

## OPTICAL PROPERTIES OF LEAVES OF SOME INDIAN PLANTS

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LEAVES function as optical filters, selectively absorbing different wavelengths of electromagnetic radiation<sup>1-3</sup>. Leaf optical properties vary, depending upon the environments in which the plants live. These properties must be measured if the photosynthetic efficiencies<sup>4</sup> and the thermal properties and thus water relations<sup>5</sup> of individual species are to be understood. Of the few species measured<sup>2,6,7</sup>, none are native to the Indian subcontinent. Here we report the leaf optical properties of 22 taxa native to different vegetation types of India.

Leaves were collected from trees of: (1) a wet evergreen forest in Kanyakumari district of South India (lat. 8° 28' N, long. 77° 18' E—KK); (2) a moist deciduous forest in the Thane District of Maharashtra (lat. 19° 13' N, long. 73° 01' E—TD); and desert plants from the Botanical Garden of the University of Jodhpur (lat. 26° 17' N, long. 73° 02' E—JP). Mature, sun-exposed leaves were collected and kept moist, and measured within 2 hr of collection. Measurements were performed with a Li-Cor  $\neq$  1800 spectroradiometer (Li-Cor Instruments, Lincoln, Nebraska, U.S.A.) with integrating sphere attachment. Diffuse transmittance and reflectance were measured from five leaves of each species, at 2 nm intervals, 350–1100 nm, in comparison to a barium sulphate reference ( $\neq$  6084, Eastman Kodak, Rochester, New York, U.S.A.). Absorbance was calculated as 1-transmittance reflectance for each leaf. To calculate leaf properties in natural sunlight, these curves were multiplied by the mean of five measurements at solar zenith in Thane District on 10 October 1984. The instrument's micro-computer calculated the integrations of these spectra for photosynthetic photon flux density (PPFD, as  $\mu$  mol sec<sup>-1</sup> m<sup>-2</sup>, 400–700 nm), and radiant energy 350–1100 nm as W m<sup>-2</sup>. Leaves absorb differently at 660 and 730 nm, and changing quantum flux densities at these wavelengths affect phytochrome equilibria and developmental processes in plants<sup>8</sup>. This ratio (the

R:FR of Smith<sup>8</sup>) was also calculated with the instrument.

A brief discussion of data for one species, *Tectona grandis*, will help in understanding the data for all of the species listed in table 1. Teak leaves (figure 1) transmit and reflect little (and thus absorb much: 0.894  $\pm$  0.010) in the visible wavelengths of 400–700 nm, and transmit and reflect almost all radiation above 750 nm. Thus, the total absorbance 350–1100 nm (0.601  $\pm$  0.013) from the leaf is greater from reflectance than from transmittance (a ratio of 1.21:1.00).

The spectral properties of the leaves of these plants are similar to others measured<sup>2,5,6</sup>. Although desert species, (e.g. *Aerva persica*), absorb less than those from other habitats, there is considerable variation among species from each habitat. These data can assist in other studies on these ecologically important species. Percentages of absorbance of PPFD will allow calculations of quantum efficiencies from photosynthetic measurements. Although differences in energy absorbance at wavelengths 350–1100 nm help to describe the thermal properties of the leaves, 25 % of solar energy (1100–3000 nm) was not measured. Ehleringer *et al*<sup>5</sup> determined the relationship between absorbance of PPFD and absorbance 400–3000 nm for 38 desert species: absorbance between 400 and 3000 nm equals 0.73 times absorbance between 400 and 700 nm minus 11.9. From these results an absorbance in the range of 400–3000 nm of 0.52 is calculated for the mean of 22 species in this sample.

