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Developmental and environmental factors driving xylem anatomy and micro-density

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The current research on the dynamics of tree ring formation in conifers has provided new insights into how rate and duration xylem-cell production and development control the size of the xylem conduits leading to the formation of earlywood and latewood. So far, the physiology behind wood formation processes and the associated kinetics has rarely been considered, leading to the impossibility to grasp the drivers of wood density changes along the tree-rings. Despite the importance of wood density for carbon sequestration and tree hydraulics, little is known about the factors controlling variations in wood density across the tree ring, i.e. micro-density, at the intra-annual scale. We first developed a process-based mechanistic model that simulates the development of conifer tracheids from a simple sugar signal that we discuss together with the main kinetics and environmental variables leading to the formation of micro-density in black spruce, the main conifers species in the boreal forest of Canada. At the beginning of the growing season, low sugar availability in the cambium results in slow wall deposition that allows for a lengthier enlargement time thus producing large cells with thin walls (i.e. earlywood). In late summer and early autumn, high sugar availability produces narrower cells with thick cell walls (i.e. latewood). Wood formation dynamics had an indirect effect on micro-density. Micro-density increased under longer periods of cell wall deposition and shorter durations of enlargement. Cell diameter indirectly affected micro-density via cell wall thickness, which was the most important parameter affecting micro-density. Cell traits experienced the joint action of enlargement and secondary wall deposition in shaping the intra-annual patterns of tree rings. Our results point to the predictive power of a simple sugar signal. During the growing season, the amount of carbon allocated to wood formation largely influences the duration of cell differentiation, thus modulating cell diameter, cell wall thickness and by result tree-ring micro-density.