Leaf Pubescence: Effects on Absorptance and Photosynthesis in a Desert Shrub

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Abstract. The presence of leaf pubescence (leaf hairs) in Encelia farinosa, a desert species of the Composite family, reduces the absorptance of photosynthetically active radiation (400 to 700 nanometers) by as much as 56 percent more than a closely related but nonpubescent species, E. californica, a native of the relatively moist southern California coast. Pubescence in E. farinosa, which increases through the growing season, modifies the leaf energy balance and dramatically reduces the photosynthetic rate. The reduction in the photosynthetic rate is caused by decreased light absorption rather than decreased carbon dioxide conductance through the boundary layer.

There is a tendency among higher plants for leaf pubescence to increase along environmental gradients of decreasing precipitation (1). From observations of the distribution of leaf pubescence among plants, it has been deduced that pubescence is an adaptive feature of plants occupying arid habitats (2). This is because pubescence can potentially reduce the heat load of leaves by increasing the reflectance from the leaf surface, which reduces the amount of radiation absorbed. The adaptive value of a reduced radiation load to plants growing in hot or arid climates in terms of reducing leaf temperatures and decreasing transpirational losses is great (3), yet the consequences of reduced light absorptance on the net photosynthetic rate have not been considered.

This report is concerned with the absorptance values in the photosynthetically active spectral range (visible spectrum, 400 to 700 nm) of Encelia farinosa, a drought-deciduous shrub with white, densely pubescent leaves, as compared with those of a closely related species, E. californica, which has green, nonpubescent leaves. The two species are allopatric in their distributions; E. californica is restricted to the relatively moist coastal regions of southern California, and E. farinosa occurs in the dry desert areas of the southwestern United States.

Previous measurements have indicated that plants with pubescent leaves often (4, 5), but by no means always (6), absorb less light in the visible spectrum than green nonpubescent leaves. The upper surface of green leaves normally absorbs 80 to 90 percent of the quanta in the photosynthetically active wavelengths (7). In contrast, pubescence reduces absorptance to as little as 68 percent (8).

Leaf absorptance spectra were measured with a Bausch & Lomb high intensity grating monochromator attached to an Ulbricht integrating sphere, according to the theory and description of Rabideau et al. (9). Solar absorption coefficients for the 400- to 700-nm spectral range were calculated from the absorptance spectra of the upper leaf surface in conjunction with the solar spectrum at the earth's surface. The calculated solar absorptance coefficients thus represented the integrated percentage of quantum absorption by the leaf over the photosynthetically active wavelengths. The percentage of quanta absorbed is not necessarily equivalent to the percentage of energy absorbed, since quanta of different wavelengths contain different amounts of energy. However, over the range of 400 to 700 nm, the percentages were nearly identical for leaves of Encelia.

The nonpubescent E. californica exhibits a spectrum typical of intact green leaves (Fig. 1), but in the pubescent E. farinosa, the absorptance values are sharply reduced. This particular E. farinosa spectrum was obtained from active leaves in the extreme environment of Death Valley, California, during September 1975. Since transmittance through the leaf hairs was less than 1 percent, the pubescent layer appears to serve as a blanket reflector, decreasing the light absorbed by approximately 56 percent below the values of E. californica at all wavelengths. The differences between the two spectra are due only to differences in pubescence. The chlorophyll contents of leaves from both species were equivalent (about 40 μg cm⁻²), and the thicknesses of the epidermis and mesophyll layers were similar. Integrated solar absorption coefficients from these spectra are 84.8 and 29.0 percent for E. californica and E. farinosa, respectively, making E. farinosa the most extreme case known in which pubescence reduces light absorption by the leaf. It is likely that other species exist with similarly low absorptances, yet they have not been measured because their leaves are quite small compared to those of Encelia.

Field observations of solar absorption coefficients for both species were made in December 1974, March 1975, and July 1975. Samples of E. californica were collected at Point Mugu (362 mm mean annual precipitation) and San Diego (240 mm) in southern California, and E. farinosa was sampled at Superior (433 mm), Tucson (270 mm), Tonopah (155 mm), and Ehrenberg (90 mm) in southwestern Arizona. Five representative samples were collected from each site. The means of all samples of a species at a given sampling time were reduced to a single value.

The mean solar absorption coefficients for E. californica were 83.9, 83.8, and 82.4 percent, and for E. farinosa, 71.7.

![Fig. 1. Absorption spectra of intact leaves of Encelia californica and E. farinosa over the wavelengths 400 to 800 nm as determined with an Ulbricht integrating sphere.](image)

![Fig. 2. Light dependence of net CO₂ uptake by single attached leaves of Encelia farinosa differing in their degree of pubescence. Rates were determined at a leaf temperature of 30°C, a CO₂ partial pressure of 325 mbar, an O₂ concentration of 21 percent by volume, and a water vapor pressure deficit of less than 10 mbar. Abbreviation: α, solar absorption coefficient.](image)
for photosynthesis. An inverse relationship between the degree of pubescence and the water availability to the plant would minimize the effects of pubescence on light-limited photosynthesis. The high correlation between solar absorption coefficients and precipitation serves as indirect evidence for such a relationship.

To determine to what degree pubescence would affect primary production, photosynthetic rates were measured on individuals of *E. farinosa* differing in their degree of pubescence. All plants were grown under conditions of sufficient water and nutrients and full sunlight in phytocells (environmentally controlled greenhouses) (12). Simultaneous measurements of CO₂ and water vapor exchange were made on single leaves with a leaf chamber and gas exchange system (13). All measurements were made in normal air (325 μbar CO₂ and 21 percent O₂).

Three significant features of the results (Fig. 2) are: (i) the incident quantum yield (slope of linear part of curve between 0 and 30 nE cm⁻² sec⁻¹) decreases as the pubescence increases, (ii) the maximum rates decrease as pubescence increases, and (iii) unlike that in many plants, net photosynthesis under all three pubescence conditions is not light-saturated even at 200 nE cm⁻² sec⁻¹, which is equivalent to full noon sunlight during the summer. Quantum yields on an incident light basis were 0.025, 0.033, and 0.041 for absorptances of 53, 65, and 82 percent, respectively. When calculated on the basis of absorbed quanta, the quantum yields were 0.048, 0.050, and 0.050, respectively. These yields, typical for high photosynthetic rates (14), indicate that although pubescence in *E. farinosa* increases light reflectance and reduces net photosynthesis, it does not affect the basic photosynthetic process (CO₂ fixed per quantum absorbed). Net photosynthesis is so dramatically affected by pubescence that at a leaf absorptance of 53 percent, the net photosynthetic rate is nearly linear with light intensity up to full sunlight. Conductance values of water vapor and CO₂ into the leaf through the stomata were similar for the leaves at any given light intensity, which suggests that CO₂ diffusion limitations were not responsible for differences among the curves. When photosynthetic data from these three curves are plotted against absorbed rather than incident quanta, all data lie on a single curve; the principal differences among the curves were thus due primarily to decreases in light absorption resulting from pubescence rather than from physiological differences.

To the best of our knowledge, this study constitutes the first report that pubescence reduces the net photosynthetic rate. In our case the reduction is caused by decreased light absorption rather than by decreased CO₂ conductance through the boundary layer. Because of the dramatic effects of leaf pubescence on the energy balance and on net photosynthesis in *Encelia*, the genus appears to be a model system for studying the possible adaptive significance of pubescence and its effects on plants along aridity gradients.

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References and Notes


11. *Papillation* data are from records of the U.S. Department of Commerce, Environmental Data Service.


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