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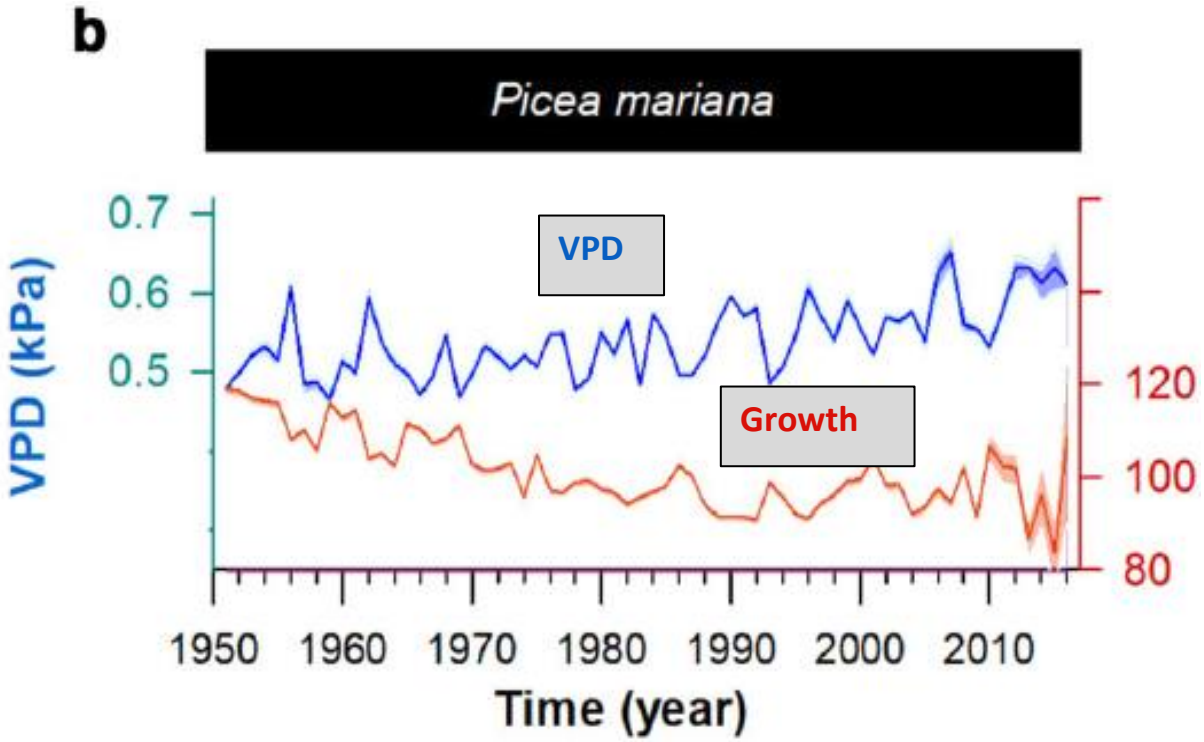
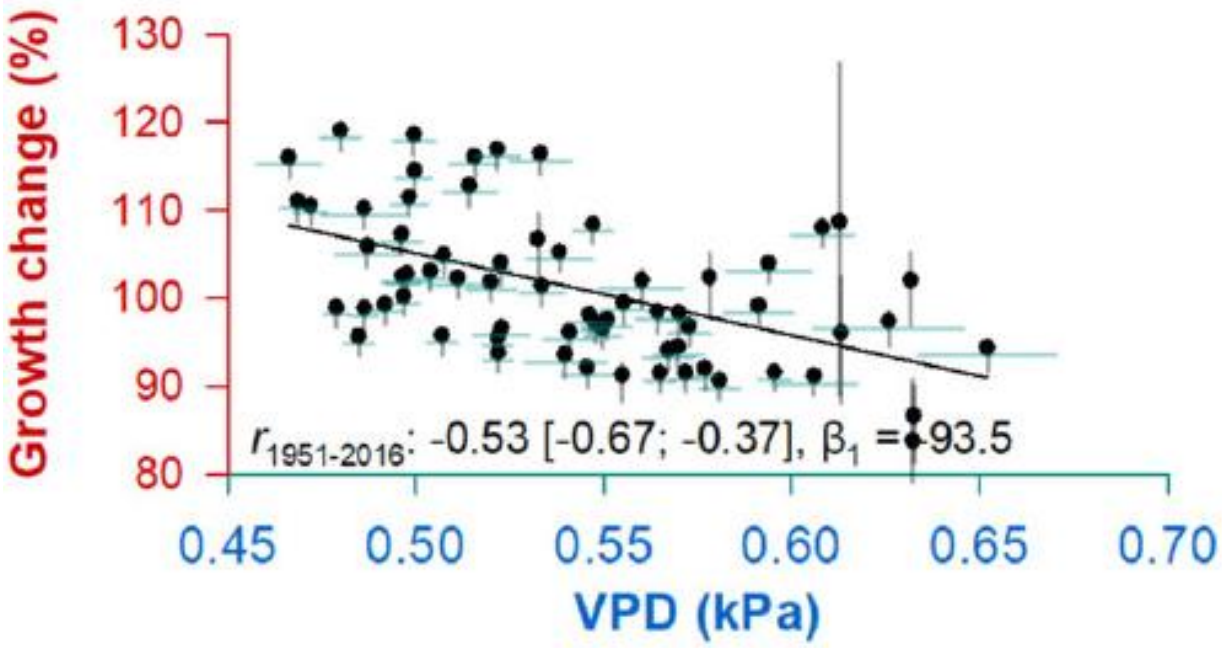
Divergence in boreal conifer responses to warming and CO_2 driven by functional strategies

