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Elimination of seasonal drought and its effect on canopy gas exchange in a dry Mediterranean pine forest

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Projected intensification of drying and warming trends imply severe risks for widespread forest mortality. Drought adapted trees in semiarid ecosystems cope with both soil water shortage and high vapor pressure deficit by regulating their leaf conductance, avoiding irreversible hydraulic failure, and maintaining CO_2 uptake.

To better understand the relative effects of soil vs. atmospheric moisture deficit on tree response we carried out a manipulation experiment in a semi-arid Aleppo pine forest exposed to long seasonal drought (the Yatir forest; 280 mm mean annual precipitation). We provided supplementary irrigation to eliminate summer soil moisture deficit in 1 ha plot with similar adjacent control plot. We investigated the tree response to the supplement irrigation with automatic branch chambers (16 chambers split in treatment and control plots), sap flow sensors (SF; 40 trees) and electronic dendrometers (20 trees) sensors.

Results from the first treatment year showed a drought-typical decline in branch net assimilation (A_n) and transpiration (T) in early summer (from $\sim$15 to $\sim$4 g C $m^{-2}h^{-1}$ and from 2 to 0.5 mm h^{-1}, respectively in midday values). However, upon the onset of the supplement irrigation in May, T increased dramatically to $\sim$5 mm h^{-1}, $\sim$2.5 times higher than the peak wet season values. This increase was in correlation with the seasonal increase in VPD to $>$5 kPa in June. This was accompanied by a large parallel increase in stem diameter, by $\sim$4.5 mm on average from May to June in the treated plot, with no increase in the control plot. This must at least partly reflect increase in tree water storage to support the large transpiration flux, and large mid-day SF that increased x2 in the treatment plots. Net assimilation in the treated plot also increased, from $\sim$15 to 20 g C m^{-2} h^{-1} $\sim$1.3 times higher than the wet season values.

We will discuss the interplay between soil moisture control and VPD as rate regulation of T across the large range observed in this study (up to VPD of 7 kPa); and the unexpectedly high flexibility in adjusting internal water storage to support large increase in T and in the synchronization between the timing of T and SF. The enhancement in A_n, could be the response to increased stomatal conductance in the treatment plot, and the seasonal increase in temperature and light levels.

The results indicate that growth of Aleppo pine at the dry timberline is clearly limited by water availability and that VPD plays a subordinated role. However, tree mortality may also be avoided by the opportunistic and fast response behavior to any improvement in conditions even in the stressful dry season.