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Elevated [CO_2] does not improve survival of Aleppo pines under extreme drought

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In the last two decades, many experimental as well as modeling approaches have been broaching the issue of how climate affects forest ecosystems. To date, however, models are not yet capable of providing precise predictions about when and how future climatic alterations such as declining water availability and rising atmospheric [CO_2] concentrations will affect forests. Experimental setups can improve knowledge about underlying physiological mechanisms of tree responses to drought under elevated CO_2.

Here, we studied [CO_2] effects on the extreme drought response of 2-year-old Aleppo pines (Pinus halepensis). Seedlings (seeds originating from the Yatir forest, Israel) were grown either under ambient (400 ppm, aCO_2) or elevated (900 ppm, eCO_2) [CO_2] for 24 month. In order to monitor the gas exchange throughout the drought experiment, seedlings (n=9 per treatment) were placed into tree cuvettes designed to measure above- and belowground gas exchange separately. After gradually increasing soil drought under constant temperature and air humidity, drought stress was intensified and irrigation was stopped until drought became lethal. Additional to continuously monitored gas exchange, leaf water potential (Ψ) was measured and non-structural carbohydrate (NSC) concentrations of needle and root samples quantified.

Trees under eCO_2 had a higher water-use-efficiency (c. +100 %) reflected by lower transpiration but higher net photosynthetic rates compared to aCO_2 trees. Although respiration rates as well were higher under eCO_2, the daily C balance (net photosynthesis – respiration) was increased compared to aCO_2. Differences between treatments diminished with increasing soil drought, and the daily C balance of trees became negative in both CO_2-treatments, when stomatal conductance (gs) reached values of 10 % of maximum gs at a leaf Ψ between -2 to -2.5 MPa. Although the C balance was more negative under eCO_2 conditions, leaf sugar concentrations increased with progressing drought and were 40 % higher than in aCO_2 at mortality (indicated by a cessation of respiration). Interestingly, just before death, we observed a distinct increase in shoot and root respiration rates, an indication that programmed cell death and/or necrotic damage occurred in leaf and root tissues simultaneously.

In summary, our results indicate that eCO_2 is advantageous for Aleppo pine seedlings under mild drought (up to -2 MPa). However, when drought progresses and stomata close, dehydration rates are not affected by elevated [CO_2].