These leaves allow a little PPFD to be transmitted (0.039  $\pm$  0.017), and the spectral quality of sunlight, at R:FR = 1.15 is radically changed (R:FR = 0.073  $\pm$  0.039). These results could assist in the calculation of spectral properties of radiation immediately beneath foliage. For these species reflectance and transmittance

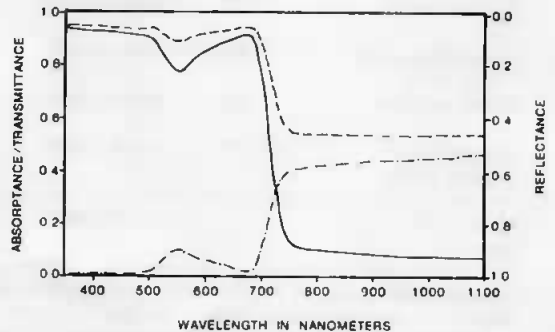


Figure 1. Leaf optical properties of *Tectona grandis*. (—) denotes absorbance; (---) diffuse reflectance; and (-.-) diffuse transmittance.

**Table 1** Leaf optical properties of 22 Indian species; values are the means  $\pm$  standard deviations of five leaves. Location abbreviations are in the text.

Species	Location <sup>1</sup>	PPFD Abs. <sup>2</sup>	350-1100 nm Abs. <sup>3</sup>	Refl./trans	PPFD trans.	R:FR trans
<i>Artocarpus hirsuta</i> Lamk.	KK	0.893 $\pm$ 0.028	0.579 $\pm$ 0.030	1.46 $\pm$ 0.14	0.036 $\pm$ 0.014	0.065 $\pm$ 0.020
<i>Aerva persica</i> (Burm. f.) Merrill	JP	0.804 $\pm$ 0.005	0.544 $\pm$ 0.004	1.71 $\pm$ 0.06	0.031 $\pm$ 0.003	0.068 $\pm$ 0.011
<i>Albizia procera</i> Benth.	TD	0.912 $\pm$ 0.009	0.584 $\pm$ 0.005	1.08 $\pm$ 0.01	0.030 $\pm$ 0.003	0.044 $\pm$ 0.005
<i>Bauhinia variegata</i> L.	JP	0.832 $\pm$ 0.016	0.543 $\pm$ 0.012	1.39 $\pm$ 0.10	0.041 $\pm$ 0.004	0.064 $\pm$ 0.025
<i>Butea monosperma</i> (Lamk.) Taubert	TD	0.887 $\pm$ 0.008	0.579 $\pm$ 0.005	1.01 $\pm$ 0.03	0.047 $\pm$ 0.005	0.124 $\pm$ 0.006
<i>Calotropis procera</i> R. Br.	JP	0.868 $\pm$ 0.010	0.563 $\pm$ 0.008	2.18 $\pm$ 0.11	0.009 $\pm$ 0.002	0.003 $\pm$ 0.001
<i>Careya arborea</i> Roxb.	KK	0.866 $\pm$ 0.008	0.547 $\pm$ 0.006	1.35 $\pm$ 0.11	0.042 $\pm$ 0.008	0.078 $\pm$ 0.015
<i>Cordia rothii</i> Roem. and Schutt.	JP	0.855 $\pm$ 0.010	0.551 $\pm$ 0.006	1.48 $\pm$ 0.10	0.032 $\pm$ 0.004	0.059 $\pm$ 0.009
<i>Cryptostegia grandiflora</i> R. Br.	JP	0.847 $\pm$ 0.023	0.547 $\pm$ 0.022	0.97 $\pm$ 0.09	0.068 $\pm$ 0.016	0.132 $\pm$ 0.033
<i>Dalbergia latifolia</i> Roxb.	TD	0.866 $\pm$ 0.014	0.567 $\pm$ 0.005	1.15 $\pm$ 0.05	0.056 $\pm$ 0.004	0.135 $\pm$ 0.017
<i>Erythrina indica</i> Lamk.	TD	0.846 $\pm$ 0.024	0.535 $\pm$ 0.017	0.86 $\pm$ 0.07	0.082 $\pm$ 0.019	0.123 $\pm$ 0.036
<i>Garcinia indica</i> (Dupetit-Thouars) Choisy	TD	0.921 $\pm$ 0.007	0.599 $\pm$ 0.008	1.71 $\pm$ 0.07	0.018 $\pm$ 0.005	0.046 $\pm$ 0.012