Yanjun Song*, Alexandria Pivovaroff, Mahmuda Islam, Martin P. Girardin, Alana Chin, Hervé Cochard, José M. Torres-Ruiz, Sylvain Delzon, Xiaohan Yin, Xiao Jing Guo, Mirindi E. Dusenge, Jeffrey M. Warren, Paul J. Hanson, Peter B. Reich, Nelly A. Avila, Lingcheng Li, Avni Malhotra, Verity G. Salmon, Nate G. McDowell

***School of Biological Sciences, College of Arts and Sciences, Washington State University**

Warming-induced high VPD reduced boreal conifer growth



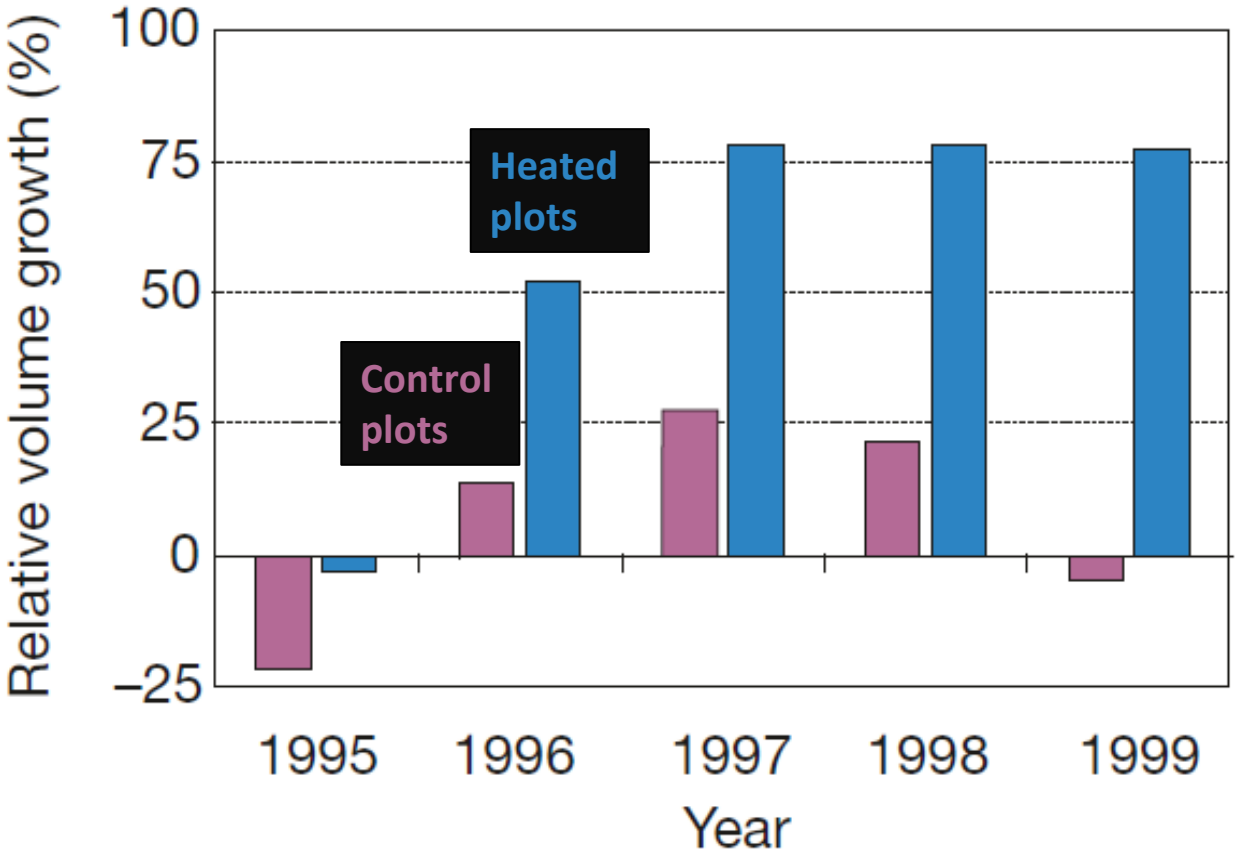


Mirabel et al. (2023). *Nat. commun. 14(1):6901.*

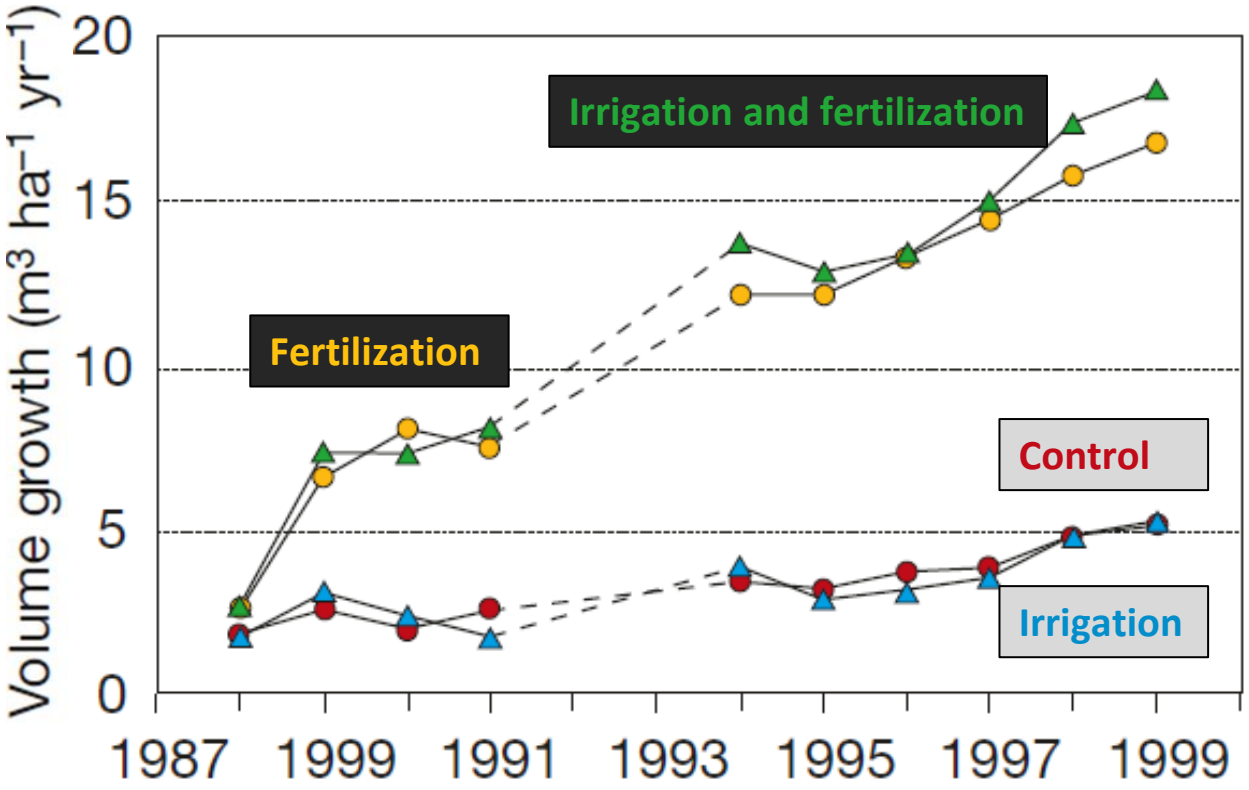
How do conifer growth response to climate in SPRUCE?

