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# Significance of hyper spectral solar radiation observation

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Land plants exhibit relatively weak absorbance of green light at around 550 nm, for reasons which remain elusive. Most research, however, has assumed that the solar radiation spectrum can be averaged without considering the spectral dynamics. The relations between the spectrum of incident radiation and light-harvesting pigments of organisms are crucial to understanding photosynthesis and light use efficiency. Although several light-harvesting pigments exist, most land plants use specific light harvesting chlorophylls, Chl a and Chl b, and carotenoids. Wavelengths longer than 700 nm or shorter than 400 nm are scarcely absorbed by chlorophylls, and cannot be used for photosynthesis. Radiation within the 400 to 700 nm waveband is defined as photosynthetically active radiation (PAR). However, chlorophylls do not absorb photons in the PAR waveband evenly. Only a few per cent of relative absorbance occurs in the green region (500 to 600 nm), nevertheless the photosynthetic quantum yields are equivalent to those from blue and red light.

Incident PAR comprises two main components, direct PAR (PARdir), which arrives directly from the sun, and diffuse PAR (PARdif), which is sunlight scattered by sky and clouds. These components are characterized by large differences in light quantity, directional characteristics and spectral quality. PARdir is highly directional and its energy can be concentrated and localized on a surface. PARdif is non-directional and its incident energy is well-averaged across a surface, allowing it to penetrate deeper into canopies. Consequently, PARdir and PARdif play different roles in the photosynthetic process both at the scale of individual leaves and of canopies. Most research, however, has assumed that the solar radiation spectrum can be averaged without considering the spectral and directional dynamics.

We had developed a precise solar tracking device for detecting direct and diffuse radiation. Direct and diffuse radiations were measured separately by two grating spectroradiometers (MS700, EKO Instruments Co. Ltd., Tokyo, Japan) fixed to sun trackers (STR-22G-S, EKO Instruments Co. Ltd.) equipped with a collimation tube (angle of view 5 degrees) for measurement of PARdir, and a shadow ball for measurement of PARdif.

Analyzing the relative absorption spectra of chlorophyll, we found that Chl a does not absorb direct solar radiation, while diffuse solar radiation is efficiently up-taken by Chl b. The spectrum of diffuse solar radiation is almost fixed with a peak wavelength ($\lambda$max) around 460 nm. However, that of direct solar radiation shifts from a broad peak with $\lambda$max around 700 nm towards a narrower peak around 540 nm, as solar zenith angle decreases. The absorption spectrum of Chl a lies outside the strongest energy regions of direct solar radiation. The $\lambda$max of the Chl b absorption spectrum matches that of diffuse solar radiation; therefore, Chl b can absorb the most energetic parts of this radiation. The spectral differences between direct and diffuse solar radiation elucidate the meaning of slight spectral differences in pigments for terrestrial organisms.

Strong light is known to enhance accumulation of carotenoids. We found that $\beta$-carotene consistently absorbed more energy per photon than other pigments, indicating that it effectively filters (i.e. accepts) the 350-500 nm waveband, independently of PAR class.

Overall, the spectral differences between PARdir and PARdif, as well as the steady $\lambda$max of PARdif, exert multiple effects on terrestrial organisms and may be effective drivers of diversification in pigment distribution and function. Further spectral-directional radiation observation at various sites is needed to reveal the effects of the dynamics of incident solar radiation on the terrestrial ecosystem.

Keywords: spectroradiomater, direct solar radiation, diffuse sky radiation, photosynthesis, spectral light use efficiency, PAR