ADAPTIVE VALUE OF LEAF HAIRS IN *Encelia farinosa*

James R. Ehleringer

The remarkable ability of leaves of *Encelia farinosa* to reflect visible radiation (400–700 nm) was reported last year (*Year Book 75*, pp. 413–418). These high reflectances were the result of an unusually thick layer of leaf hairs surrounding the leaf tissue on both upper and lower surfaces. It was reported last year that the presence of this pubescence reduced the net photosynthetic rate because light that would otherwise be used in the carbon fixation process was being reflected from the leaf surface. The lower photosynthetic rate may be disadvantageous to plants growing in highly competitive, light-limited environments. On the other hand, the reduced heat load on the leaf resulting from the presence of the pubescence will result in a lower rate of transpiration and lower leaf temperature, which can be beneficial in a hot, arid environment.

Investigations over the past year have centered on the following: (1) the effects of leaf pubescence on leaf-energy balance, (2) the effects of temperature on photosynthesis in *Encelia*, and (3) the trade-offs arising in the physiological processes of photosynthesis and transpiration because of the presence of leaf hairs. It was hoped that from the experiments of this year and last year and by means of trade-off analysis an understanding of the adaptive significance of the leaf hairs could be reached.

Measurements of absorptance to total solar radiation (300–4000 nm) were made with an integrating sphere on *E. farinosa* leaves which varied from light to heavy pubescence. The solar absorption coefficients (α) were found to vary dramatically from 46% in the lightly pubescent leaves to 16% in the heavily pubescent leaves. The typical absorption coefficient of green leaves is 50% (Birkebak and Birkebak, 1964). As a consequence of this low absorption, pubescent *E. farinosa* leaves will be under a much lower heat load than green, glabrous leaves.

An energy-budget analysis (Raschke, 1960; Gates, 1965) of the effect of the lower leaf absorptance on leaf temperature reveals that a heavily-pubescent leaf ($\alpha = 16\%$) may have a leaf temperature 5.9°C lower than a green leaf ($\alpha = 50\%$) under typical midday desert spring conditions. The actual leaf temperatures predicted are 30.1° and 36.0°C for an air temperature of 30°C, and a leaf-conductance to water loss of 0.2 cm sec^{-1}. Assuming this leaf conductance and an atmospheric water-vapor density of 10 g m^{-3}, the pubescent leaf will lose water at a rate 35 percent slower than the glabrous leaf. In hot, arid climates, this saving in water may allow the pubescent-leafed plant to extend its period of activity into the drought periods.

The temperature dependence of light-saturated photosynthesis was measured in *E. farinosa* with the mobile laboratory facilities (*Year Book 72*, pp. 393–403). From these experiments it is clear that *E. farinosa* has a photosynthetic temperature optimum at 25°C. The temperature optimum does not vary with time of year or degree of leaf pubescence. Leaves of *E. farinosa* are able to photosynthesize at high air temperatures in their native habitats, even though they have a low temperature optimum because the pubescence allows the leaf temperature to be lower than that of the air. The pubescence also allows the leaf to maintain temperatures below the level that would be lethal if the leaf heat load were that of a green, glabrous leaf.

Along with these benefits, the leaf hairs bring the disadvantage of increased light reflection, which reduces the photosynthetic rate. To assess the overall value of the leaf hairs, a trade-off analysis was conducted. The analysis used a leaf energy-budget–photosynthesis model (Ehleringer and Miller, 1975) to ask the following question: For any given environment, defined by air temperature and aridity, what amount of leaf pubescence will maximize the carbon-gaining capacity of the leaf? The analysis assumes that if leaf pubescence is adaptive, then it should provide a greater carbon-gaining capacity for the leaf, thereby increasing plant performance in any environment in which it is adaptive.

The results of the trade-off analysis show that the degree of pubescence yielding the highest carbon-gaining capacity varies with environmental conditions (Fig. 96). If water is freely available (leaf conductance 1.0 cm sec^{-1}), the optimal leaf will be lightly pubescent (absorptance around 80%) until air temperatures reach 40°C. Above 40°C air temperature, the optimal leaf absorptance will decrease. If the aridity of the environment increases (that is, if leaf conductance decreases), optimal leaf pubescence will be greater at air temperatures below 40°C.

The model predicts that the optimal degree of pubescence should vary with environmental conditions. An *E. farinosa* leaf should become more pubescent when the decline in photosynthesis resulting from increased leaf reflectance is less than the decline due to increased leaf temperature.

Two predictions from the model are evident in the field observations. First, leaves should become more pubescent as the season progresses and air temperatures increase. This is clearly the case from the seasonal courses of leaf absorptances (*Year Book 75*, Fig. 28, p. 416). Second, as aridity increases, the leaf absorptances should decline. The field correlation between absorption coefficient and precipitation corroborates this prediction (*Year Book 75*, Fig. 29, p. 417).

The integration of the effects of leaf pubescence on plant physiological per-

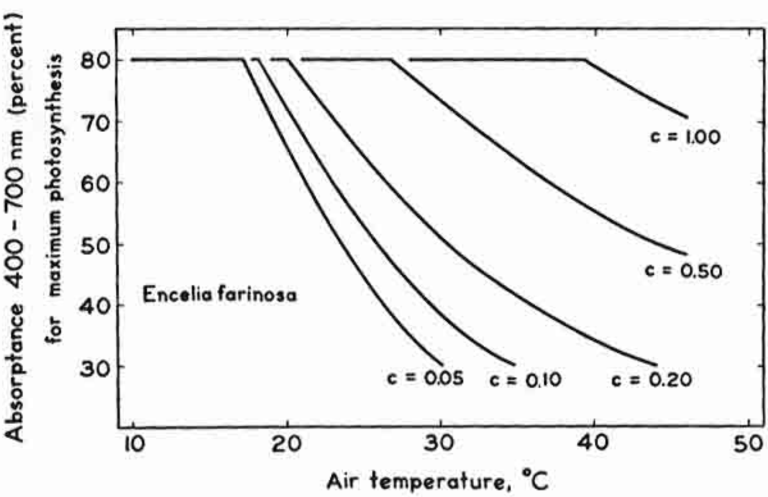

Fig. 96. Predicted optimal leaf absorptances for *Encelia farinosa* for various combinations of air temperature and aridity. Aridity is represented by the leaf conductance to water loss in cm sec^{-1}. Simulation uses typical values for midday solar radiation, wind speed, and water vapor density.

formance and carbon-gaining capacity via the model show that leaf hairs are an adaptive feature in *E. farinosa*. With the pubescence, the plant is able to maintain a greater carbon-gaining capacity. Without the pubescence, the leaf would be unable to survive the high temperatures of its native habitat.

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