Warming perhaps increased nutrients release for growth

Soil-warming experiment on Norway spruce



Nutrient experiment on Norway spruce



Jarvis and Linder (2000). *Nature, 405 (6789), 904-905.*

Research questions and hypotheses

- **Question 1:** How do increasing CO_2 and VPD affect conifer growth?

- **Question 2:** What underlying mechanisms can explain the growth response of two divergent species to increasing CO_2 and VPD?

- **Hypothesis 1 (VPD):**

High VPD is expected to negatively affect growth due to high possibility of hydraulic failure or positively affect growth because high temperature benefits carbon acclimation.

- **Hypothesis 2 (CO_2):**

Elevated CO_2 benefits tree growth since high CO_2 improves water use efficiency and increases carbon gain.

- **Hypothesis 3 (Nutrient):**

Warming-induced nutrients release is expected to increase tree growth.

SPRUCE: The unique whole ecosystem warming experiment

- **Site:**

Marcell Experimental Forest, Minnesota, USA

- **Five warming treatments since 2015:**

+0, +2.25, +4.5, +6.75, +9 °C

- **Two CO_2 treatments since 2016:**

Ambient CO_2
Elevated CO_2 +500 ppm

- **Two dominant peatland conifers:**

Larix laricina (anisohydric larch)
Picea mariana (isohydric spruce)

- **SPRUCE growth:**

Growth data from 2017 to 2021 at SPRUCE

- **Regional growth:**

Dendrochronology data from 115 sites in Canada

More than 50 functional traits were collected for target trees in SPRUCE

Carbon assimilation:

Photosynthesis (A_{25}, g_s, V_{cmax}, J_{max}, T_{opt});

Leaf and branch nutrients (C, N and P);

Leaf size and weight (SLA, LDMC);

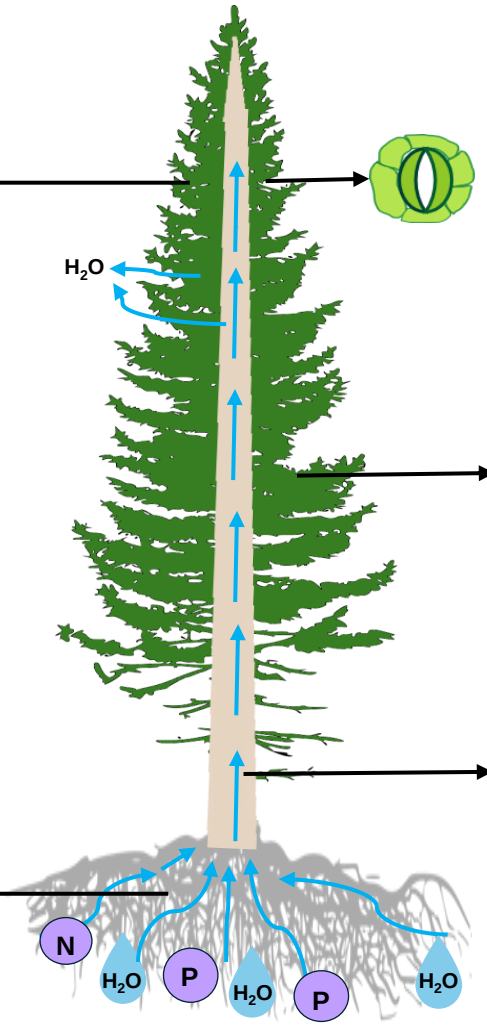
Crown greenness.

Stomata anatomy:

Stomata size (Guard cell and epidermal cell);

Stomata number (stomatal density);

Stomata pore area index SPI (size and number).



Wood anatomy:

Tracheid (Dh, TD, Tw, TSR);

Pit (DPA, DPM, DT, MF, TO, VE).

