Thermal acclimation of needle photosynthesis of two white spruce seed sources tested along a regional climatic gradient

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Introduction

Understanding how physiological processes involved in photosynthesis and respiration will acclimate to warmer conditions is crucial to :

- Predict climate change effect on carbon uptake at different scales
- Determine the ability of tree species to adapt to climate change
- Increase the accuracy of process based models predictions

The level of acclimation of net photosynthesis (A_n) and dark respiration (Rd) to temperature (T), and underlying morphological, biochemical and biophysical mechanisms remains unknown for boreal tree species

Introduction

Thermal acclimation of photosynthesis

1. Upshift in the thermal optimum (T_{opt})
2. Increase in the rate of assimilation (A_{opt}) at T_{opt}
3. Adjustment of the activation energy maximal rate of carboxylation (V_{cmax}) and J_{max} (maximal rate of electron transport)
4. Adjustment of the J_{max}/V_{cmax} ratio

Thermal acclimation of respiration

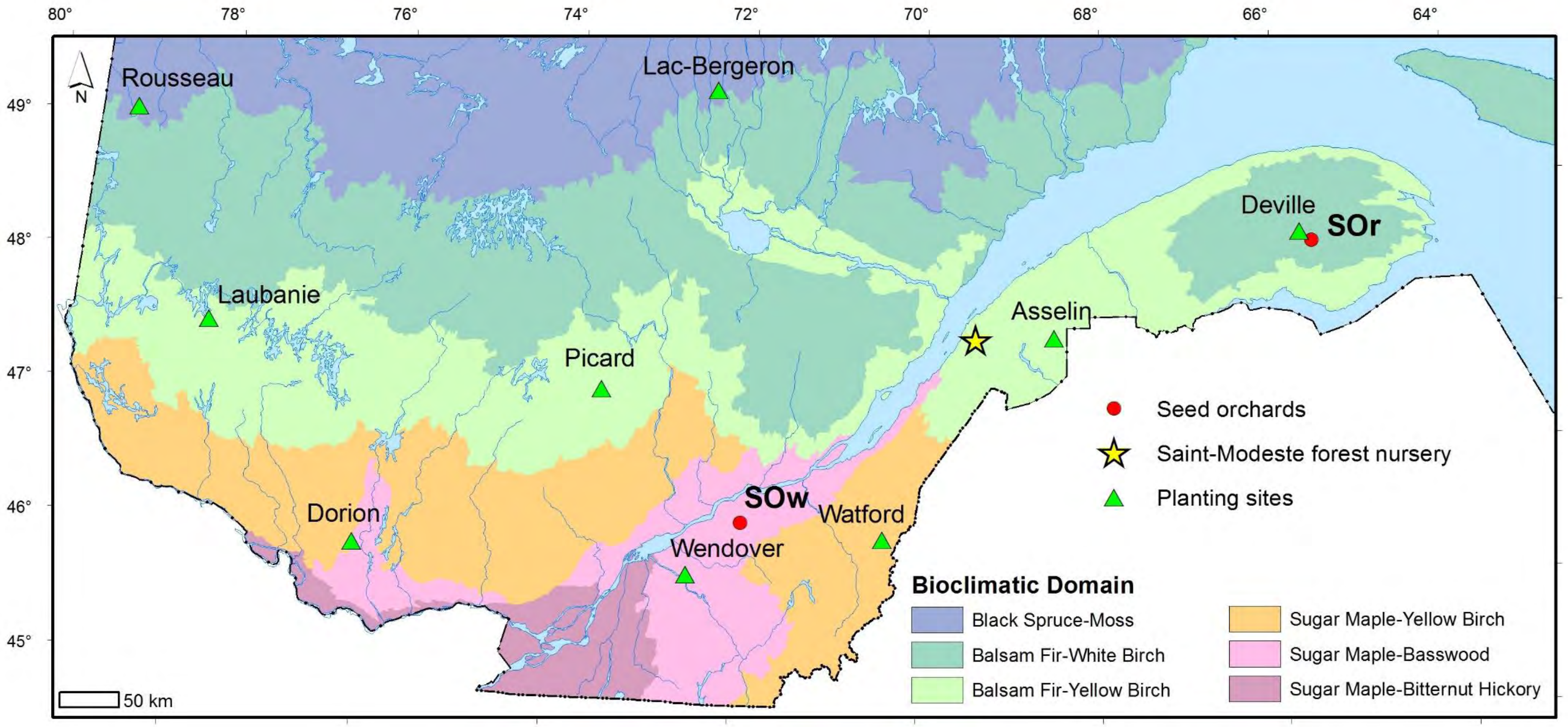
1. Downshift in Q_{10} (acclimation type I)
2. Downshift in basal rate of respiration (Rd_{10}) (acclimation type II)

