

# Genetic variation of drought-stress tolerance in Scots pine

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## INTRODUCTION

Mainly extreme drought events like the one in 2018 in Western Central Europe contribute to tree mortality (Buras *et al.*, 2020). Tree mortality is also accompanied by an overall reduction of ecosystem services in European forests (Bose *et al.*, 2020), with economic damages, same as all climate-exposed sectors, where forestry is included (IPCC, 2022).

Due to its phenotypic plasticity, Scots pine (*Pinus sylvestris* L.) is characterised by a wide range of distribution, with low ecological requirements, especially high drought tolerance. Drought tolerance is determined by optimization of hydraulic architecture, which is intraspecific variable (Martínez-Sancho *et al.*, 2017), genetically dependent (Semerci *et al.*, 2017), and latitudinally differentiated among the European provenances.

We monitored the progeny of three locally adapted populations from the Czech Republic, representing the montane (Decin) and lowland (Plasy, Trebon) Scots pine ecotypes. We induced drought stress in biennial seedlings in controlled greenhouse experiment and studied their reaction to long-term lack of water at the beginning of the vegetation season during the new shoot development and follow-up recovery.

We used high-throughput phenotyping unit - fully automated system equipped by fluorescence and infrared thermal imaging technique. We tested the genetic variability of functional leaf physiological traits among the families by the linear (mixed) model, using the 'asrem1' function from the 'ASReml' package in R.

## HYPOTHESES

**H1:** Selected functional leaf physiological traits (Steady-state PSII quantum yield, Maximum quantum efficiency of PSII, Steady-state non-photochemical quenching, Needle chlorophyll content and  $\Delta T$ ) have different sensitivity to the early season drought and summer rewatering.

**H2:** The genetic variability is expected to remain stable for selected functional leaf physiological traits in response to the early-season drought and summer rewatering.

**H3:** Growth traits (Root Collar Diameter, Needle Length, Leaf Mass per Area, Needle Water Content) vary among the locally adapted populations after the early season drought and summer rewatering