Hydraulic traits:

Water potential (P_{50}, P_{min}, P_{pre}, HSM);

Water flux (Ks, Js, g_{res});

Soil nutrients:

-Plant organic nutrients from decomposition:

Soil total C, N and P;

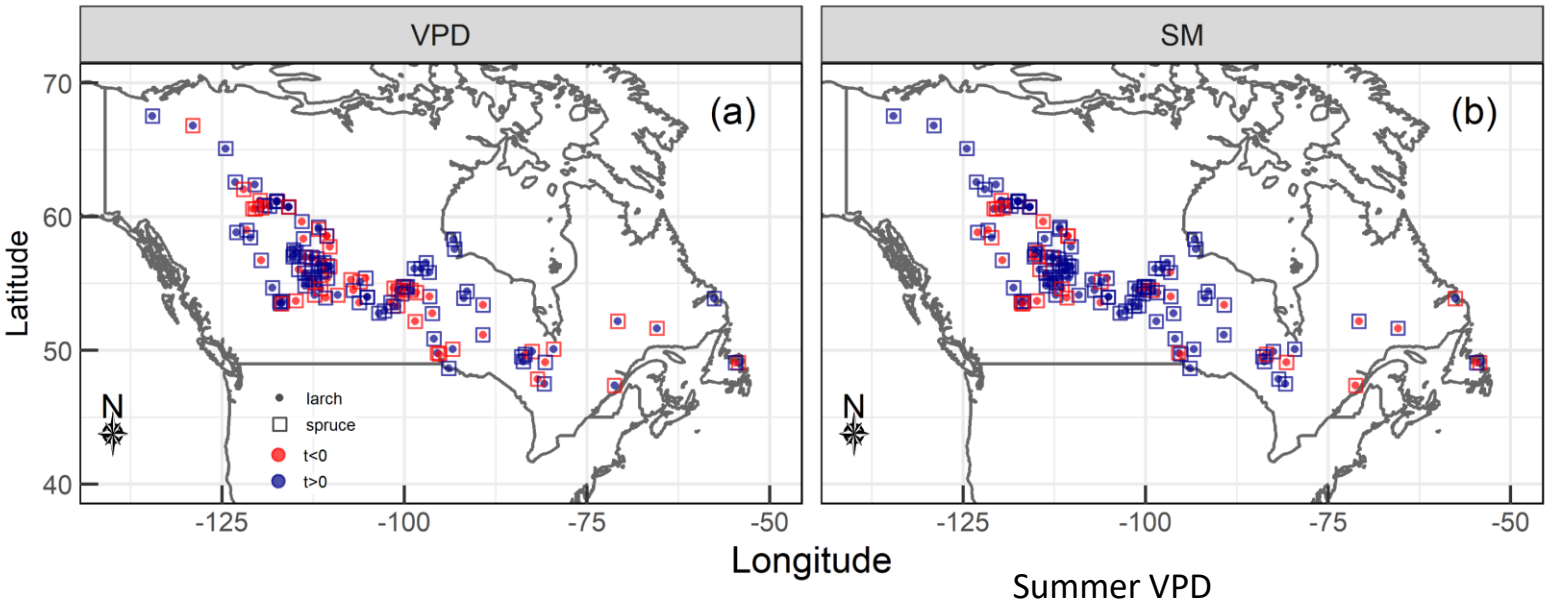
-Plant inorganic available nutrients:

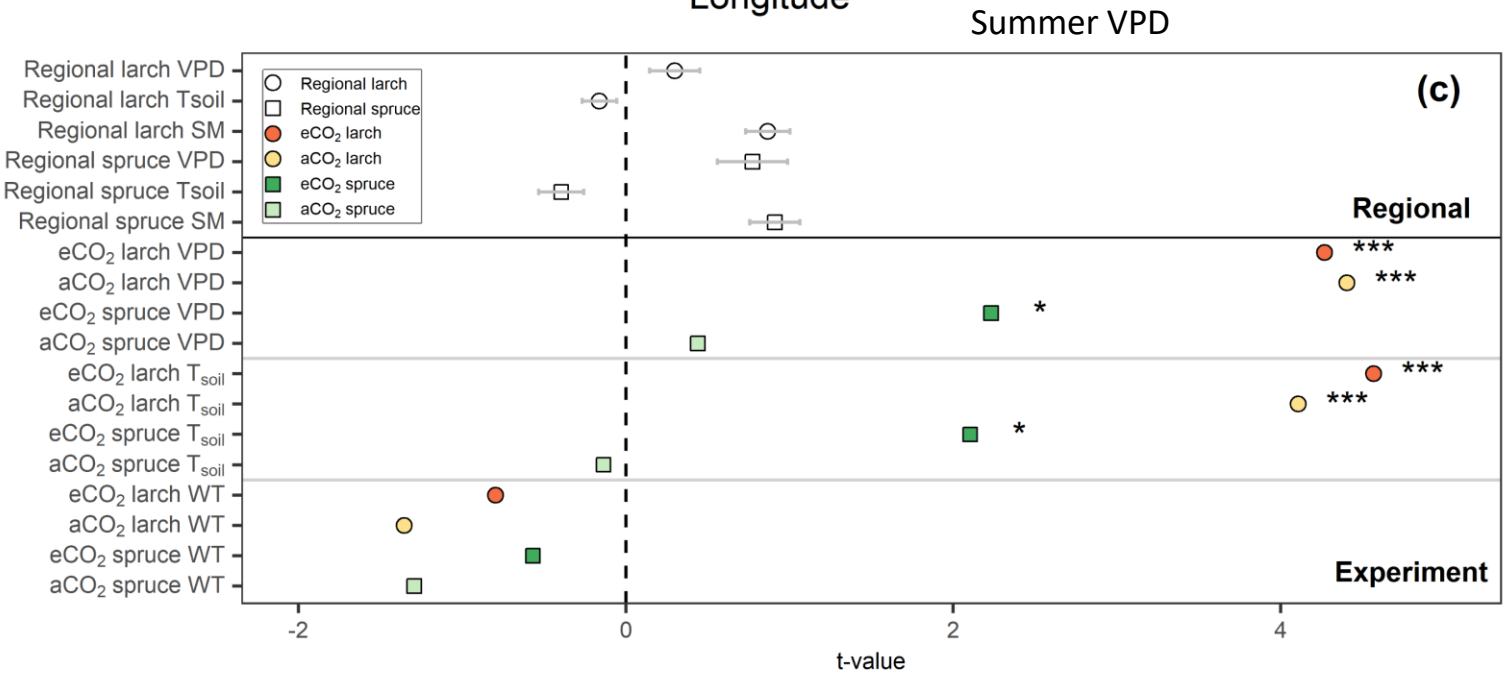
NH4-N, PO4-P, NH_4-N/PO_4-P.

