



UMEÅ UNIVERSITY

How could Christmas trees remain evergreen?

Photosynthetic acclimation of Scots pine and Norway spruce needles during winter

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Abstract

Plants and other green organisms harvest sunlight by green chlorophyll pigments and covert it to chemical energy (sugars) and oxygen in a process called photosynthesis providing the foundation for life on Earth. Although it is unanimously believed that oceanic phytoplanktons are the main contributors to the global photosynthesis, the contribution of coniferous boreal forests distributed across vast regions of the northern hemisphere cannot be undermined. Hence boreal forests account significantly for social, economical and environmental sustainability. Not only do conifers thrive in the tundra regions with extreme climate, but they also maintain their needles green over the boreal winter. A question remains; what makes them so resilient? In this respect, we aimed to understand the remarkable winter adaptation strategies in two dominant boreal coniferous species, i.e., *Pinus sylvestris* and *Picea abies*. First, we mapped the transcriptional landscape in Norway spruce (*Picea abies*) needles over the annual cycle. Transcriptional changes in the nascent needles reflected a sequence of developmental processes and active vegetative growth during early summer and summer. Later after maturation, transcriptome reflected activated defense against biotic factors and acclimation in response to abiotic environmental cues such as freezing temperatures during winter. Secondly, by monitoring the photosynthetic performance of Scot pine needles, we found that the trees face extreme stress during the early spring (Feb-Mar) when sub-zero temperatures are accompanied by high solar radiation. At this time, drastic changes occur in the thylakoid membranes of the chloroplast that allows the mixing of photosystem I and photosystem II that typically remain laterally segregated. This triggers direct energy transfer from PSII to PSI and thus protects PSII from damage. Furthermore, we found that this loss of lateral segregation maybe a consequence of triple phosphorylation of Lhcb1 (Light harvesting complex 1 of photosystem II). The structural changes in thylakoid membranes also lead to changes in the thylakoid macro domain organisation and pigment protein composition. Furthermore, we discovered that while PSII is protected by direct energy transfer, the protection of PSI is provided through photoreduction of oxygen by flavodiiron proteins, which in turn allows P700 to stay in an oxidised state necessary for direct energy transfer. These coordinated cascades of changes concomitantly protect both PSI and PSII to maintain the needles green over the winter.

Keywords

Scots Pine, Norway spruce, Photosynthesis, Winter adaptation

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