Association between tree-ring and needle δ13C and leaf gas exchange in Pinus halepensis under semi-arid conditions

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Associations between δ13C values and leaf gas exchanges and tree-ring or needle growth, used in eco-physiological compositions, can be complex depending on the relative timing of CO2 uptake and subsequent redistribution and allocation of carbon to needle and stem components. For palaeoenvironmental and dendroecological studies it is often interpreted in terms of a simple model of δ13C fractionation in C3 plants. However, in spite of potential complicating factors, few studies have actually examined these relationships in mature trees over inter- and intra-annual time-scales. Here, we present results from a 4 years study that investigated the links between variations in leaf gas-exchange properties, growth, and dated δ13C values along the needles and across tree rings of Aleppo pine trees growing in a semi-arid region under natural conditions or with supplemental summer irrigation. Sub-sections of tissue across annual rings and along needles, for which time of formation was resolved from growth rate analyses, showed rapid growth and δ13C responses to changing environmental conditions. Seasonal cycles of growth and δ13C (up to 4‰) significantly correlated (P<0.01) with photosynthetically active radiation, vapour pressure deficit, air temperature, and soil water content. The irrigation significantly increased leaf net assimilation, stomatal conductance and needle and tree-ring growth rate, and markedly decreased needle and tree-ring δ13C values and its sensitivity to environmental parameters. The δ13C estimates derived from gas-exchange parameters, and weighted by assimilation, compared closely with seasonal and inter-annual δ13C values of needle- and tree-ring tissue. Higher stomatal conductances of the irrigated trees (0.22 vs. 0.08 mol m$-$2 s$-$1 on average) corresponded with 2.0‰ lower average δ13C values, both measured and derived. Derived and measured δ13C values also indicated that needle growth, which occurs throughout the stressful summer was supported by carbon from concurrent, low rate assimilation. For Aleppo pine under semi-arid and irrigated conditions, the δ13C of tree-ring and needle material proved, in general, to be a reasonable indicator of integrated leaf gas-exchange properties.
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