A kinetic analysis of leaf isoprene emission and photosynthesis in aspen

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Studies on plant isoprene emissions importantly contribute to understanding of biosphere-atmosphere interactions, in particular, tropospheric chemistry. Apart form the role of isoprene in atmospheric processes, intensive research is carried out to understand the role of isoprene in plant physiological activity, and gaining insight into the controls of plant isoprene emissions bear major consequences for both atmosphere/plant interactions and plant physiology. It has been previously demonstrated that the bulk of foliage isoprene emission, especially in non-stressed plants, relies on a small recently assimilated chloroplastic carbon pool. Thus, studies have attempted to link isoprene emissions to foliage photosynthetic processes. However, so far it has been observed that there is no universal relationship between isoprene emission and foliage photosynthesis rates across different light, temperature and ambient CO_2 concentrations. We have used a rapid gas-exchange system FAST-EST (response time ca. 3 s) together with a proton-transfer reaction mass spectrometer (PTR MS, response time ca. 0.1 s) to study the light, CO_2 and O_2 dependencies of isoprene emission in hybrid aspen (*Populus tremula* x *P. tremuloides*). A method based on quantitative integration of dark release of isoprene emission was used to determine in vivo the isoprene substrate, dimethylallyldiphosphate (DMADP), pool size responsible for isoprene emission. The kinetic analysis of isoprene emission and photosynthesis rates conducted in this study suggests that isoprene emission is not limited by carbon-based intermediates for DMADP synthesis under most conditions. The carbon supply for DMADP synthesis becomes saturating already at CO_2 concentrations close to the CO_2 compensation point. No changes in the activation state and kinetic characteristics of isoprene synthase were also observed during at least 20-30 min. under specific environmental conditions. Our studies further demonstrated that isoprene synthase activity was very large compared with its substrate, DMADP concentration, at different CO_2, O_2 concentrations and light intensities. Accordingly, the synthase operates at the linear part of the emission vs. DMADP concentration curve under most environmental conditions. Although DMADP synthesis and isoprene emission are weakly associated with the production rate of carbon-based intermediates of DMADP, our studies further demonstrate that DMADP synthesis is strongly linked to photosynthetic processes, being controlled by the availability of energetic co-factors, most likely by chloroplastic ATP concentration. We suggest that over short-term, 20-30 min., the availability of ATP for DMADP synthesis explains the light and CO_2 dependencies of isoprene emission. These data collectively provide encouraging evidence that ATP level controls isoprene emission from plants under diurnal fluctuations of environmental drivers.