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Effects of physical blockage of axial phloem transport on growth of Norway spruce (Picea abies) saplings under drought

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Early culmination of maximum radial growth in late spring was found in several coniferous species in a dry inner Alpine environment (Oberhuber et al. 2014). We hypothesized that early decrease in radial stem growth is an adaptation to cope with drought stress, which might require an early switch of carbon allocation to belowground organs. To test this hypothesis we manipulated tree carbon status by physical blockage of phloem transport and soil water availability of Norway spruce saplings (tree height c. 1.5 m) in a common garden experiment to investigate influence of carbon availability and drought on above- and belowground growth. Girdling occurred at different phenological stages during the growing season, i.e. before growth onset, and during earlywood and latewood formation. Non-structural carbohydrates (NSC, soluble sugars and starch) were determined before and after the growing season to evaluate change in tree carbon status. Tree ring analysis revealed that compared to non-girdled controls earlywood width above girdling strikingly increased by c. 170 and 440 %, while latewood width decreased by c. 85 and 55 % in watered and drought stressed trees, respectively. Below girdling no xylem formation was detected. Unexpectedly, preliminary analyses of carbon status revealed striking reduction (c. -80 %) of NSC above and below girdling. Most likely due to reductions in xylem hydraulic conductance, girdling before growth onset reduced leader shoot growth compared to non-girdled controls by c. 45 %, irrespective of water availability. Root dry mass of girdled trees was significantly reduced compared to non-girdled controls (c. 30 % in drought stressed and 45 % in watered trees; $p < 0.001$). Results suggest that in Norway spruce saplings (1) carbon availability affects radial stem growth, (2) higher basipetal carbon transport occurs under drought supporting our hypothesis of early switch of carbon allocation to belowground when drought stress prevails and (3) minor acropetal transport of carbon from carbon stores in the root system to the stem. We conclude that physical manipulation of carbon availability by disruption of phloem transport is a valuable tool to study relevance of carbon status for tree growth exposed to environmental stress.

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Reference

Oberhuber W, A Gruber, W Kofler, I Swidrak (2014) Radial stem growth in response to microclimate and soil moisture in a drought-prone mixed coniferous forest at an inner Alpine site. Eur J For Res 133:467-479.