Objectives

- Examine the thermal acclimation of photosynthesis and respiration in two white spruce seed sources in response to long-term variation in growing conditions along a regional climatic gradient (ΔT=5.5 °C)

- Determine whether thermal acclimation of A_n is driven by thermal sensitivity of the maximum rate of Rubisco carboxylation (V_{cmax}) or maximum electron transport rate (J_{max}) or mesophyll conductance (g_m).

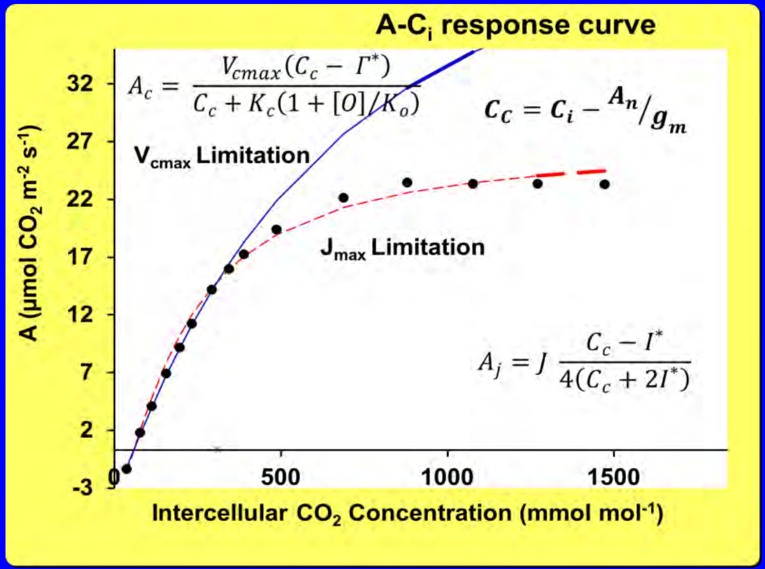
Materials & Methods



- Eight plantation sites established in 2013, 2014 and 2015
- Two first-generation white spruce seed orchards (SOw and SOr) commonly used for reforestation in Québec

Materials & Methods

- Temperature response curves of needle respiration (Rd-T) and net photosynthesis (An-T) on one year-old needles (T, from 10 to 40 °C)
- CO_2 response curve of photosynthesis
- (A-C_i) at different temperatures (from 10 to 40°C)
- Seasonal pattern of Rd-T and An-T
- $V_{cmax,}$ J_{max} and their temperature dependencies



Materials & Methods

Characterization of the temperature response of gas exchange parameters

$$An(T) = Aopt - b(T - Topt)^2$$

Net photosynthesis: thermal optimum

$$Rd\ (T) = Rd_{10} Q_{10}{}^{[(T-10)/10]}$$

Respiration: Q10

$$V_{cmax}(T_k) = k_{25}\ \frac{e^{\left[\frac{H_a}{RT_{ref}}\left(1-\frac{T_{ref}}{Tk}\right)\right]}}{1+e^{\left[\frac{\Delta S T_k - H_a}{RT_k}\right]}}\ \left[1+e^{\left(\frac{\Delta S\, T_{ref}-H_d}{R\, T_{ref}}\right)}\right]$$

