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Influence of drought on radial stem growth of Scots pine (Pinus sylvestris) in an inner Alpine environment

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Radial stem growth indices of trees are known to be valuable long-term measures of overall tree vigor and are frequently applied to identify the climatic factors limiting tree growth. Based on several tree-ring studies conducted within inner-Alpine dry valleys, it is well established that growth of Pinus sylvestris is primarily limited by spring precipitation (April through June) and severe drought results in abrupt growth reductions and increased tree mortality. However, the record breaking heat-wave in summer 2003 had only minor impact on growth of drought exposed coniferous trees within the dry inner-Alpine valley of the Inn river (750 m a.s.l., Tyrol, Austria), where mean annual precipitation and temperature amount to 716 mm and 7.3 °C, respectively. To examine short-term influences of drought stress on growth processes more closely, we determined the influence of meteorological factors (air temperature, precipitation) and soil moisture on intra-annual dynamics of tree ring development and stem radial growth in Pinus sylvestris at two sites differing in soil moisture characteristics (xeric and dry-mesic). Radial stem development was continuously followed during 2007 and 2008 by band dendrometers and repeated micro-sampling of the developing tree ring of mature trees.
In 2007, when air temperature at the beginning of the growing season in April exceeded long-term mean by 6.4 °C, cambial cell division started in early April at both study plots. A delayed onset of cambial activity of c. 2 wk was found in 2008, when average climate conditions prevailed in spring, suggesting that resumption of cambial cell division after winter dormancy is temperature-controlled.
Wood formation stopped c. 4 wk earlier at the xeric compared to dry-mesic site in both study years, which indicates a strong influence of drought stress on cell differentiation processes. This is supported by radial widths of earlywood cells, which were found to be significantly narrower at the xeric compared to the dry-mesic site ($P < 0.05$). Furthermore, early culmination of radial growth was found at both study plots around mid-May, prior to occurrence of more favourable climatic conditions, i.e. an increase in precipitation during summer. We suggest that early achievement of maximum growth rate in spring can be regarded as an adaptation to cope with extreme environmental conditions prevailing within the study area, which require an early switch of carbon allocation to belowground organs to ensure adequate resource acquisition on the drought prone substrate. Sustainably reduced tree vigor, higher tree mortality and strikingly reduced stem growth of shallowly rooted trees support our reasoning.
In conclusion, our results suggest that in Pinus sylvestris exposed to dry inner-Alpine climate (i) a temperature threshold rather than water availability triggers onset of aboveground stem growth in spring, and (ii) recurring drought periods combined with nutrient deficiency of shallow, stony soils cause elevated carbohydrate requirements of the root system and associated symbiotic mycorrhizal hyphae to maintain the capability of absorbing scarce water und nutrient resources at the expense of aboveground stem growth.