Growth pattern in boreal range

Hypothesis 1 (VPD)

Regional growth





Regional growth:

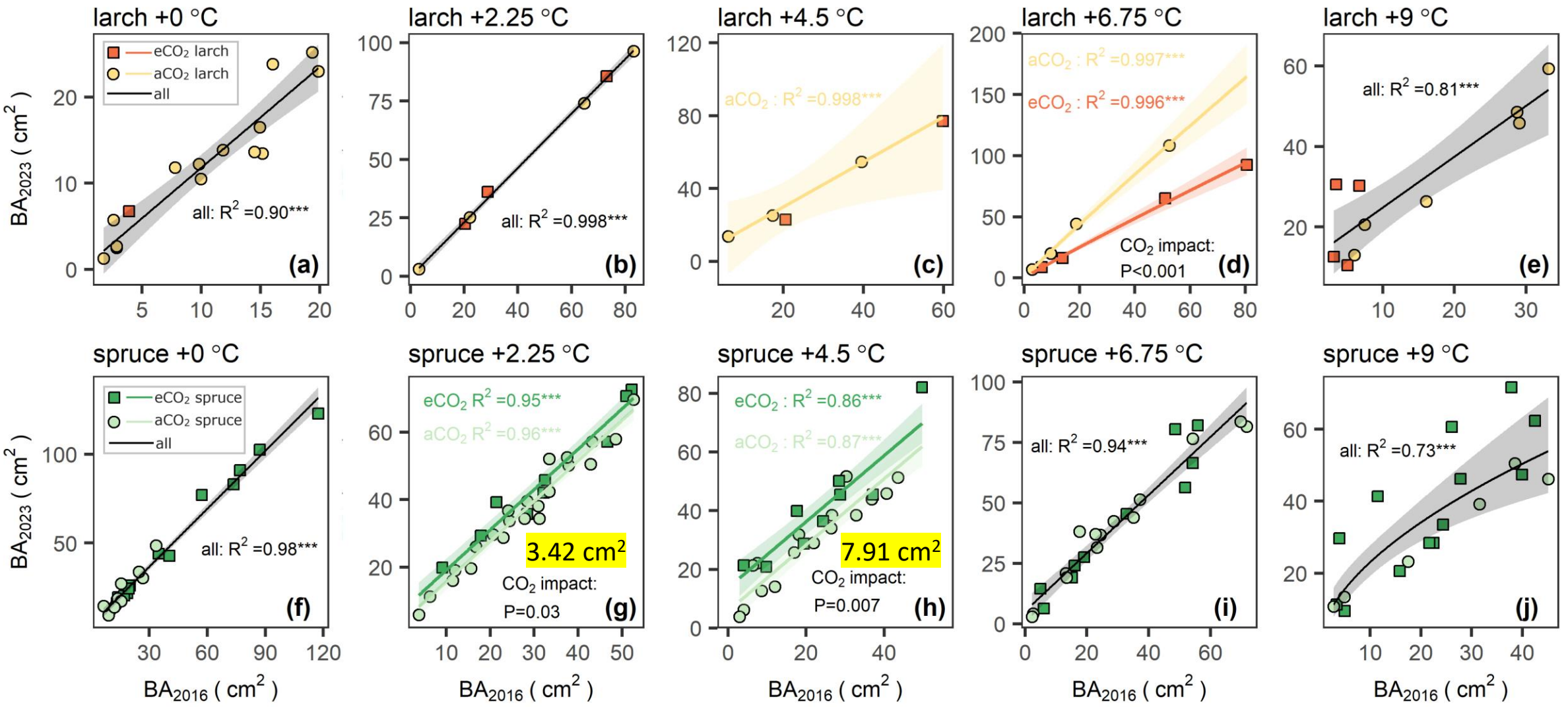
- VPD positively affected 63% of larch and 52% of spruce
- T_{soil} positively affected >40% of larch and spruce
- Soil moisture (SM) positively affected >75% of larch and spruce

SPRUCE site:

- VPD and T_{soil} : positively affected larch and spruce under eCO_2
- Soil moisture or soil water table depth (WT): no impacts on growth

