The low temperature limit of tree xylem

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Trees are among the most frost-hardy plants of all. In midwinter, boreal tree species can survive immersion in liquid nitrogen (-196°C) completely unscathed. Many Central European trees do withstand much less frost. This clearly limits their north-eastern distribution. The living wood cells in the sapwood are generally the most frost-sensitive tree tissue and therefore also the crucial point for survival. The mechanisms of frost hardiness of the wood cells have been insufficiently researched and are still largely unknown, especially for most European tree species. For the most frost-resistant woods (-196°C), it is assumed that they survive by freeze dehydration, i.e. that they have real frost tolerance. How this is supposed to work is unknown. However, it is assumed that the cells are successively dehydrated and put into a kind of vitrified state. Less frost-hardy wood cells are likely to survive through deep supercooling. The cellular water remains supercooled even at low freezing temperatures. However, it ultimately freezes out spontaneously between -24 and -50 °C, which kills the wood cells. Apple wood, for example, freezes to death at around -40°C. However, recent findings suggest that superimposed freeze dehydration could also be involved in the deep supercooling capability.

Innovative methods are used to measure the frost hardiness, freezing behaviour and localization of ice masses in sapwood on wood cells of trees with different frost hardiness and to correlate them with structural parameters such as cell structure and wood anatomy, as well as cell wall elasticity and chemistry. The mechanistic involvement of wood architecture and molecular components in the frost survivability of wood cells is - apart from some recent studies - a little explored topic. A new tool, the differential scanning calorimeter, allows to quantify the extent and temperature-dependent dynamics of supercooling and freeze dehydration of wood cells. This should enable species-specific differences in the frost-hardiness mechanism and seasonal changes to be recorded. In this context, specific molecular components within the wood cells (anti-ice nucleation substances) and the cell walls, which influence their porosity and stiffness, as well as the black cap (lipids), which are associated with the piths, are analyzed using RAMAN spectroscopy.

In view of climate change, the resprouting dates of our woody plants are steadily advancing. In Central Europe, trees are already sprouting around 3 weeks earlier on average compared to the long-term mean. In addition, more frequent and more severe cold snaps and frosts are expected, especially in late spring. This increases the probability of frost damage to trees overall. The results will lead to a much better prediction of how trees will react to climate change. This is extremely relevant for forestry, but also for the cultivation of fruit trees and ornamental plants.