$$Topt = \frac{H_d}{\Delta S - R\ ln\left[{}^{Ha}/_{(H_d - H_a)}\right]}$$

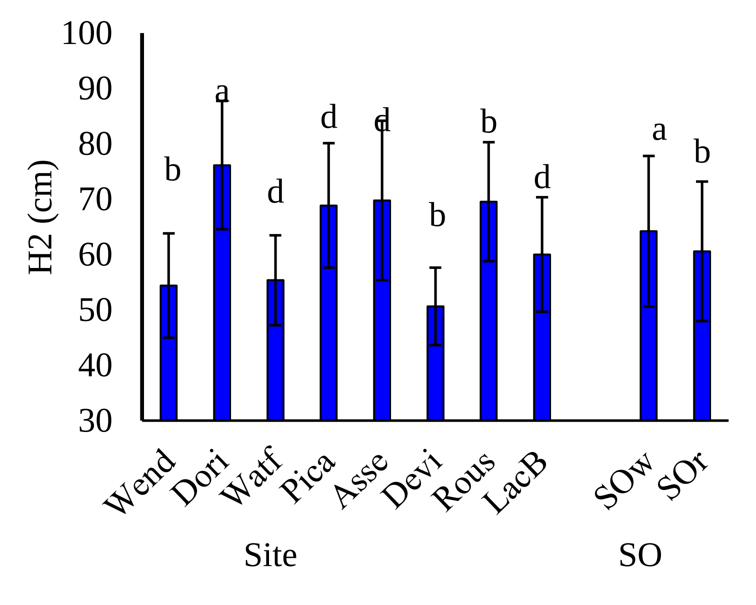
Carboxylation and electron transport

$$gm = gm_{opt}\ e^{\left[-0.5\left[ln\left({}^{T}/_{T_{opt}}\right)/b\right]^2\right]}$$

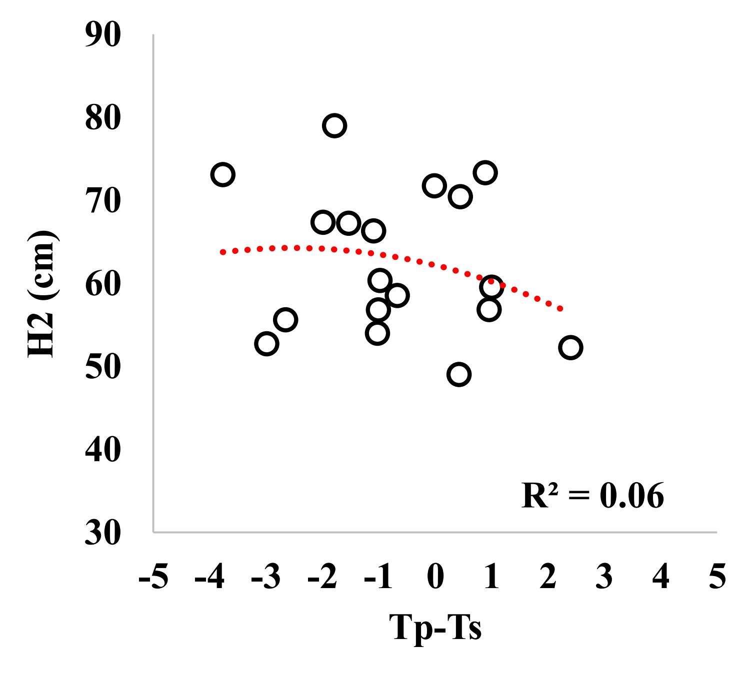
Mesophyll conductance

Results & Discussion

Height growth after two growing (H2) seasons of the two seed sources responded similarly to change in site conditions along the climatic gradient



