Geographical variation in photosynthetic traits of white spruce

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Introduction

Clinal variation for functional traits that results from evolutionary adaptation of populations to their local biophysical environment may help us understand and predict the physiological and growth responses of populations to climate change. It may explain trade-offs in resource use efficiency and growth strategies.

Question

Do photosynthetic-related traits in withe spruce exhibit a climate-related gradient ?

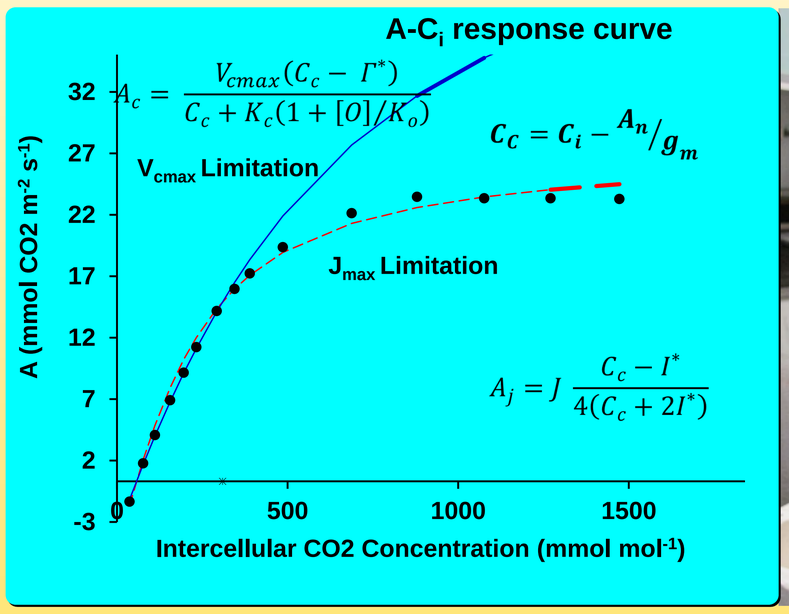
Genetic material

Two-year-old seedlings from eight seed orchards of white spruce commonly used in Québec were grown under greenhouse conditions.
Day night temperature: 25/18°C
Photoperiod:18h
Irrigation:40-45% ($v_{eau}/v_{substrat}$)

Measurement

Growth :
Height growth, total dry mass (TDM) and root to shoot ratio were measured at the end of the experiment.

Gas exchange :
Maximum rates of carboxylation (V_{cmax}), maximum rate of electron transport (J_{max}) and mesophyll conductance (g_m) were estimated from the A-C_i response curves based on the biochemical leaf photosynthesis model proposed by Farquhar et al. (1980).



Leaf morphology:
Specific leaf area (SLA)

Leaf chemistry:
Non-structural carbohydrate (NSC) and nitrogen content on a mass-basis (N_{mass}) and on an area basis (N_a).

Resource use efficiency:
Water use efficiency (WUE) is the ratio of A_{max} to transpiration.
Photosynthetic nitrogen use efficiency (PNUE) is the ratio of A_{max} to N_a.

Data analysis

The relationship between functional traits (as response variables) and geoclimatic variables of seed origin (as explanatory variables) was investigated using canonical redundancy analysis (RDA). The bi-plot approximation of the association between functional traits and climate variables displays the two set of variables as vectors in a two dimensional space. The length and position of the vectors of an explanatory variable explain its relative significance on the canonical axes. The angles in the bi-plot between response and explanatory variables and among each set of variables reflect their correlations.

Results

Clinal variation in functional traits

MGST was strong in the first canonical axis (RDA1), along with latitude and elevation. MAP was strong in the RDA2 along with longitude.
Negative latitudinal cline: Total dry mass (TDM), height, stomatal conductance (g_s), PNUE, and to a lesser extent SLA, mesophyll conductance (g_m), and photosynthetic capacity (A_{max}).
Positive latitudinal cline : WUE_i, and to a lesser extent N_{mass}.
Positive longitudinal cline: Root to shoot ratio (R_S).

