Explicitly accounting for needle sugar pool size crucial for predicting intraseasonal dynamics of needle carbohydrates δ 18 O and δ 13 C

JournalArticle (Originalarbeit in einer wissenschaftlichen Zeitschrift)

ID 4646993
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Year 2022
Title Explicitly accounting for needle sugar pool size crucial for predicting intraseasonal dynamics of needle carbohydrates δ 18 O and δ 13 C
Journal New phytologist
Pages / **Article-Number** 18227
Keywords Scots pine (Pinus sylvestris); boreal forest; carbon isotope; dynamic modeling; needle sugar; oxygen isotope; photosynthesis
We explore needle sugar isotopic compositions (δ 18 O and δ 13 C) in boreal Scots pine (Pinus sylvestris) over two growing seasons. A leaf-level dynamic model driven by environmental conditions and based on current understanding of isotope fractionation processes was built to predict δ 18 O and δ 13 C of two hierarchical needle carbohydrate pools, accounting for the needle sugar pool size and the presence of an invariant pinitol pool. Model results agreed well with observed needle water δ 18 O, δ 18 O and δ 13 C of needle water-soluble carbohydrates (sugars + pinitol), and needle sugar δ 13 C (R2 = 0.95, 0.84, 0.60, 0.73, respectively). Relative humidity (RH) and intercellular to ambient CO2 concentration ratio (Ci /Ca) were the dominant drivers of δ 18 O and δ 13 C variability, respectively. However, the variability of needle sugar δ 18 O and δ 13 C was reduced on diel and intra-seasonal timescales, compared to predictions based on instantaneous RH and Ci /Ca , due to the large needle sugar pool, which caused the signal formation period to vary seasonally from 2 d to more than 5 d. Furthermore, accounting for a temperature-sensitive biochemical 18 O-fractionation factor and mesophyll resistance in 13 C-discrimination were critical. Interpreting leaf-level isotopic signals requires understanding on time integration caused by mixing in the needle sugar pool.
Publisher Blackwell Science
ISSN/ISBN 0028-646X ; 1469-8137
edoc-URL https://edoc.unibas.ch/89270/
Full Text on edoc No;
Digital Object Identifier DOI 10.1111/nph.18227
PubMed ID http://www.ncbi.nlm.nih.gov/pubmed/35575976
ISI-Number WOS:000815022800001
Document type (ISI) Article; Early Access