Unexpectedly, Height growth was unrelated to site climate

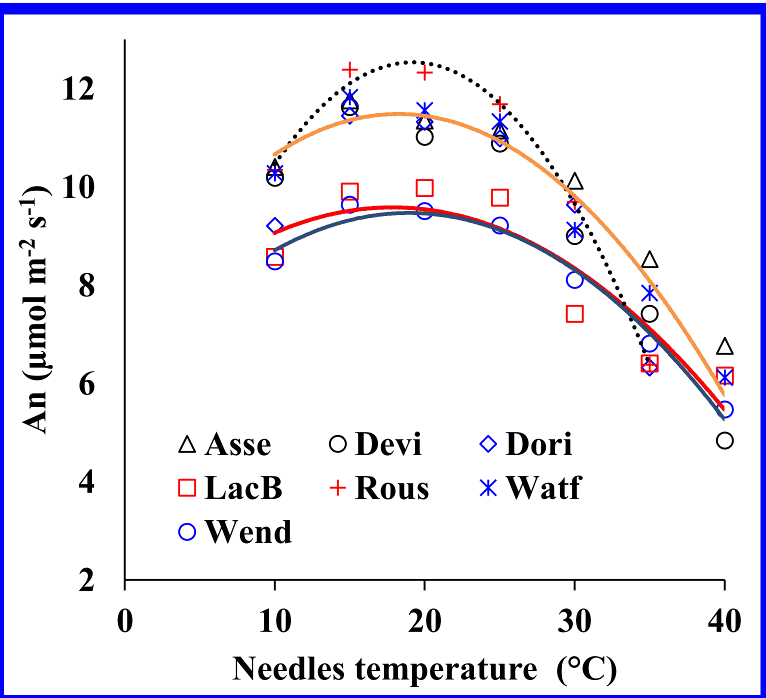


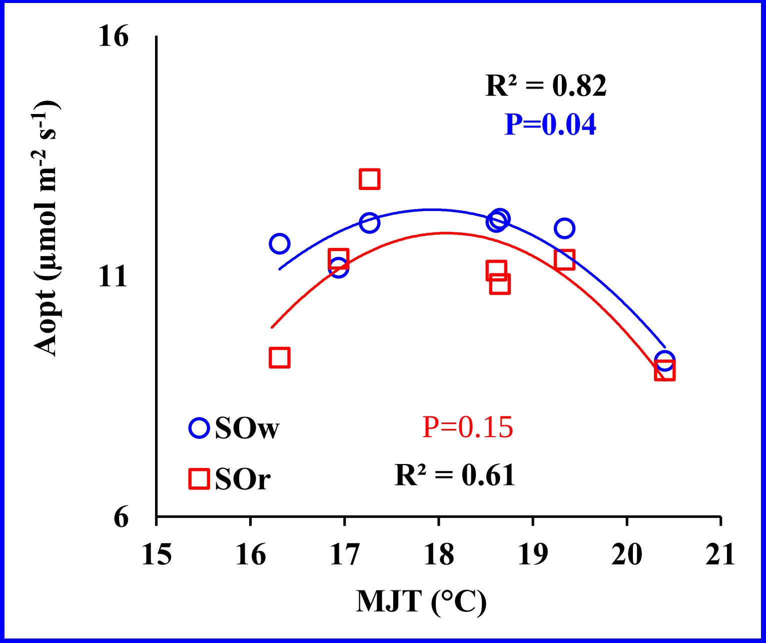
Results & Discussion

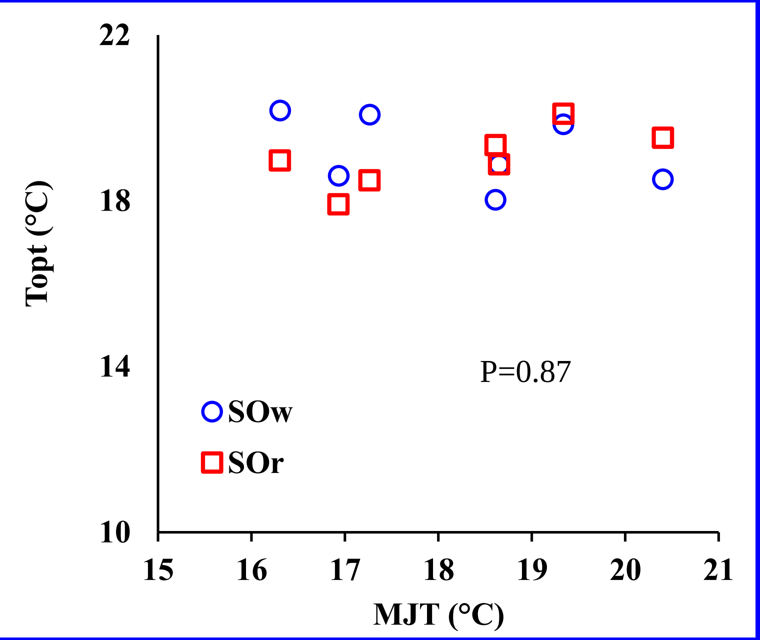
The thermal optimum (T_{opt}) for net photosynthesis was 19 °C.

