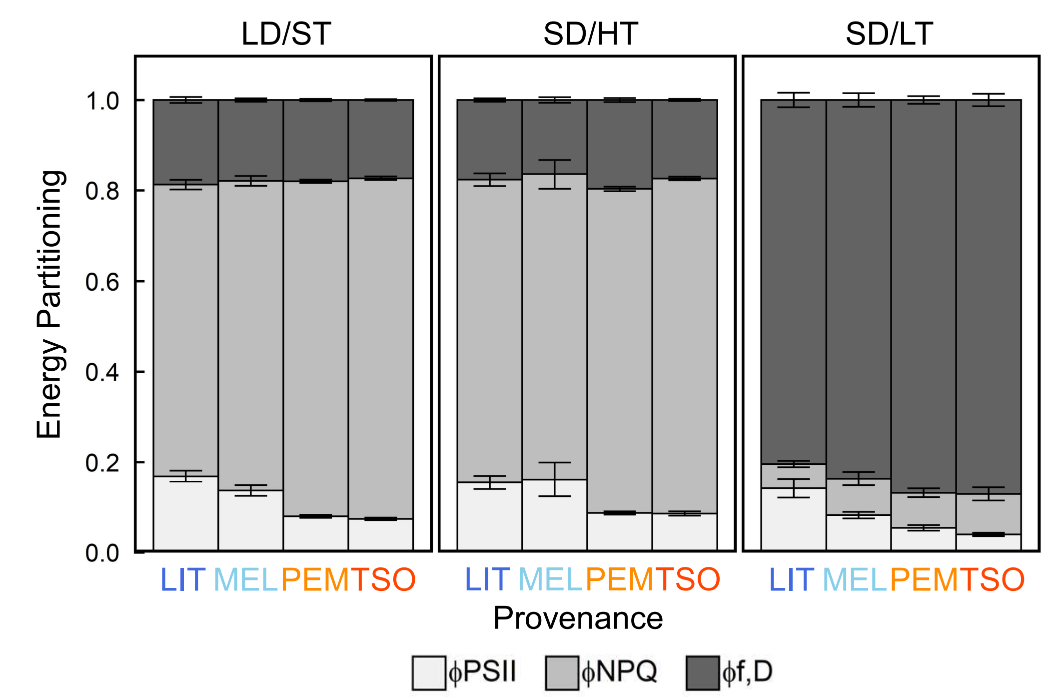

Fig. 4 *Changes in energy partitioning toward sustained nonphotochemical quenching (ϕf,D) in response to short day/high temperature (SD/HT) and short day/low temperature (SD/LT). Data shows mean ± SE, n = 10.*

NO INCREASE IN FREEZING DAMAGE RISK

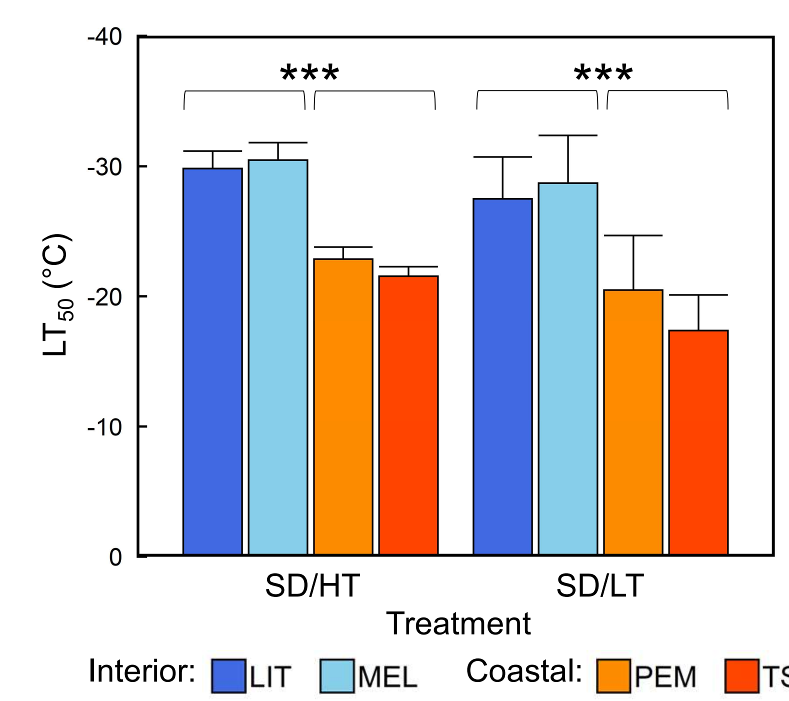

Fig. 5 *Response of freezing tolerance for interior and coastal Douglas-fir to short day/high temperature (SD/HT) and short day/low temperature (SD/LT). Bars represent mean LT_{50} ± 95% CI, n = 5, estimated via sigmoidal curves fit to data. Stars indicate statistically different groups ($p < 0.001$) as determined by ratio test [6].*

REFERENCES

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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?