Rapid hydraulic collapse as cause of drought-induced mortality in conifers

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Understanding the vulnerability of trees to drought-induced mortality is key to predicting the fate of forests in a future climate with more frequent and intense droughts, although the underlying mechanisms are difficult to study in adult trees. Here, we explored the dynamic changes of water relations and limits of hydraulic function in dying adults of Norway spruce (; Picea abies; L.) during the progression of the record-breaking 2018 Central European drought. In trees on the trajectory to drought-induced mortality, we observed rapid, nonlinear declines of xylem pressure that commenced at the early onset of xylem cavitation and caused a complete loss of xylem hydraulic conductance within a very short time. We also observed severe depletions of nonstructural carbohydrates, though carbon starvation could be ruled out as the cause of the observed tree death, as both dying and surviving trees showed these metabolic limitations. Our observations provide striking field-based evidence for fast dehydration and hydraulic collapse as the cause of drought-induced mortality in adult Norway spruce. The nonlinear decline of tree water relations suggests that considering the temporal dynamics of dehydration is critical for predicting tree death. The collapse of the hydraulic system within a short time demonstrates that trees can rapidly be pushed out of the zone of hydraulic safety during the progression of a severe drought. In summary, our findings point toward a higher mortality risk for Norway spruce than previously assumed, which is in line with current reports of unprecedented levels of drought-induced mortality in this major European tree species.
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