Negative effects of low root temperatures on water and carbon relations in temperate tree seedlings assessed by dual isotopic labelling

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Low root zone temperatures restrict water and carbon (C) uptake and transport in plants and may contribute to the low temperature limits of tree growth. Here, we quantified the effects of low root temperatures on xylem conductance, photosynthetic C assimilation and phloem C transport in seedlings of four temperate tree species (two broad-leaved and two conifer species) by applying a simultaneous stable isotope labelling of 2H-enriched source water and 13C-enriched atmospheric CO2. Six days before the pulse labelling, the seedlings were transferred to hydroponic tubes and exposed to three different root temperatures (2, 7 and 15 řC), while all seedlings received the same, warm air temperatures (between 18 and 24 řC). Root cooling led to drought-like symptoms with reduced growth, leaf water potentials and stomatal conductance, indicating increasingly adverse conditions for water uptake and transport with decreasing root temperatures. Averaged across all four species, water transport to leaves was reduced by 40% at 7 řC and by 70% at 2 řC root temperature relative to the 15 řC treatment, while photosynthesis was reduced by 20 and 40% at 7 and 2 řC, respectively. The most severe effects were found on the phloem C transport to roots, which was reduced by 60% at 7 řC and almost ceased at 2 řC in comparison with the 15 řC root temperature treatment. This extreme effect on C transport was likely due to a combination of simultaneous reductions of phloem loading, phloem mass flow and root growth. Overall, the dual stable isotope labelling proved to be a useful method to quantify water and C relations in cold-stressed trees and highlighted the potentially important role of hydraulic constraints induced by low soil temperatures as a contributing factor for the climatic distribution limits of temperate tree species.

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