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This Week's Citation Classic

Gates D M, Keegan H J, Schleter J C & Weidner V R. Spectral properties of plants. *Appl. Optics* **4**:11-20, 1965. [National Bureau of Standards, Boulder, CO and Washington, DC]

The spectral reflectance, transmittance, and absorptance of plant leaves is given for the ultraviolet, visible, and infrared frequencies. Mechanisms for the interaction of radiation with a leaf are described. The amount of sunlight absorbed by a leaf through clear or overcast sky is given and seasonal changes in leaf properties. [The *SCI*® indicates that this paper has been cited over 125 times since 1965.]

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"This article reflected my training as a physicist and my interest in plant ecology. I had worked out the energy budget of a plant leaf and realized that the most dominant energy exchange was radiation followed by convection and evaporation. I needed accurate values for the amount of solar radiation absorbed by a leaf as a function of wavelength. I knew how to get these measurements since I had published an early paper on the infrared properties of leaves.[1] However, I did not possess the equipment for making these measurements. Furthermore, I was working at the Boulder laboratories of the National Bureau of Standards (NBS) in atmospheric physics and my interest in botany and ecology was not considered valid within the mission of the laboratory. All of my botanical research was being done evenings, weekends, and holidays at home and in the field. Ironically, at the NBS in Washington they had the world's best spectrophotometers and a person in charge, Harry J. Keegan, with a desire to measure the spectral properties of plants. He had done some spectral plant measurements (unpublished) for the Air Force some years earlier. Also we did not have any project support funds for this research, so Keegan cleverly charged it to an Advanced Research Projects Agency, DOD, account. John Schleter and Victor Weidner at NBS ran the spectrophotometer but Weidner gathered local plant material in Washington, DC which added considerably to the material I supplied from the western US.

"The paper contained a great deal of unique information not previously well displayed in the scientific literature. Although spectral reflectance curves for leaves had been published previously, no one had described spectral reflectance, transmittance, and absorptance in so much detail. In particular, no one had combined the spectral energy distribution of sunlight and skylight or cloud light with the spectral absorptance of a leaf to show the spectral distribution of absorbed energy. Comparisons were made of desert plants (largely succulents) with the broad thin leaves of deciduous plants of more temperate environments. Furthermore, I introduced the method of plotting the spectral properties of leaves on a wavenumber basis rather than a wavelength basis. This demonstrated to puzzled readers that the apparent peak of the spectral solar energy curve in the green when plotted against wavelength is an artifact of the scale used. When plotted against wavenumber the peak occurs in the near infrared.

"The paper is much cited because it was extremely comprehensive, fundamental, and interdisciplinary. The field of remote sensing was just beginning to grow vigorously, and, in addition, physiological plant ecology was also ready to become more biophysical and analytical. This paper among others on radiation resulted in my being given the Award for Outstanding Achievement in Bioclimatology by the American Meteorological Society in 1971."

1. **Gates D M & Tantraporn W.** The reflectivity of deciduous trees and herbaceous plants in the infrared to 25 microns. *Science* **115**:613-16, 1952.