T_{opt} was similar among sites and seed sources

Photosynthesis at T_{opt} (A_{opt}) was quadratically related to site mean July temperature (MJT)







Results & Discussion

Rd_10 but not Q_{10} showed a downshift with increasing site temperature

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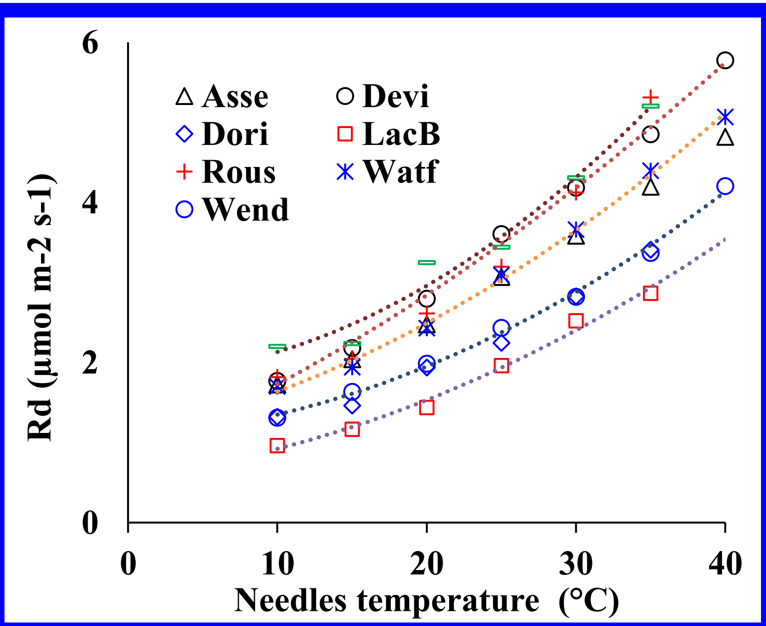
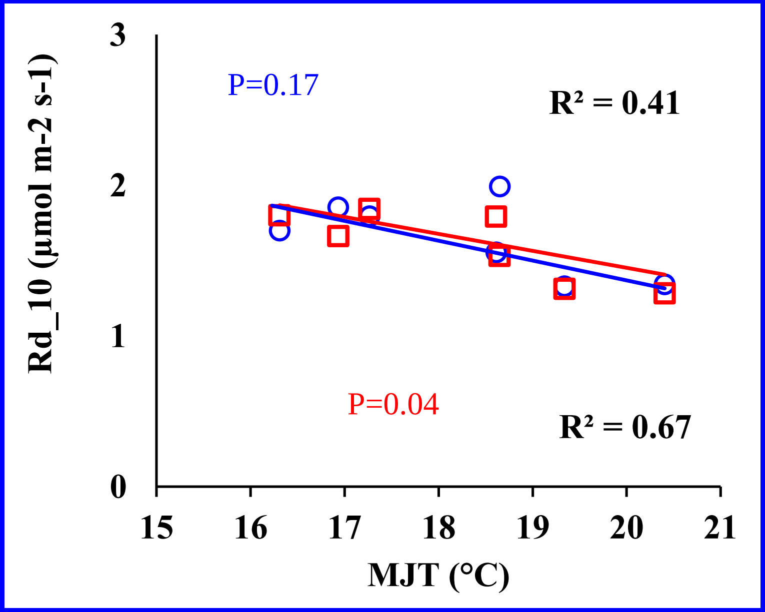
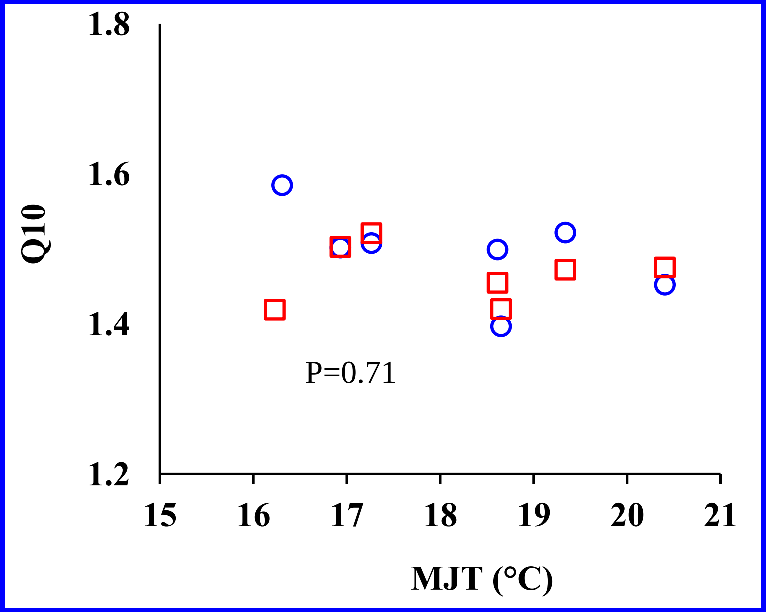
Acclimation type II but not type I