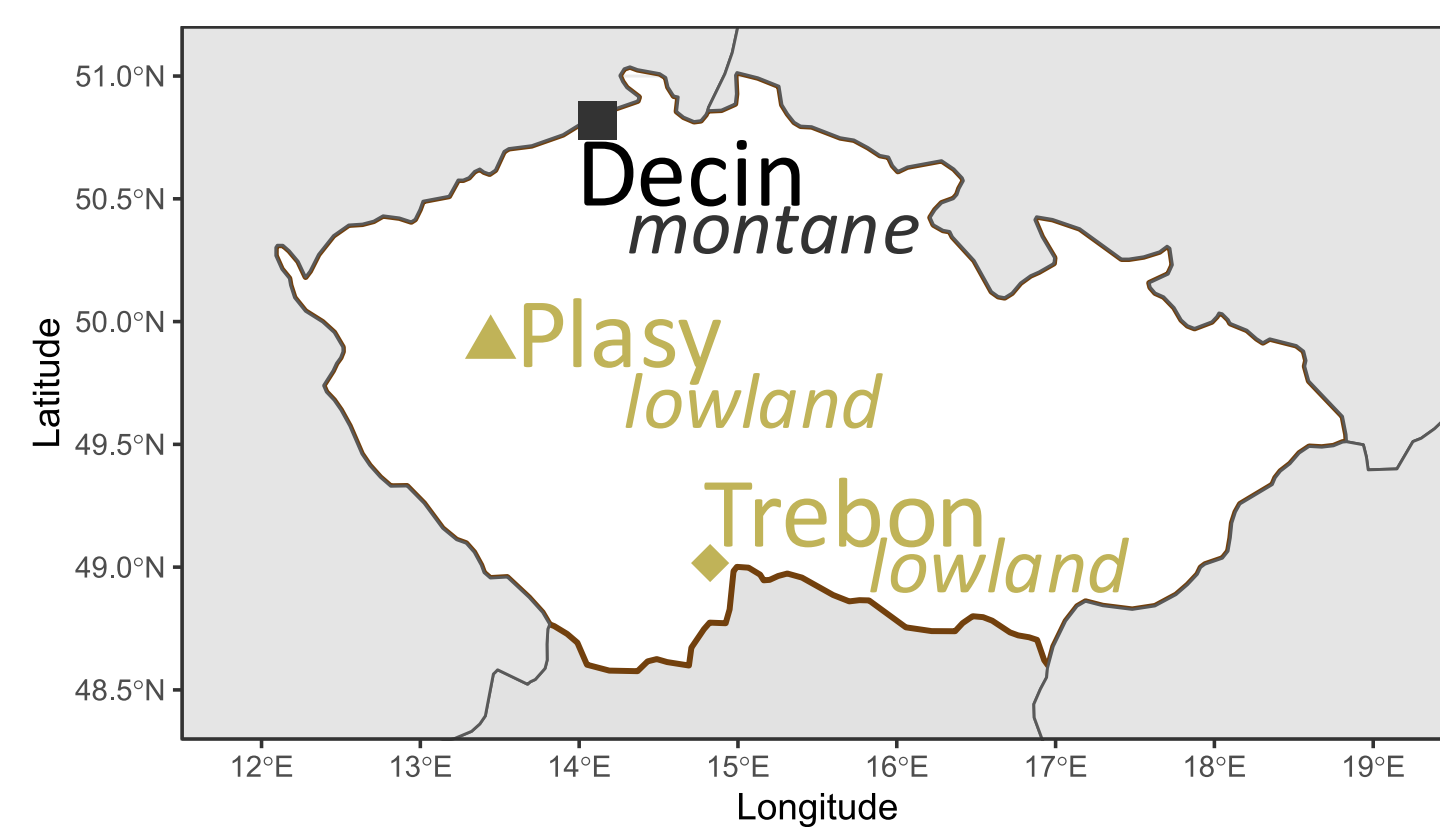
## RESEARCH QUESTIONS

**Q1:** How do the functional leaf physiological traits respond to the early season drought period and summer rewatering in Scots pine seedlings?

