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See the forest for the trees: Whole-plant allocation patterns and regulatory mechanisms in Norway spruce

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For more than 40 years plant carbon (C) allocation have been of central interest to plant scientists. Most studies on C allocation focus on either biomass partitioning (e.g., root:shoot ratios), particular fluxes (e.g., non-structural carbohydrate, NSC; biogenic emissions of volatile organic compounds, VOCs) or short-term proportional allocation patterns (e.g., pulse-chase studies using isotopic tracers). However, a thorough understanding of C allocation priorities, especially at the whole-plant level, requires assessing all of these aspects together.

We investigated C allocation trade-off in Norway spruce (Picea abies) saplings by assessing whole-plant fluxes (assimilation, respiration and VOCs) and biomass partitioning (structural biomass; NSC; secondary metabolites, SMs). The study was carried out over 8 weeks and allowed us, by modifying atmospheric CO_2 concentrations ([CO_2]), manipulating plant carbon (C) availability. Treatments included control (400 ppm), carbon compensation (down to 120 ppm) and starvation (down to 50 ppm) C availability levels. Reductions in [CO_2] aimed to reveal plant allocation strategies assuming that pools receiving more C than others under C limitation have a high allocation priority.

Respiration was less sensitive to declining [CO_2] compared to assimilation, NSC and SMs. Strong declines in NSC at low [CO_2] suggest that respiration was maintained by using stored NSC. Furthermore, reduced NSC and SMs concentrations also indicate preferential C allocation to growth over NSC and SMs at low C availability. SMs decreased to a lesser extent than NSC in old needles, and remained relatively constant in branches until death from starvation. These results suggest that pools of stored NSC may serve as a buffer for respiration or growth under C limitation but also that SMs remain largely inaccessible for metabolism once they are stored in tissues. VOCs emissions, however, showed contrasting responses to [CO_2]; oxygenated VOCs (methanol and acetone) decreased whereas monoterpene and sesquiterpene emissions slightly increased with decreasing [CO_2].

Our experimental design provides an excellent platform for studying control mechanisms of C allocation. The range of C availabilities applied in our study will allow partitioning compensatory mechanisms (e.g., up-regulation of C storage due to sugar signalling at high C availability) from evolutionary programming (e.g., storage formation to increase long-term survival at expense of other functions with decreasing C availability). Such partitioning is corroborated via phytohormone and transcriptome analysis, and results will hopefully be available at the time of presentation.