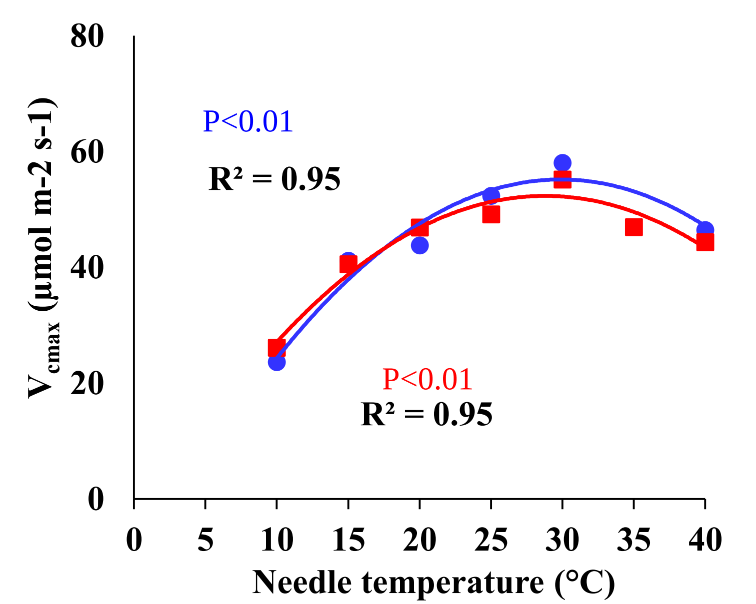




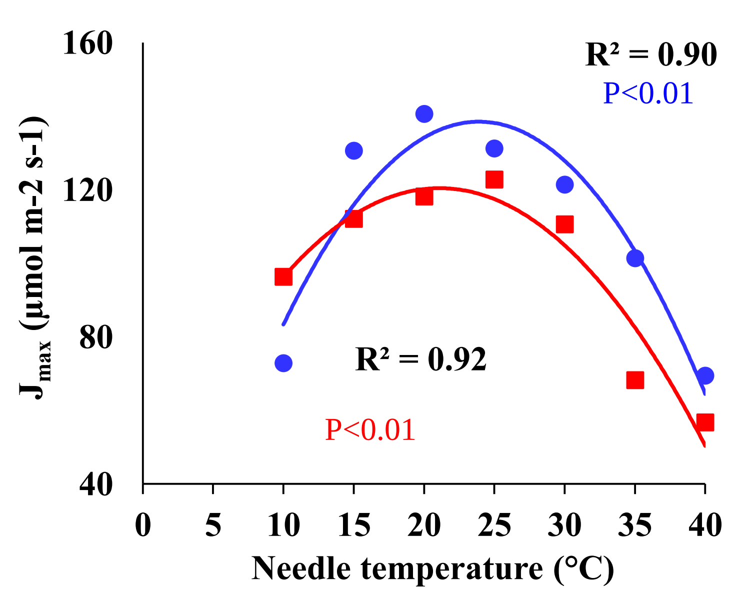


Results & Discussion

Thermal optimum of maximal rate of carboxylation (V_{cmax}) was greater for SOw (32.9°C) than SOr (30.9°C) However, V_{cmax} activation energy and value at 25 °C were similar for the two seed sources



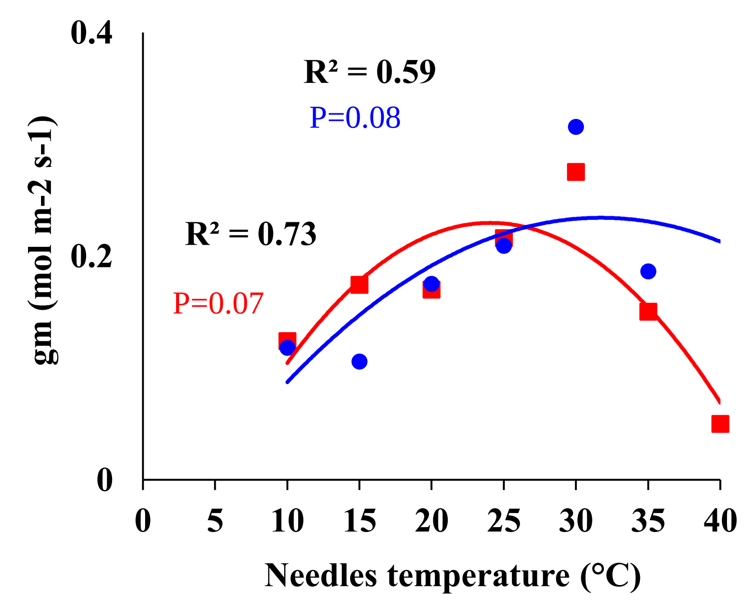
Thermal optimum, activation energy and value at 25 °C of maximal rate of electron transport (J_{max}) were greater for SOw than SOr