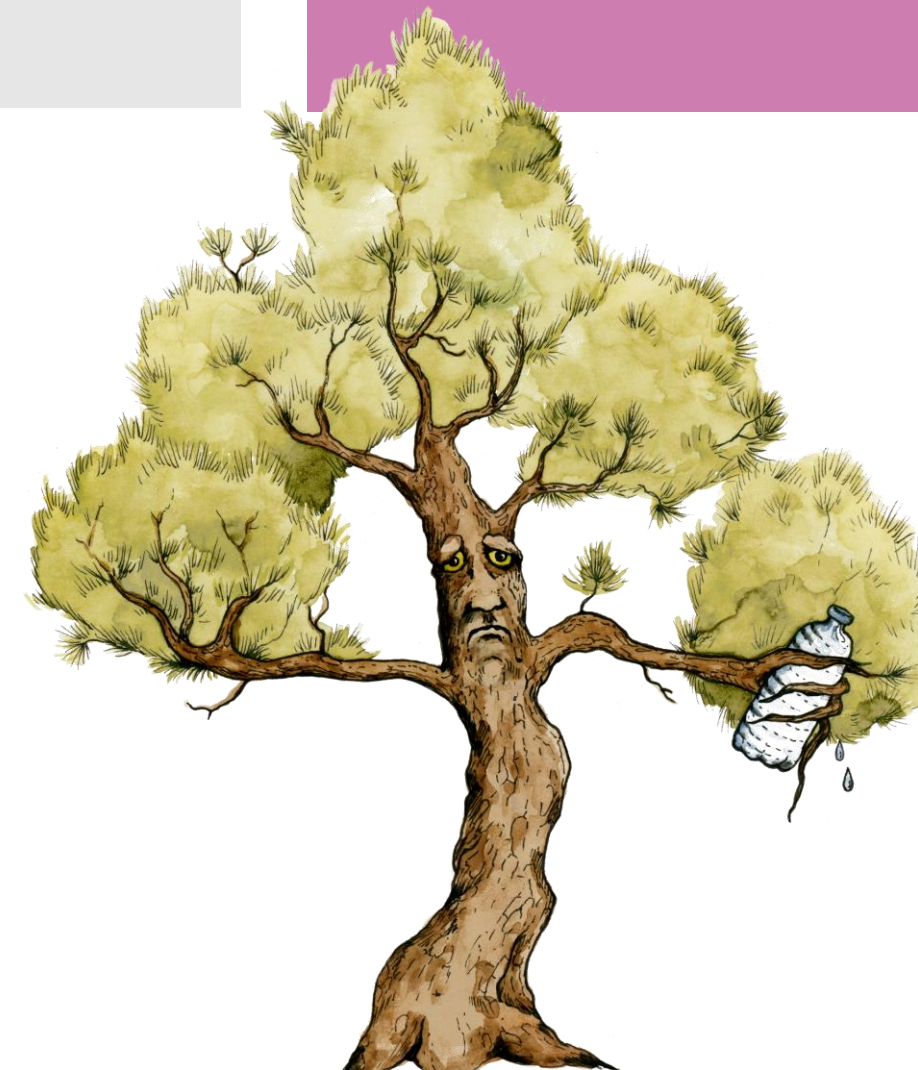
**Q2:** What is the extent of genetic variability in functional leaf physiological traits among families of Scots pine seedlings in the reaction to the early season drought period and summer rewatering?

**Q3:** What are the differences in the growth traits among the three locally adapted populations of Scots pine seedlings after the early season drought and summer rewatering?

**TAKE HOME MESSAGE:**  
Functional leaf physiological traits vary in sensitivity to the early season drought.  
Genetic variability decreased during the drought stress and increased during recovery after rewatering.  
Populations do not differ in the growth traits during the recovery phase.



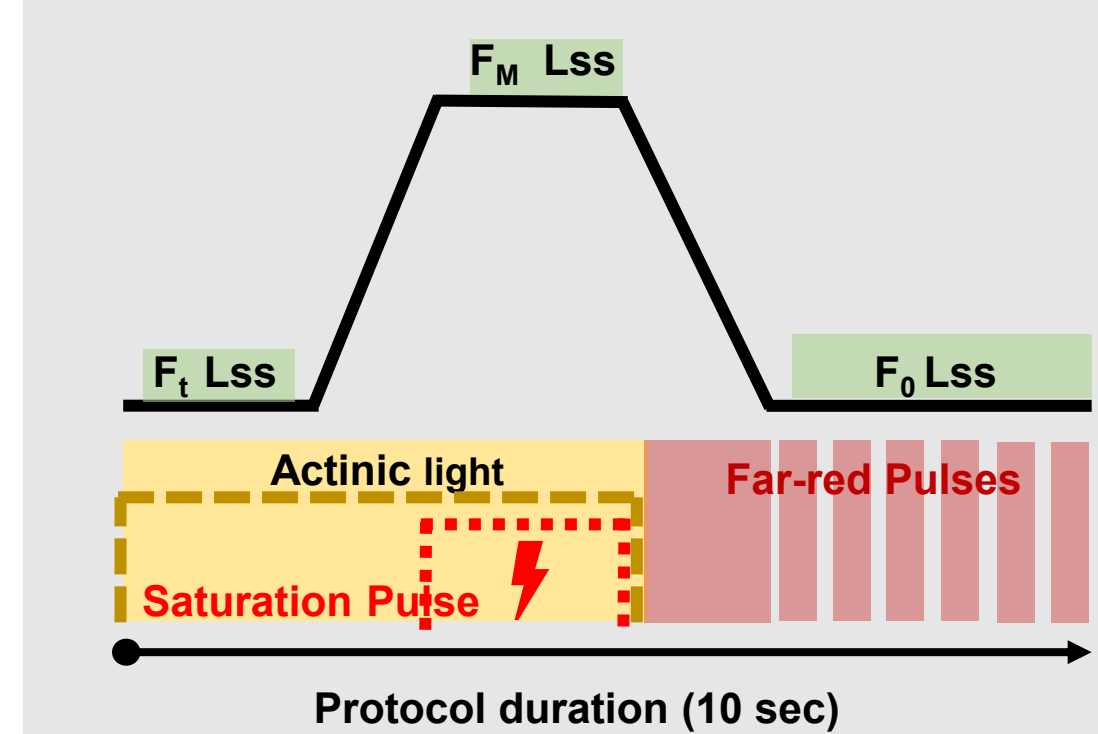
**MATERIAL**  
3 locally adapted populations (D,P,T)  
380 - 500 m a. s. l.  
810 individuals  
270 pots  
3 seedlings per pot  
1 treatment