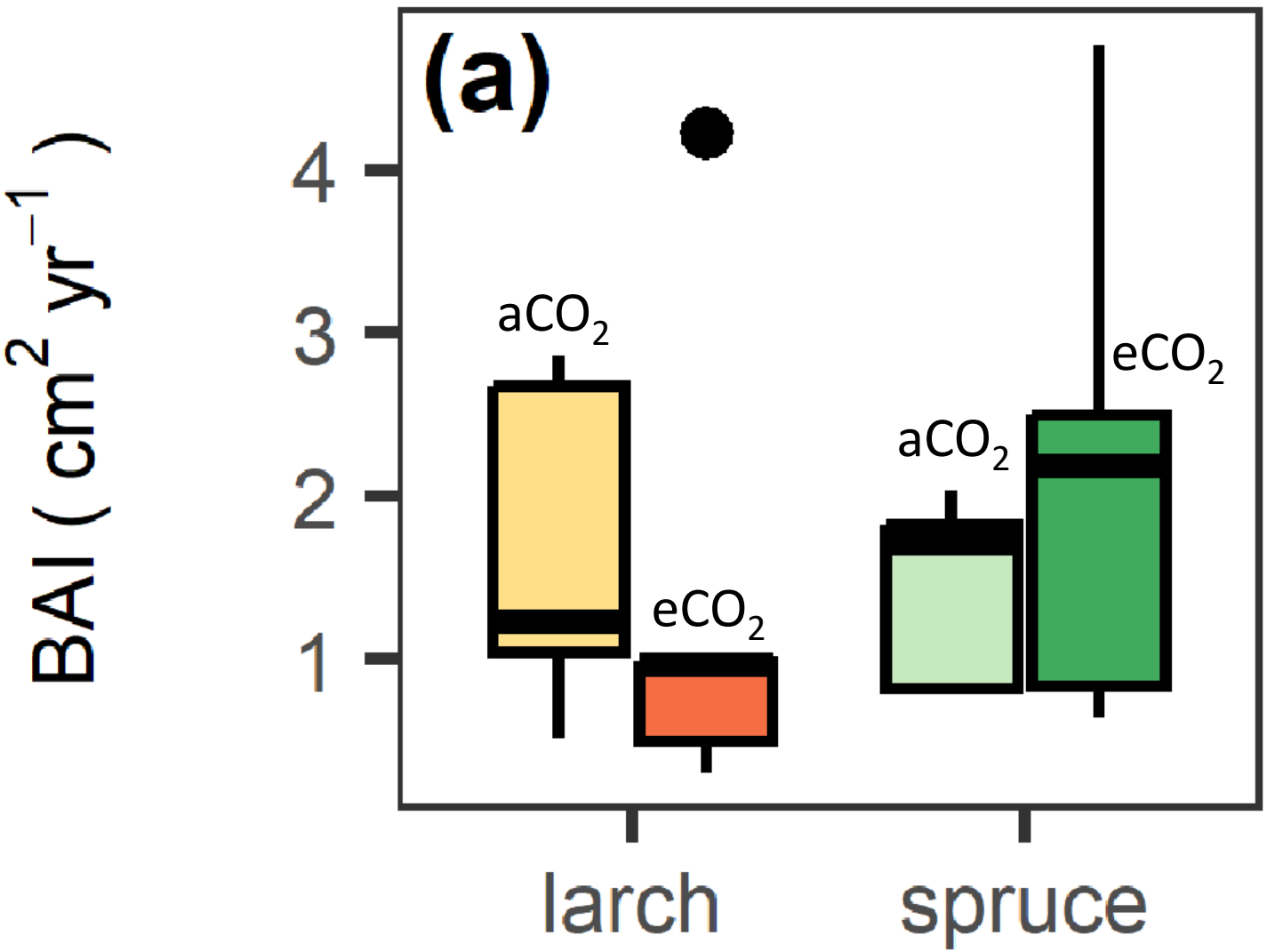
CO_2 impacts on growth

Hypothesis 2 (CO_2)



- There is no clear CO_2 impact on growth.

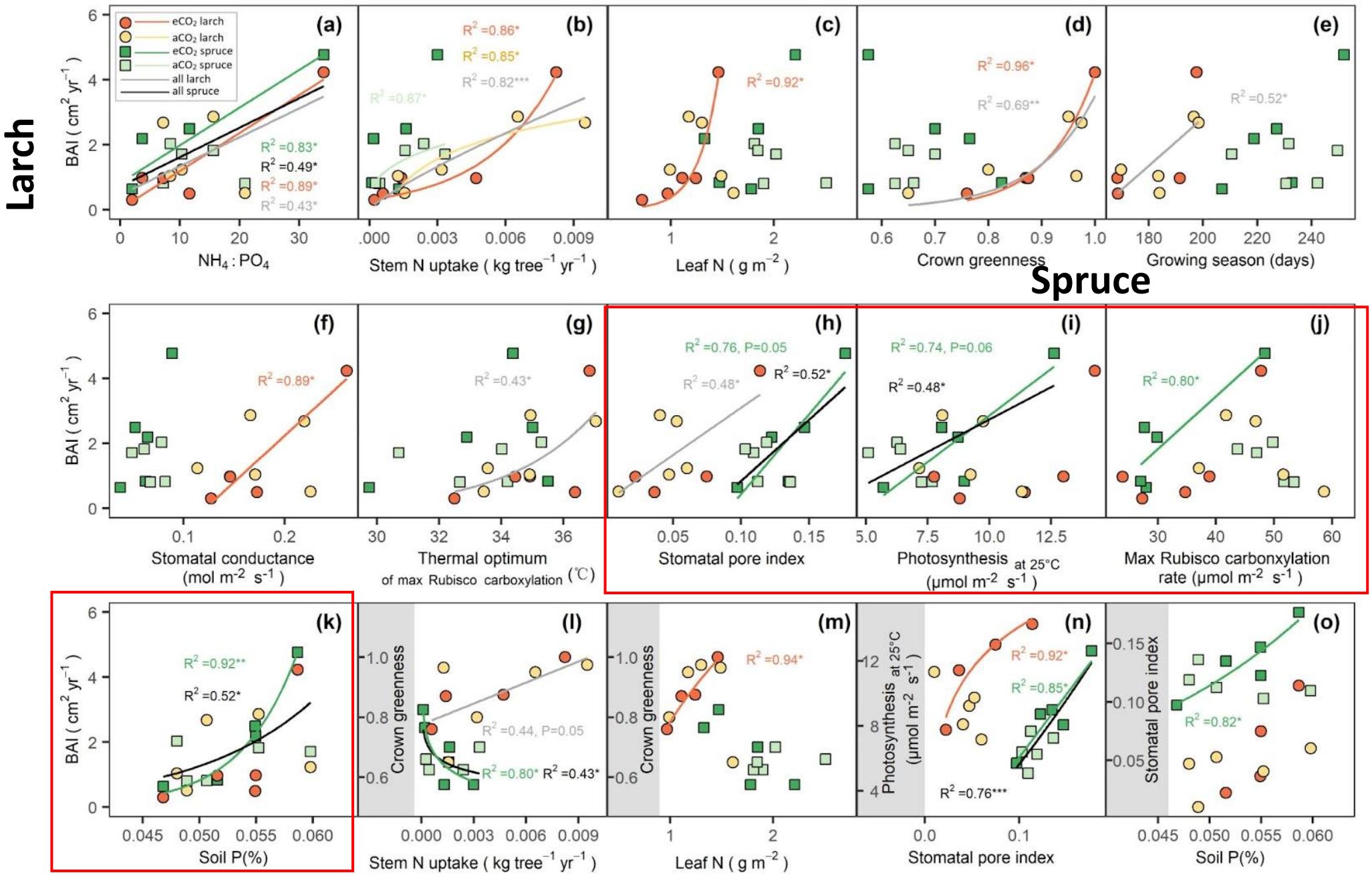
The paired t-test based on mean differences



- Elevated CO_2 didn't affect tree growth of larch and spruce.