<i>Gordonia obtusa</i> Wall.	KK	0.905 $\pm$ 0.017	0.578 $\pm$ 0.025	1.10 $\pm$ 0.10	0.040 $\pm$ 0.016	0.063 $\pm$ 0.043
<i>Morinda tinctoria</i> Roxb.	TD	0.909 $\pm$ 0.003	0.602 $\pm$ 0.008	1.51 $\pm$ 0.04	0.021 $\pm$ 0.001	0.036 $\pm$ 0.007
<i>Salvadora oleoides</i> Decne.	JP	0.869 $\pm$ 0.008	0.572 $\pm$ 0.006	1.29 $\pm$ 0.08	0.028 $\pm$ 0.002	0.025 $\pm$ 0.003
<i>Salvadora persica</i> L.	JP	0.875 $\pm$ 0.007	0.575 $\pm$ 0.005	1.36 $\pm$ 0.04	0.020 $\pm$ 0.001	0.013 $\pm$ 0.002
<i>Syzygium phylloraeoides</i> (Trim.) Santapau	KK	0.898 $\pm$ 0.010	0.580 $\pm$ 0.012	0.95 $\pm$ 0.01	0.046 $\pm$ 0.007	0.055 $\pm$ 0.012
<i>Tecomella undulata</i> (Smith) Seem.	JP	0.817 $\pm$ 0.018	0.533 $\pm$ 0.003	1.21 $\pm$ 0.25	0.067 $\pm$ 0.017	0.132 $\pm$ 0.023
<i>Tectona grandis</i> L.f.	TD	0.894 $\pm$ 0.010	0.601 $\pm$ 0.013	1.21 $\pm$ 0.01	0.030 $\pm$ 0.003	0.086 $\pm$ 0.039
<i>Terminalia tomentosa</i> W. A.	TD	0.895 $\pm$ 0.006	0.581 $\pm$ 0.009	1.35 $\pm$ 0.06	0.036 $\pm$ 0.005	0.073 $\pm$ 0.011
<i>Trewia nudiflora</i> L.	TD	0.897 $\pm$ 0.005	0.602 $\pm$ 0.018	1.14 $\pm$ 0.05	0.047 $\pm$ 0.005	0.089 $\pm$ 0.010
<i>Ziziphus mauritiana</i> Lamk.	TD	0.908 $\pm$ 0.006	0.590 $\pm$ 0.005	1.71 $\pm$ 0.07	0.028 $\pm$ 0.005	0.096 $\pm$ 0.017
Mean of all species		0.875 $\pm$ 0.032	0.572 $\pm$ 0.022	1.33 $\pm$ 0.31	0.039 $\pm$ 0.017	0.073 $\pm$ 0.039

<sup>1</sup> relative absorbance of PPFD; <sup>2</sup> relative absorbance of solar energy 350-1100 nm; <sup>3</sup> ratio of solar energy 350-1100 nm reflected to that transmitted through the leaf; <sup>4</sup> fraction of PPFD transmitted through the leaf; and <sup>5</sup> spectral quality of transmitted radiation as indicated by the quantum ratio between 660 and 730 nm. The means and standard deviations are given for all species at the bottom of the table.

vary in their contribution in limiting absorptance, and this could certainly correlate with the anatomical comparison of the leaves, such as the extent and distribution of intercellular spaces, as well as pigment concentration and composition. Although greater reflectance compared to transmittance would be expected from desert plants (from leaf surface features), no clear trend is seen in the data. Further studies, anatomical and physiological, would reveal the importance of leaf optical properties for each species' particular ecological requirements.

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