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# Needle phenology as an indicator of changes of xylem cell formation in Pinus sylvestris L.

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Drought and heat waves negatively impact tree growth and vitality. They change the timing and duration of both needle and cambial phenological stages. Even though the needle and cambium phenology in conifers possess some degree of autonomy (i.e. cambium activity usually begins before needle flush) as source-sink processes they need to behave in a concert to maintain the balance of tree internal processes. Very few information exists about mutual timing of needle and cambium phenology especially in relation to temperature and drought stress in coniferous species. We analyzed the interplay between xylem formation and needle development of mature Scots pine trees in three consecutive years (2014–2016) differing in the spring temperatures and onset and duration of summer drought. By the wood micro-cores (including cambium and phloem) sampling and the phenological observations in weekly intervals, we monitored the growth course in the three vegetation seasons (2014–2016). Permanent microscopic slides of the cross-section were made from the micro-cores to analyze the cambial activity, the phases of xylem formation and morphometric parameters of the tracheids. The onset of cambial activity was observed on the day of a year (DOY) 83–87, while the bud break occurred on DOY 113–119, same as the beginning of secondary cell wall thickening of tracheids. The timing of bud break correlated with the sum of effective temperatures but the onset of cambium activity did not, suggesting higher importance of other internal and external factors than air temperature for wood formation than to needle growth. The needles were fully unfolded around DOY 170 when the first forming latewood tracheids were found. The needle development was not affected by summer drought, but drought changed the rate of production and morphology of latewood tracheids. The summer drought period was the longest and most severe in the year 2015 when the latewood tracheids were 32% narrower and they had 34% thicker cell walls than in 2014 and 2016. The improved tree water status after summer drought period (in July) influenced the cambial activity which resulted to formation of intra-annual density fluctuations (IADF) in two years out of the three. But the summer drought did not affect the needle phenology, because the current needles were already developed summer drought before. The link between needle and cambium phenology contributed to a mechanistic understanding of how the tree allocates the resources to stem growth under varying temperature and soil water availability.