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The effect of carbohydrate accumulation and nitrogen deficiency on feedback regulation of photosynthesis in beech (Fagus sylvatica) under elevated CO_2 concentration

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One of the main manifestations of global change is an increase in atmospheric CO_2 concentration. Elevated concentration of CO_2 has stimulating effect on plant photosynthesis and consequently also on the productivity. Long-term studies, however, show that this effect is progressively reduced due to feedback regulation of photosynthesis. The main causes of this phenomenon are considered as two factors: i) increased biomass production consumes a larger amount of nitrogen from the soil and this leads to progressive nitrogen limitation of photosynthesis, particularly at the level of the enzyme Rubisco, ii) the sink capacity is genetically limited and elevated CO_2 concentration leads to increased accumulation of carbohydtrates (mainly sucrose, which is the main transport form of assimilates) in leaves. Increased concentrations of carbohydrates leads to a feedback regulation of photosynthesis by both, long-term feedback regulation of synthesis of the enzyme Rubisco, and also due to reduced capacity to produce ATP in the chloroplasts. However, mechanisms for interactive effects of nitrogen and accumulation of non-structural carbohydrates are still not well understood.

Using 3-year-old Fagus sylvatica seedlings we have explored the interactive effects of nitrogen nutrition and sink capacity manipulation (sucrose feeding) on the dynamics of accumulation of non-structural carbohydrates and changes in photosynthetic parameters under ambient (385 μmol (CO_2) mol-1) and elevated (700 μmol(CO_2) mol-1) CO_2 concentration. Sink manipulation by sucrose feeding led to a continuous increase of non-structural carbohydrates in leaves, which was higher in nitrogen fertilized seedlings. The accumulation of non-structural carbohydrates was also slightly stimulated by elevated CO_2 concentration. Exponential decay ($p < 0.01$) was observed in CO_2 assimilation rate and stomatal conductance when the content of non-structural carbohydrates increased. However, this relationship was modified by the nitrogen content. Accumulation of non-structural carbohydrates had relatively smaller effect on actual quantum yield of photosystem II. Both, CO_2 assimilation rate and the actual quantum yield of photosystem II decreased more rapidly during sink manipulation in elevated concentrations of CO_2 than in ambient.

Application of chlorophyll fluorescence imaging enabled us to evaluate changes in spatial distribution of feedback regulation of photosynthesis on the leaf-level. We can conclude that the accumulation of non-structural carbohydrates down-regulates photosynthesis mainly through the stomatal conductance, and this effect is further modified by nitrogen content.