Submitted Abstract

ID IMC22-FSAbstr- 350

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Country	Austria
Region	Western Europe

Title	Drought Resistance And Recovery Of Norway Spruce Seedlings.
Keywords	Climate Change, Drought Stress, Drought Recovery, Tree Hydraulics
Type	List Of Focus Session
Focus Session ID	05

Abstract

Climate change substantially alters temperature and precipitation patterns, leading to more frequent and/or intense drought events in Central Europe and the Alpine region. Increasing drought stress can have severe influences on tree productivity, carbon and water relations, and may cause species range shifts. Severe and/or prolonged droughts can impair tree water transport via emboli in xylem tissue with potential long-term consequences on tree fitness. However, knowledge of resilience and recovery potential under and after different drought stress intensities/durations of juvenile trees is scarce.

In this study, tree hydraulic traits were combined with gas exchange measurements on an alpine tree species (Picea abies). We used specially designed greenhouse gas exchange chambers for individual seedlings and compared drought effects on, and recovery patterns of juvenile Norway spruce trees under long-term (DD), intermitted (DR) and short-term drought (CD). Measurements of water potential, gas exchange fluxes and non-structural carbohydrates (NSC; starch and soluble sugars) in combination with climate data, soil water content, and high-resolution stem increment data allowed for evaluation of detailed drought and recovery patterns.

During the first drought period, critical water potentials induced reduction in increment, net photosynthesis, and caused emboli in DD and DR trees. This resulted in an even faster drop in water potentials during the second drought period. DR trees recovered within a few days between droughts. However, in the second drought period they showed a faster drop in water potentials and net photosynthesis compared CD trees. Drought led to a depletion of starch in branches and needles. Stress release resulted in a fast recovery of water potentials, except for DR trees which did not reach levels of control trees after 10 days. NSC storages recovered within 10 days. Albeit the recovery of photosynthesis was delayed in the long-term drought treatments (DD, DR), and even CD trees did not reach levels of control trees within 10 days after re-watering.

Incomplete recovery of net photosynthesis and water potential indicate long-term impairments in the water transport system of drought-treated trees. Low water and carbon storage of juvenile trees might not be sufficient to repair damages induced by embolized vessels and the limited hydraulic capacity thus lowered the potential of full recovery. Especially long-term and intermitted long-term droughts render juvenile Norway spruce trees susceptible to long-term impairments. Limited recovery potential may ultimately become decisive for tree survival in face of repeated drought events as expected due to climate change.