## METHODS

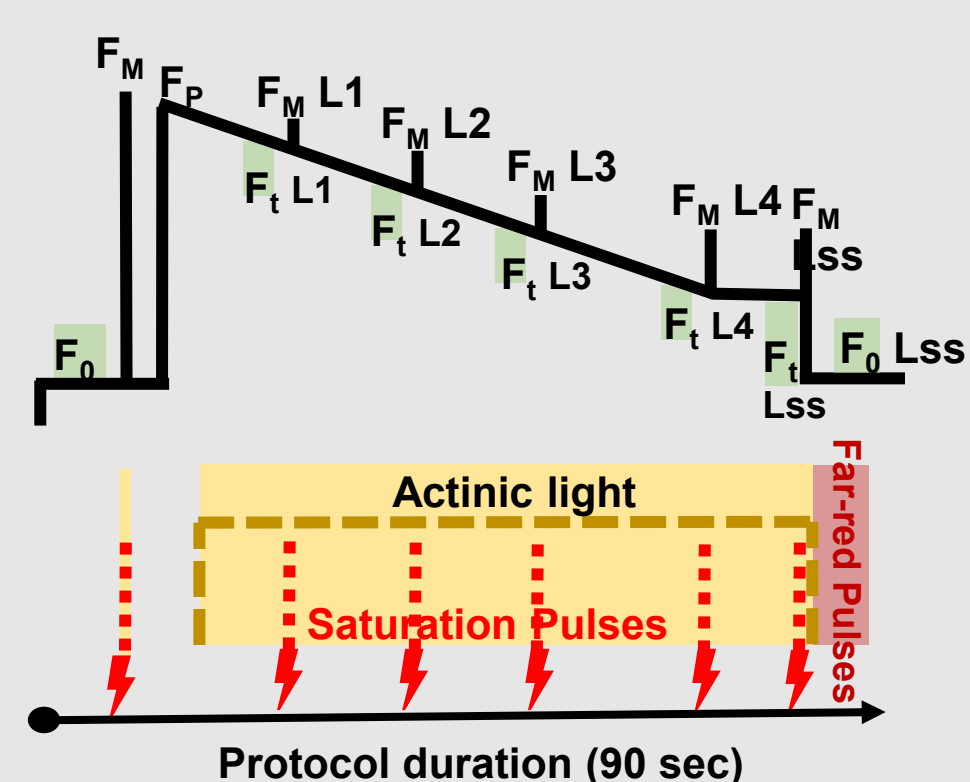
### Light Adapted Chlorophyll Fluorescence:

**QY Lss** (Steady-state PSII quantum yield) =  $(F_M Lss - F_t Lss) / F_M Lss$



### Dark Adapted Chlorophyll Fluorescence:

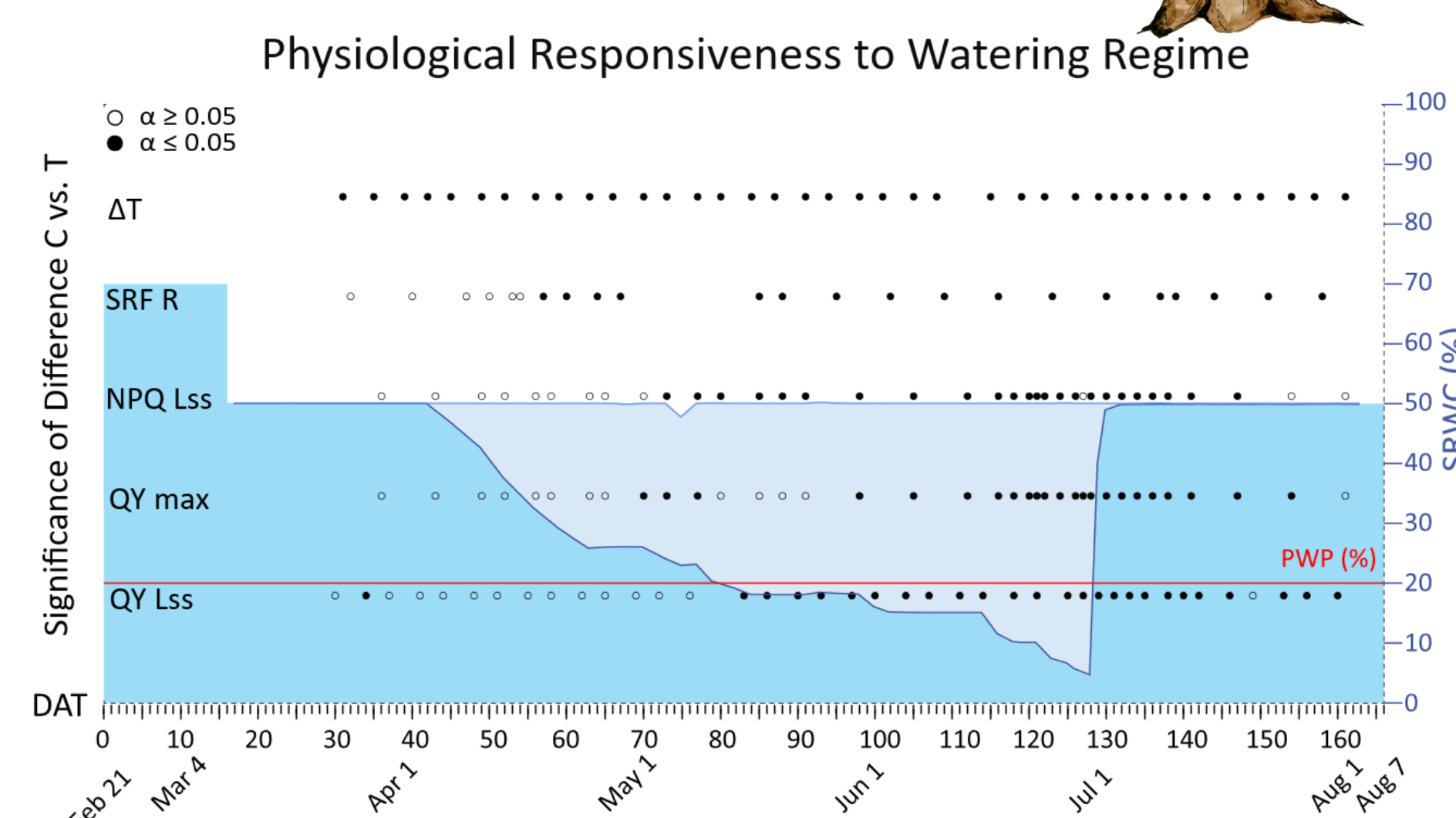
**QY max** (Maximum quantum efficiency of PSII photochemistry) =  $(F_M - F_0) / F_M$   
**NPQ Lss** (Steady-state non-photochemical quenching) =  $(F_M - F_M Lss) / F_M Lss$