Nutrients and photosynthesis lead to high BAI for larch and spruce

Hypothesis 3 (Nutrient)



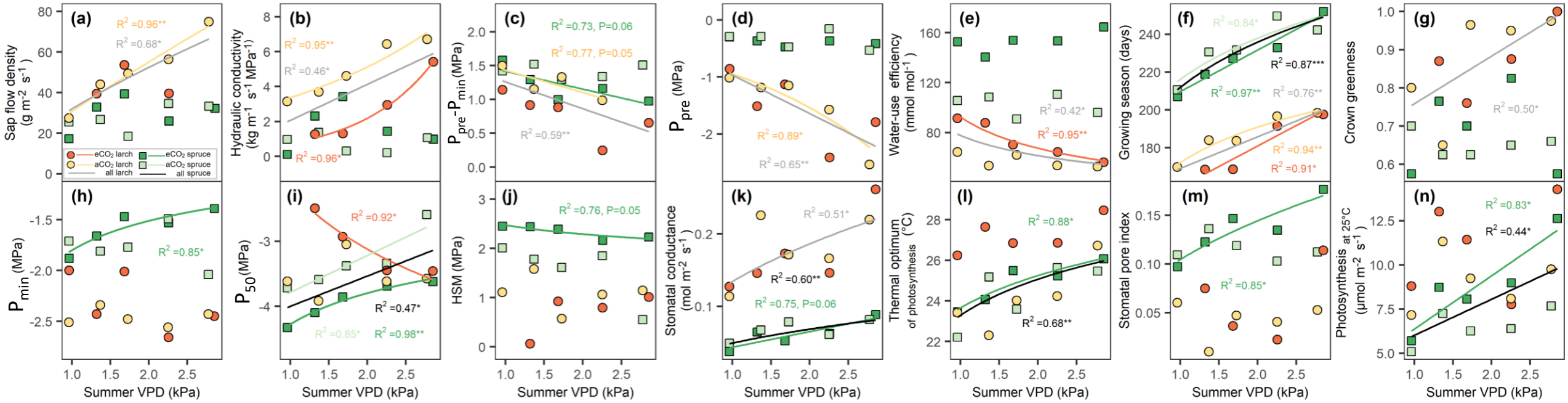
- Larch:

Nitrogen benefits a higher growth.

- Spruce:

Stomatal pore index benefits a higher carbon assimilation capacity, hence a higher growth rate.

Divergent hydraulic strategies for larch and spruce



Larch (a-g)under rising VPD:

- Strong water transport capacity and High resistance (i.e. Low P_{50}) → High growth
- Low water use efficiency
- eCO_2 decreased hydraulic efficiency (low K_s).

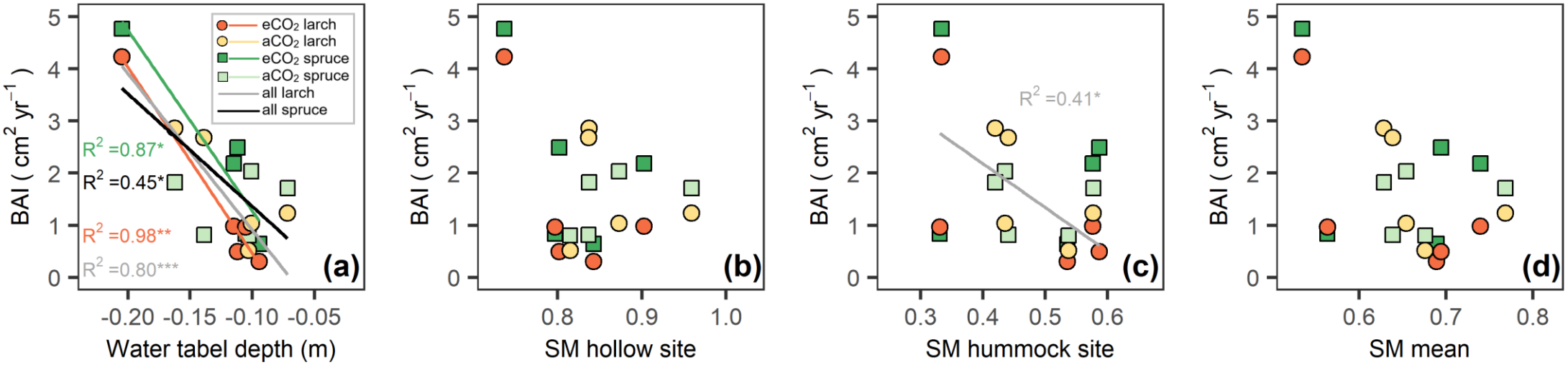
Spruce (h-n) under rising VPD :

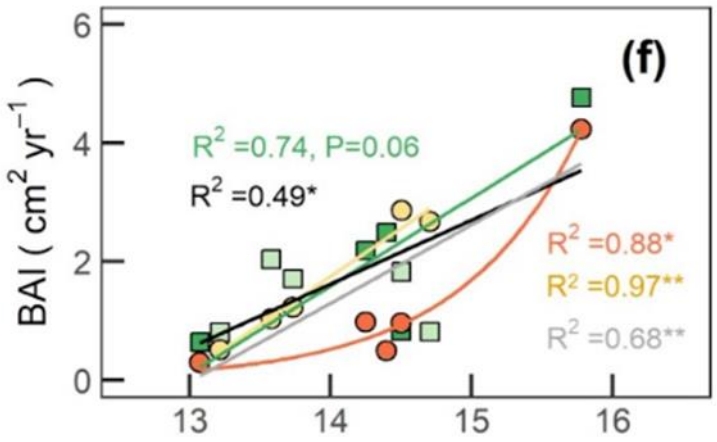
- Low resistance (high P_{min} and P_{50}; low hydraulic safety margin)
- High carbon assimilation capacity → High growth especially for eCO_2.
- eCO_2 increased hydraulic safety (i.e. low P_{50}. and high HSM).

