Water use and growth responses of Norway spruce and European larch to experimental drought at the subalpine tree line

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1. Background

Climate projections suggest an increase in the frequency and severity of drought events across many parts of Europe. Little is known about the effects of sustained and recurrent drought events on forest systems with previously ample water supply.

We performed a replicated rain-exclusion experiment at the subalpine tree line in the Austrian Central Alps and studied water use and growth responses of two dominating coniferous tree species to severe summer drought.

2. Methods

2.1 Study site:

- LTER-forest site Kaserstattalm, Stubai Valley, Tyrol, Austria, at 2000 m.a.s.l.
- Main species: European larch (*Larix decidua*) and Norway spruce (*Picea abies*)

Figure 1: Rainout shelters at the study site.

2.2 Experimental setup:

- Up to 4.5 months of severe summer drought in 2016, 2017 and 2018
- Simulated by rain exclusion with rainout shelters (Fig. 1)
- Continuous monitoring of radial growth and xylem sap flow dynamics (Fig. 2 + 3) on 24 trees (n = 6 per species and treatment)

Figure 2: High-resolution circumference dendrometer monitoring stem radial variations

Figure 3: Tissue heat balance sap flow sensors used for monitoring sap flow dynamics

3. Results

3.1 Sap flow

- Sap flow rates and threshold responses to vapor pressure deficit (VPD) decreased under drought mainly during periods of high evaporative demand (Fig. 4)
- Overall, drought effects on sap flow were more pronounced for spruce than for larch (Fig. 4)
- Effects of VPD on sap flow were prominent in spruce across all study years and increased over time in larch (Fig. 4)

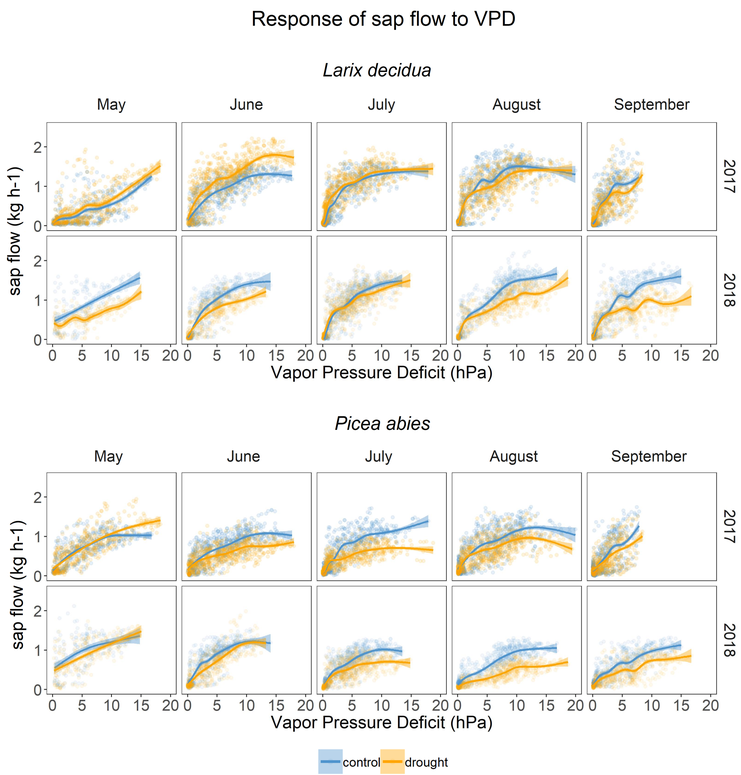

Figure 4: Response of sap flow to vapor pressure deficit (VPD) in European larch (Larix decidua) and Norway spruce (Picea abies) . Dots represent single, half-hourly measurements of sap flow rate and VPD, lines and shading represent smoothed mean ± 95% point-wise confidence interval, respectively (n = 6 per species and treatment). Treatment lasting from end of May until end of October (cf. grey shading in Fig. 6).

3.2 Stem water content

- At peak drought stem water content across stem basal area was strongly reduced in Norway spruce (Fig. 5)

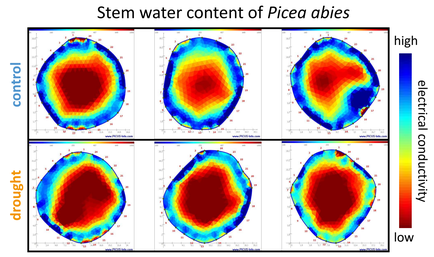

Figure 5: Visualisation of stem water content across stem basal area of 6 Norway spruce individuals obtained from stem tomography measurements performed at peak drought in 2018. Electrical conductivity is proportionally related to water content.

3.3 Radial growth

- Radial growth was significantly reduced by drought treatment for both species (Fig.6)
- Effects became more pronounced in spruce under recurrent drought (Fig. 6)

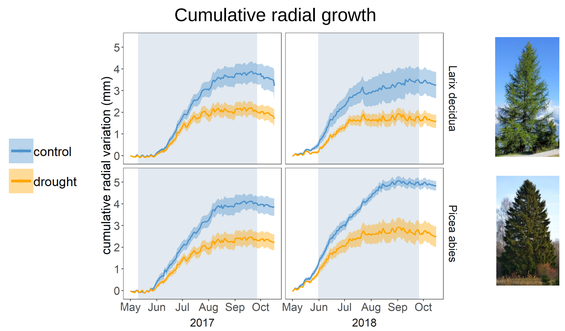

Figure 6: Cumulative stem radial increment obtained from continuous dendrometer measurements (mean ± SE, n = 6 per species and treatment). Grey shading indicates rainout period.

4. Summary and Conclusions

- Prolonged and sustained **drought significantly reduced tree radial growth** at the subalpine tree line.
- **Significant drought effects on sap flow** occurred during periods of high evaporative demand.
- Water use and growth **responses to drought were more pronounced in Norway spruce** compared to European larch.

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