**Multi-Colour Fluorescence for Chlorophyll Content Estimation:**  
**SFR R** (Red /Far-Red chlorophyll fluorescence at red-orange and green excitation)

**IR Thermal Imaging:**  
 $\Delta T (^{\circ}C) = T_{Needle} - T_{Air}$

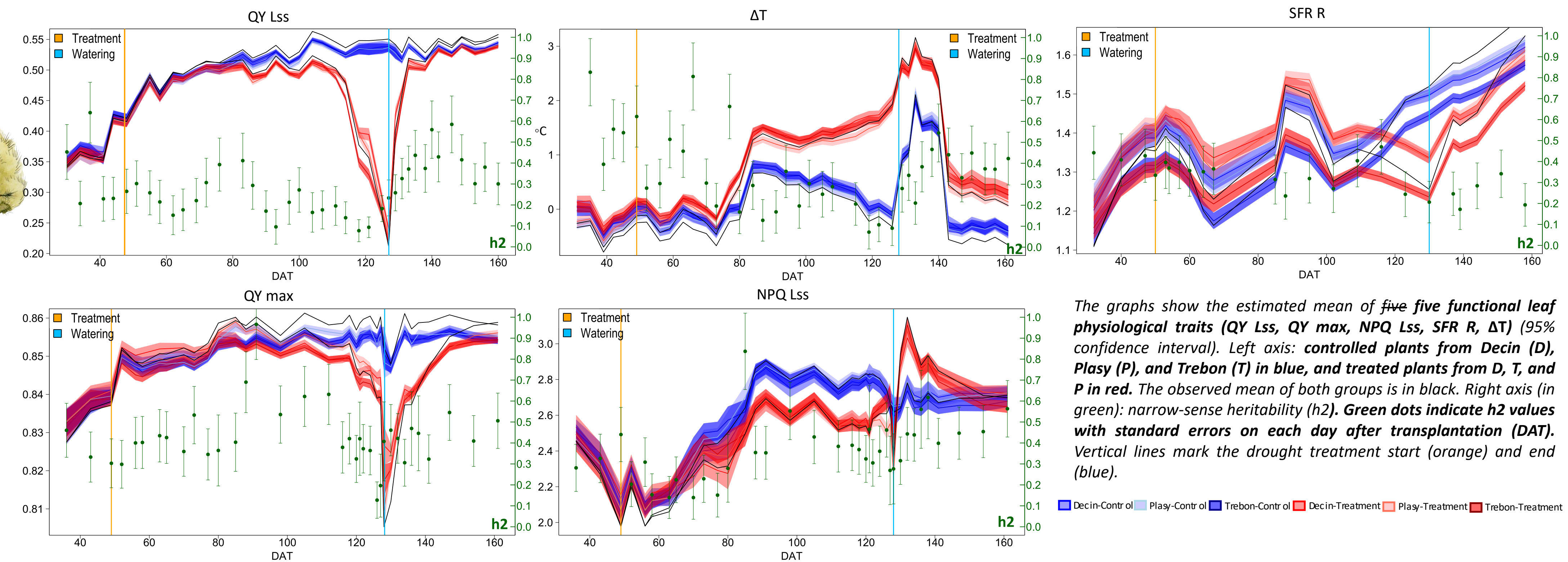
**Growth parameters:**  
**RCD** (Root Collar Diameter; cm)  
**NL** (Needle Length; mm)  
**LMA** (Leaf Mass per Area; mg/cm<sup>2</sup>)  
**WC** (Needle Water Content; %)



The impact of differential watering regimens on five functional leaf physiological traits (QY Lss, QY max, NPQ Lss, SFR R,  $\Delta T$ ) over 166 days (day after transplantations = DAT), from February 21, 2022, to August 7, 2022. Two groups of plants were studied: controlled plants (C) receiving a consistent 50% SRWC watering and treated plants (T) exposed to progressive substrate dry-down. Soil Relative Water Content (SRWC, right vertical axis) assessed gravimetrically. Left axis represent tested physiological traits. Symbols indicate significant ( $\alpha \leq 0.05$ ; full symbols) and non-significant ( $\alpha \geq 0.05$ ; open symbols) differences between controlled and treated plants. The red line represents the permanent wilting point (PWP), a crucial water stress threshold.