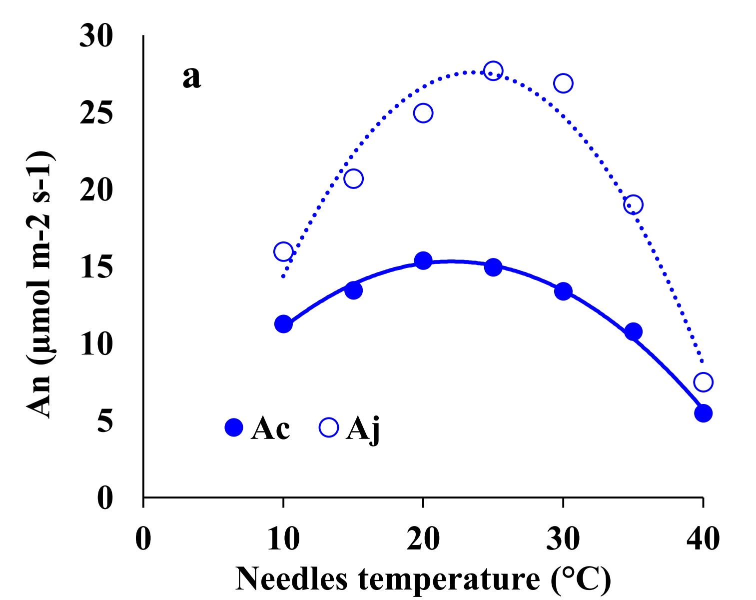
Results & Discussion

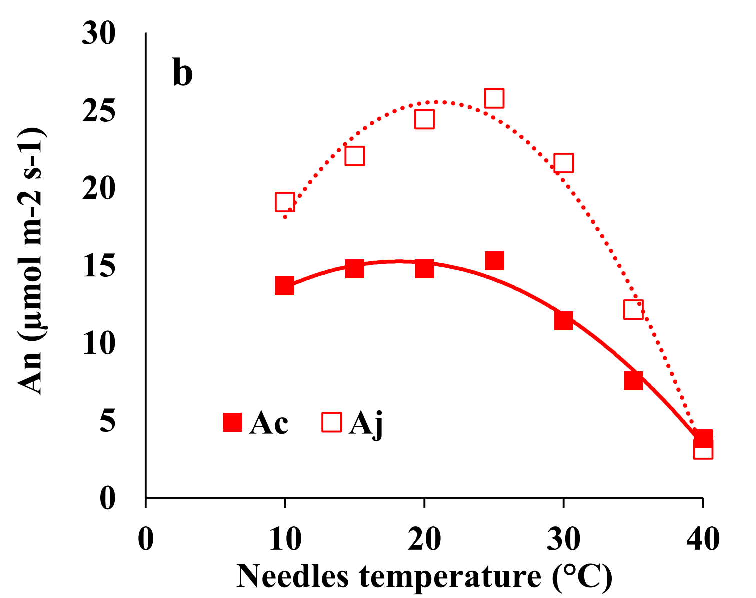
Mesophyll conductance (g_m) limits photosynthesis at low and high Temperature

T_{opt} of g_m, 28°C was similar among seed sources



Photosynthesis is limited by V_{cmax}





Conclusion

- Seed sources were similar in their thermal behavior
- Thermal acclimation of dark respiration occurred via a down-regulation of basal rate but not a change in Q_{10}.
- Photosynthetic thermal acclimation along the tested climatic gradient was lacking
- Temperature response of photosynthesis is driven by V_{cmax} as such the lack of thermal acclimation of photosynthesis may be related to the lability of Rubisco activase and/or the low investment of nitrogen in Rubisco in warm conditions.

Overall, based on our results on growth and thermal acclimation-related traits, we suggest that white spruce populations of south Quebec are already and will be above their thermal thresholds under climate change.

Merci