Functional trait trade-offs:

PNUE, g_m, g_s and SLA were negatively correlated to N_{mass} and WUE

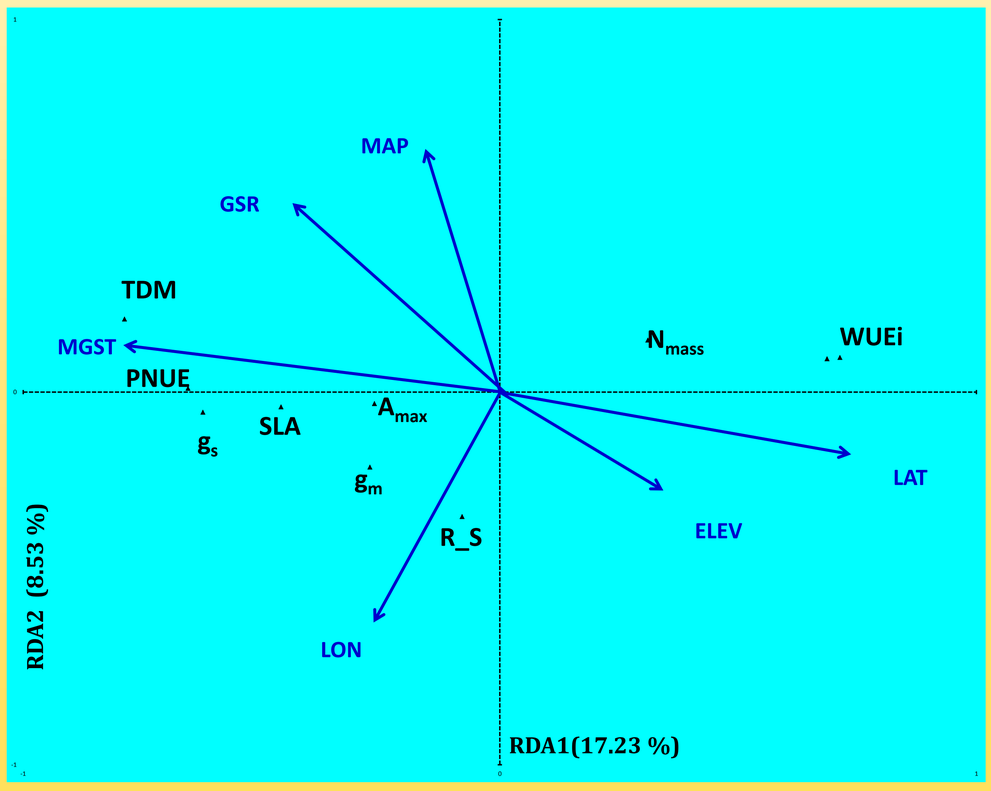


Figure: Bi-plot of the canonical redundancy analysis between functional traits and geoclimatic variables. The response variables were height, TDM, R_S, A_{max}, g_s, g_m, WUE_i, SLA, N_{mass}, PNUE). The explanatory variables vectors (LAT, latitude; LON, longitude; ELV, elevation; MAP; mean annual precipitation; MGST, mean growing season temperature;. MGR, growing season radiation) were presented in solid line.

Conclusion and Perspectives

Growth, biophysical limitations (g_s and g_m) to photosynthesis and resource use efficiency (WUE and PNUE) showed local adaptations. Trade-off between WUE and PNUE may result from temperature driven trade-offs between leaf productivity and persistence. The observed clinal trends in functional traits suggest a limited adaptive ability of white spruce populations to keep pace with rapid climate changes.
Assisted migration as a proactive management strategy should be considered to match populations to their future environment. However, the degree of physiological acclimation of populations to different climate conditions through assisted migration tests are essential to making science- based decision about the potential of this adaptive approach to climate change.

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