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Bose AK, Gessler A, Bolte A, Bottero A, Buras A, Calleret M, Camarero JJ, Haeni M, Heres A, Hevia A, et al. 2020. Growth and resilience responses of Scots pine to extreme droughts across Europe depend on predrought growth conditions. *Global Change Biology* 26: 4521–4537.  
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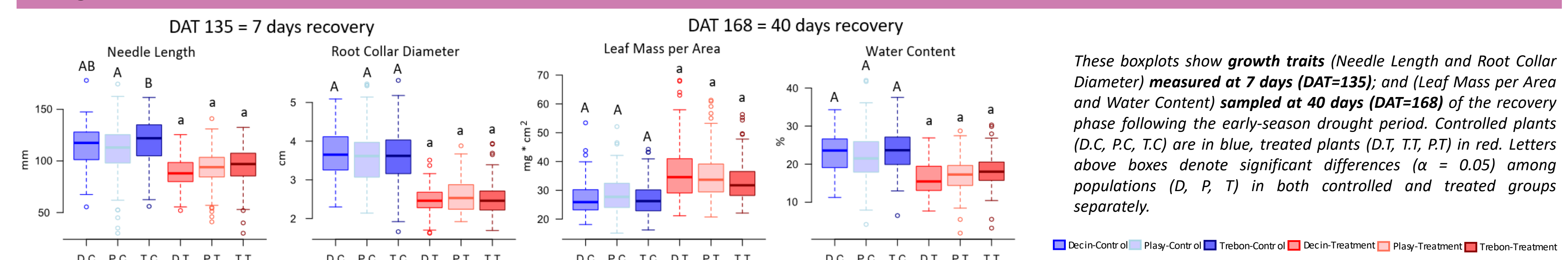
The graphs show the estimated mean of five functional leaf physiological traits (QY Lss, QY max, NPQ Lss, SFR R,  $\Delta T$ ) (95% confidence interval). Left axis: controlled plants from Decin (D), Plasy (P), and Trebon (T) in blue, and treated plants from D, T, and P in red. The observed mean of both groups is in black. Right axis (in green): narrow-sense heritability ( $h^2$ ). Green dots indicate  $h^2$  values with standard errors on each day after transplantation (DAT). Vertical lines mark the drought treatment start (orange) and end (blue).

## CONCLUSIONS

**C1:** Functional leaf physiological traits vary in sensitivity to differential watering.  $\Delta T$  consistently differs on all test dates, while NPQ Lss shows the highest responsiveness, followed by SFR R, displaying early differentiation. QY max and QY Lss indicated reaching the permanent wilting point.

**C2:** Genetic variability among families for all functional leaf physiological traits followed a consistent pattern, decreasing during the initial drought period and subsequently increasing during the recovery phase.

**C3:** There is no difference in growth traits among the three locally adapted populations during the recovery after the early-season drought.



These boxplots show growth traits (Needle Length and Root Collar Diameter) measured at 7 days (DAT=135); and (Leaf Mass per Area and Water Content) sampled at 40 days (DAT=168) of the recovery phase following the early-season drought period. Controlled plants (D.C., P.C., T.C.) are in blue, treated plants (D.T., P.T., T.T.) in red. Letters above boxes denote significant differences ( $\alpha = 0.05$ ) among populations (D, P, T) in both controlled and treated groups separately.

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