Diagnostics in beech exposed to chronic free-air o3 fumigation in the Exceptional Summer 2003: Ozone uptake and gas exchange responses of adult Trees

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Since spring 2000, 60-year-old beech trees (Fagus sylvatica) have been exposed throughout the growing seasons to an enhanced O3 regime (2 x ambient O3 at the site) using a “Free-Air Canopy O3 Exposure” system at the “Kranzberg Forest” research facility. Trees under the ambient O3 regime serve as a control. To prevent acute O3 injury, the experimental regime is confined to a maximum of 150 nl O3 l-1. Scaffolding and a research crane provide access to the sun and shade crowns of the trees being 27 m in height. Given the ample information on short-term responses of juvenile trees, the study aims at clarifying the sensitivity of adult forest trees to chronic O3 impact. The growing season of 2003 provided the opportunity to analyze the interaction between the exceptional drought conditions and ozone impact.

For creating a mechanistic basis of quantitative risk assessment, diagnostic findings on O3 effects are scaled from the leaf to the tree level. Gas exchange and chlorophyll fluorescence are measured simultaneously to assess changes in photosynthetic performance. Leaf injury is quantified by the novel “Imaging-PAM” technique that provides a two-dimensional analysis (patches of 3.7 cm^2) of chlorophyll fluorescence as reflected in quantum yield, ETR and non-photochemical quenching. The false-color images can be used as a tool for detecting early leaf responses prior to discoloration. Light dependence of chlorophyll fluorescence within the patches is analyzed for quantifying responsiveness. Symptoms detected by “Imaging-PAM” are validated in comparison with microscopic and histochemical assessments (cooperation with “Ozone Validation Centre”, Birmensdorf / Switzerland). CO2 fixation is assessed by porometry (analysis of light and CO2 dependence) for parameterizing models that allow scaling (in combination with structural data) to the crown level and the calculation of O3-affected C gains of the whole tree.

The duration of the assimilation period is determined through phenological observations. During the past five years, the assimilation period became significantly shortened in the sun crowns due to accelerated leaf senescence under the enhanced O3 regime, with the largest effect occurring in 2000. Similar trends of shade crowns were not significant. Lammas shoots initiated in beech in response to stress appear to support the conception that their high photosynthetic capacity, stomatal conductance and maximum quantum yield may counteract photosynthetic limitations in the foliage of the spring flush.

The persisting drought caused the pre-dawn water potential to drop to –1.4 MPa, and stomatal conductance was lowered by more than 50% as compared to previous years, which resulted in decreased ozone uptake.