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Evaluation of leaf energy dissipation by the Photochemical Reflectance ()

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Starting from the early paper by Heber (1969), several studies have demonstrated a subtle shift in leaf spectroscopic characteristics (both absorbance and reflectance) in response to rapid changes in environmental conditions. More recent work, briefly reviewed here, has also demonstrated the existence of two components in the maked peak centered at 505-540 nm: an irreversible component, attributed to the interconversion of leaf xanthophylls, and a reversible component at slightly longer wavelengths, resulting from conformational changes induced by the buildup of a pH gradient across the thylakoid membrane associated with photosynthetic electron transport. Both processes (xanthophyll de-epoxidation and conformational changes) are known to contribute to the dissipation of excess energy in Photosystem II (PSII). Leaf spectroscopy could therefore provide a powerful non-invasive tool for the determination of leaf photosynthetic processes. This led to the development of the normalized spectral index PRI (Photochemical Reflectance Index; Gamon, Penuelas &Field 1992; Gamon, Serrano &Surfus 1997), which relates the functional signal at 531 nm to a reference signal at 570 nm. The index has been found to track diurnal changes in xanthophyll de-epoxidation state, radiation use efficiency and fluorescence in response to light, both at the leaf and more recently at the canopy level. A common relationship has also beenreported across species and functional types, although such a generality has not always been confirmed. Recent reports (Stylinski et al. 2000) have also hinted of a possible link between PRI and leaf photosynthetic potential, possibly through the correlation between xanthophyll content and electron transport machinery in the chloroplast. Such a link, if confirmed, could prove very useful for the remote sensing and modelling ofvegetation. Some of these open questions were addressed in the present study. The correlation between leaf function and reflectance was studied in seedlings of 10 broadleaf tree species (Arbutus unedo, Castanea sativa, Fraxinus angustifolia, Fagussylvatica, Juglans regia, Laurus nobilis, Ligustrum vulgare, Platanus occidentalis, Quercus robur, Q. ilex, Salix capraea) under controlled conditions. To avoid the possibility of a spurious correlation in response to light, electron transport rate was modulated through changes in ambient CO2 concentration, whilst irradiance waskept constant at saturating levels. This would mimic the effects of stomatal changes under midday field conditions. Leaf photosynthetic potential (Jmax, Vcmax) and electron transport rates were derived from the resulting A/ci curves through the Farquhar model (Farquhar &von

Caemmerer 1982; Farquhar, von Caemmerer &Berry 1980). Leaf reflectance in the visible region was continuously monitored with a ZEISS MCS-501 spectrometer, with a digitalisation accuracy of 16 bit, band-to-band spacing of 0.8 nm and a bandwidth of approx 3 nm (FWHM). The manipulation of ambient [CO2] and electron transport rate induced marked changes in leaf spectroscopy. Apart from an apparent shift in the 680-730 nm region, resulting from leaf fluorescence, a marked peak was observed at 531 nm whilst the signal at 570 nm remained almost constant after an initial acclimation to high light. The shift in leaf reflectance mirrored parallel changes in assimilation rates. As a result, a very strong correlation between PRI and computed PSII quantum efficiency was observed at the leaf level. Different leaves and species, however, differed both in the slope of the relationship and in the absolute PRI level. When all the results were pooled together, however, a significant correlation (R2 = 0.64) was still apparent. This would mimic the situation in distal remote sensing, where a variety of sunlit leaves from different species and with different photosynthetic potential would be sampled together. An even stronger correlation (R2 = 0.69) was observed, however, between PRI and leaf photosynthetic potential (Jmax, maximum electron transport rate), with the same slope as in the dataset of Stylinski et al. (2000). The PRI offset between the two datasets could be explained by different spectrometer characteristics (resolution of 3 vs 10 nm FWHM). The correlation was further improved (R2 = 0.81) through the correction for a baseline reflectance induced by leaf pubescence in some samples, leading to the development of an improved index [PRIred = (R531 - R570) / (R531 + R570 - 2 R660)].

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