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Dual 2H/13C isotopic labelling reveals strong reductions of water and carbon transport in temperate tree seedlings exposed to cool (non-freezing) root zone temperatures

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Low, non-freezing soil temperatures are known to negatively affect tree productivity even at warmer air temperatures. A likely reason might be a reduction of water-uptake and -transport at low root zone temperatures. Although, this effect has been previously shown mainly for cold-sensitive herbs and grasses, there is limited experimental evidence that cool root temperatures can also impair the water household of temperate and even boreal tree species. The potential consequences of restricted water uptake in cold soils for carbon (C) assimilation and phloem transport have so far not been investigated in trees.

In a new experiment, we analyzed the effect of three root zone temperatures (2°C, 7°C, 15°C) on seedlings of two broadleaved (Alnus glutinosa, Ulmus glabra) and two coniferous (Picea abies, Pinus sylvestris) European tree species. The effects of root cooling on water and carbon uptake and transport were quantified by simultaneous labelling with 2H and 13C. Two month after germination, naked-rooted seedlings were transferred to constant root zone temperatures in water baths, while all shoots experienced warmer greenhouse temperatures. 10 days after the transfer, all seedlings received a 2H-H_2O labelling within the source water and a simultaneous 13C-CO_2 pulse labelling of shoots. Sequential tracking of the isotopic label of 2H in extracted leaf water following the labelling, showed a reduction of xylem water transport rates by up to -70 % at 2°C compared to 15 °C root zone temperature, but also severely reductions of up to -50% already at 7 °C. These negative effects on water uptake correlated well with reductions of shoot water potential and stomatal conductance. The analyses of 13C signals in leaves and roots after 13C-leaf-labelling, revealed moderately reduced C uptake (-30 % at 2°C) and very strong reductions of C transport to roots at both, 7°C (-60 %) and 2 °C (-80 %) as compared to 15 °C root zone temperatures.

In summary, the results suggest drought-like stress in warm adapted tree seedlings already at moderately cool root zone temperatures, probably due to reduced symplastic root water uptake by aquaporins and the increasingly higher water viscosity between 15°C and 2°C. Further investigations with cold-adapted tree seedlings and field observations would be needed to assess the significance of cold root temperatures for water and C transport under natural conditions and in mature trees.