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Recovery of Pinus sylvestris from severe drought: Impacts on leaf gas exchange and xylem embolisms

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Climate change increases the incidence of weather extremes with large implications for forest functioning. In order to estimate forest responses to extreme drought we need a better process understanding of the ability of trees to recover from stress. Scots pine (Pinus sylvestris L.) belongs to the most abundant conifers worldwide, but is generally susceptible to xylem embolism at dry sites. To detect a potential refilling of xylem embolisms after drought release, we investigated stress and recovery dynamics of leaf gas exchange and hydraulic properties in 3-year-old Scots pine saplings. Trees were grown under controlled conditions and irrigation was withhold for about four weeks until stomata were fully closed and xylem water potential declined to -3.2 MPa (+/- 0.4), which indicated substantial loss of hydraulic conductivity (40 - 50%). Drought progression and recovery trajectories were assessed by frequent measurements of xylem water potential, relative needle water content, photosynthesis and stomatal conductance. To assess the degree of embolised xylem in stems we combined in vivo X-ray tomography with classical techniques (hydraulic conductivity and dye staining of stem segments), which were measured during the end of drought, immediate recovery (1-2 days after re-irrigation) and prolonged recovery (4 weeks after re-irrigation). While xylem water potential recovered within 2 days close to control values, both classical and X-ray tomography measurements revealed that hydraulic conductivity did not recover. In contrast, we found stomatal conductance and photosynthesis to recover to about 60% of control values. Our findings demonstrate that Scots pine is able to survive severe drought, although it shows a reduced ability to recover once embolism formation in stem xylem has occurred. We assume that growth of new wood in the next growing season might compensate for some of the loss in hydraulic conductivity. Such processes should be considered by vegetation models in order to predict forest functioning under future conditions.