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Allocation of recent photoassimilates in mature European beech and Norway spruce – seasonal variability and responses to experimentally increased tropospheric O_3 concentration and long-term drought

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This contribution summarizes a series of C allocation studies in maturing European beech and Norway spruce trees at Kranzberg Forest, located in southern Germany. Study objects are 60 to 70 year old trees, readily accessible via scaffoldings and canopy crane. Allocation of recently fixed photoassimilates is assessed either by conventional branch-bag labelling with 99 atom% $13CO_2$ or whole-tree labeling using 13C-depleted CO_2 (isoFACE system). While labeling in branch bags, employed for few hours only, focused on phloem functionality in particular under long-term drought, C labeling of whole tree canopies was employed for up to 20 days, studying allocation of recent photoassimilates from the canopy along branches and stems to roots and soils below ground. In all experiments, dynamics of C allocation were mostly pursued assessing carbon isotopic composition of CO_2 efflux from woody tissues which typically reflected isotopic composition of phloem sugars.
Effects of severe and long-term summer drought are assessed in an ongoing experiment with roughly 100 trees assigned to a total of 12 plots (kroof.wzw.tum.de). Precipitation throughfall was completely excluded since early spring, resulting in pre-dawn leaf water potentials of both beech and spruce up to -2.2 MPa. The hypothesis was tested that long-term drought affects allocation of recently fixed C to branches and phloem functionality. In the annual course under unstressed conditions, phloem transport speed from the canopy to the stem (breast height) was double in beech compared to spruce, with highest transport velocities in early summer (about 0.51 and 0.26 m/h) and lowest in spring (0.26 and 0.12 m/h for beech and spruce, respectively).
After leaf flush in spring, growth respiration of beech trunks was largely supplied by C stores. Recent photoassimilates supplied beech stem growth in early summer and refilled C stores in late summer, whereas seasonality was less pronounced in spruce. The hypothesis that growth respiration is exclusively supplied by recently fixed C was rejected for both species.
After long-term (7 years) exposure to elevated (i.e. twice-ambient) O_3 concentrations, allocation of recently fixed C to stems was distinctly affected when studied during later summer. In correspondence with significantly lowered woody biomass development in beech (- 40 %), C allocation to stems was reduced in response to O_3 exposure. Conversely in spruce, photoassimilate allocation to stems and coarse root respiration was hardly affected, reflecting the overall lower sensitivity of spruce to elevated O_3 concentrations. Compartmental modeling characterized functional properties of substrate pools supplying respiratory C demands. Stem respiration of spruce appeared to be largely supplied by recent photoassimilates. Conversely in beech, stored C, putatively located in stem parenchyma cells, was a major source for respiration, reflecting the fundamental anatomical disparity between angiosperm beech and gymnosperm spruce.
Overall, the observed differences in C allocation between the two study species reflect the high plasticity of beech trees in response to seasons and stressors such as drought and elevated O_3, whereas spruce displayed much lower responsiveness to the applied stressors and along the seasonal course of the year.