Take home messages

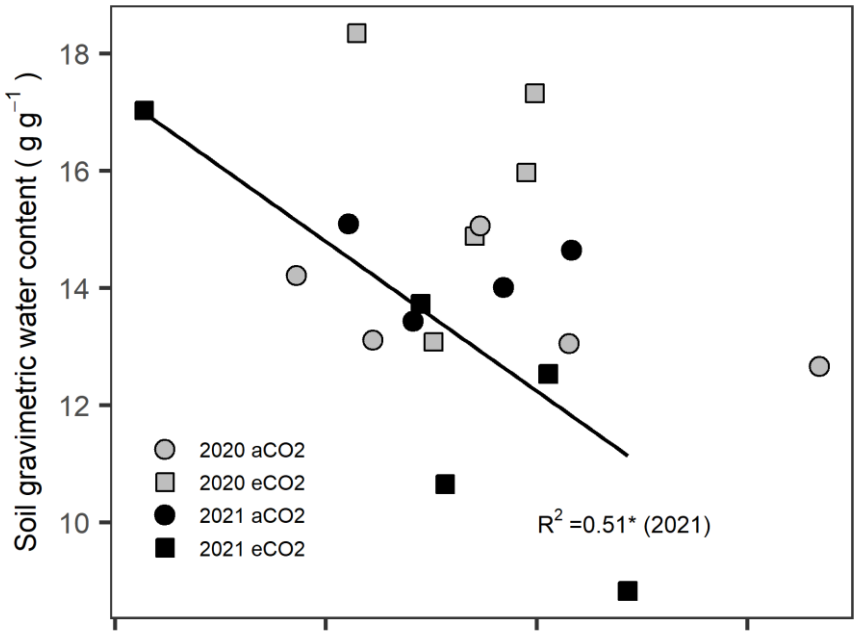
- VPD positively affected both larch and spruce
- High VPD and soil temperate benefit the more soil N release for better growth of larch especially under eCO_2.
- Soil P increased photosynthesis related stomata traits and hence spruce growth especially under eCO_2.
- eCO_2 didn't affect tree growth.
- Rising VPD still increases the carbon sink for larch, but may reduce the carbon sink for spruce with the increassed hydraulic failure.

Why soil gravimetric water content matter for tree growth?





Soil gravimetric water content (g g^{-1})



$$GWC = \frac{\text{Mass of Water}}{\text{Mass of Dry Soil}}$$

$$VWC = \frac{\text{Volume of Water}}{\text{Total Volume of Soil}}$$

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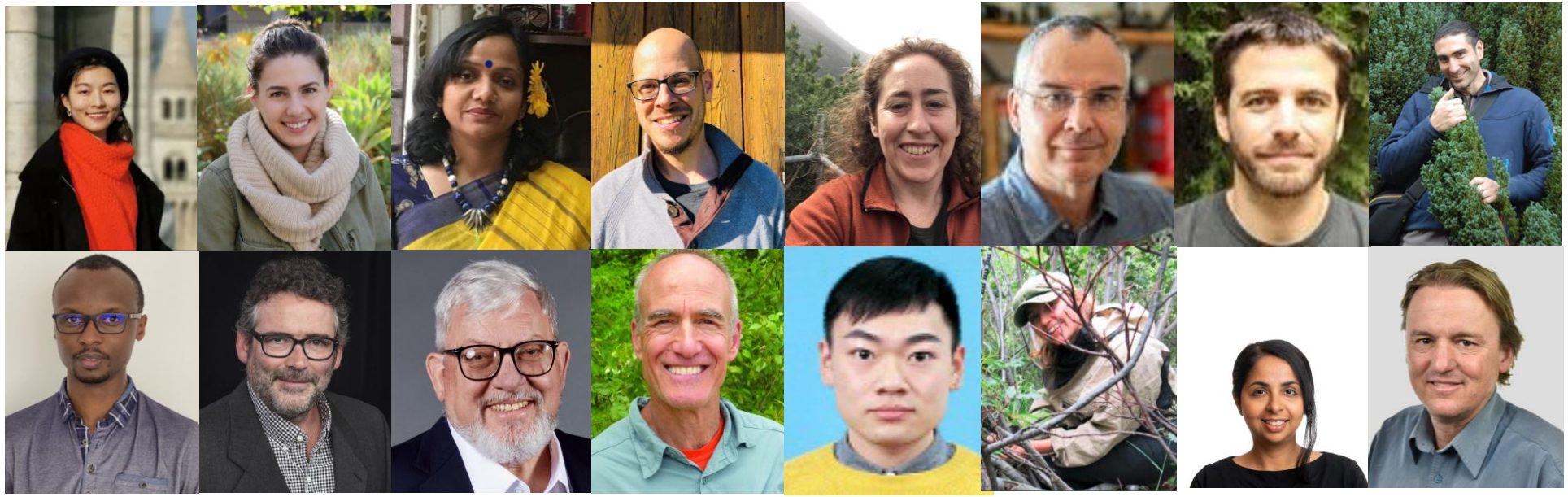
Acknowledgements



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