A test of the tree-line carbon limitation hypothesis by in situ CO2 enrichment and defoliation

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Historically, carbon limitation, through a shortage of photoassimilates has been argued to limit the growth of trees at the upper altitudinal treeline. In a three-year free-air CO2 enrichment (FACE) experiment, two species of 30-year-old alpine conifers (Larix decidua and Pinus uncinata) were studied to test this hypothesis in situ in the Swiss Central Alps (2180 m above sea level). CO2 enrichment was combined with foliage removal to test the effect of altered source-sink relationships on tree growth and leaf level responses. Elevated CO2 enhanced photosynthesis and increased nonstructural carbohydrate (NSC) concentrations in the needles of both species. While the deciduous larch trees showed longer needles and a stimulation of shoot growth over all three seasons when grown in situ under elevated CO2, pine trees showed no such responses. Irrespective of CO2 concentration, defoliation in both species stimulated photosynthesis and increased stomatal conductance in remaining current-year needles in the treatment year and reduced leaf nitrogen concentration in the year following defoliation. Defoliated larch trees had fewer and shorter needles with reduced NSC concentrations in the year following defoliation and showed no stimulation in shoot elongation when exposed to elevated CO2. In contrast, defoliation of evergreen pine trees had no effect on needle NSC concentrations, but stimulated shoot elongation when defoliated trees were exposed to elevated CO2. After three years, our results suggest that deciduous larch is carbon limited at treeline, while evergreen pine is not. However, as indicated by the defoliation treatment, the carbon economy of these trees can clearly be modified by extreme events. The expected changes in growth of these treeline trees with improving carbon availability as atmospheric CO2 continues to increase will thus depend on both the interplay between biotic and abiotic processes, and the species or tree functional types involved.

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