The effect of leaf texture on water retention on Urticaceae leaves

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Abstract: Plants in high moisture environments, such as the tropical cloud forest of Monteverde, Costa Rica, often have smooth or waxy leaf surfaces that allow them to shed excess water. In contrast, plants of the family Urticaceae have hairy leaves, presumably as a defense against herbivory. However, we found that hairy leaves of this family are also effective at retaining more water than smooth leaves. We also found a higher abundance of Urticaceae plants at high elevation than at low elevation. This may be due to a trade-off between herbivore defense and water load, or greater light availability at high elevation.

Key Words: herbivory, leaf morphology, tropical cloud forest

INTRODUCTION

Excess water on leaf surfaces can reduce transpiration (Richards 1981), photosynthetic ability (Lightbody 1985), and the rate of nutrient uptake (Leigh 1975). Water retained on leaves can encourage epyphyllic growth (Richards 1981). In addition, excess water may add sufficient weight to damage a plant. Thus, high moisture conditions such as those experienced by plants in tropical cloud forests can be detrimental. Leaves have developed many strategies to shed water from their surfaces, including drip tips (Dean and Smith 1978), deep venation, and waxy surfaces.

Plants in the Urticaceae are characterized by stinging hairs on their leaf surfaces, which aid in deterring herbivores, but may be disadvantageous in a high moisture environment, such as the Monteverde cloud forest. Cloud cover, mist input, and precipitation levels generally increase with elevation and exposure to trade-winds (Nadkarni and Wheelwright 2000). We predicted that hairy Urticaceae leaves would retain more water than smooth leaves. We also predicted that there would be fewer Urticaceae plants at high elevation than at low elevation, due to the increased costs associated with water retention.

METHODS

We conducted our study on 21 January 2003 at the Monteverde Biological Station, Costa Rica. We collected three leaf types: 15 Urticaceae leaves from high elevation (~1800 m), 15 Urticaceae from low elevation (~1540 m) and 15 smooth leaves of similar size and shape to the Urticaceae from approximately six different species. We did not distinguish among Urticaceae species in our sampling.

We determined hairiness of each leaf type by calculating the average number of hairs/cm^2 from five leaves of all three leaf types. We used a 1 cm^2 grid system to measure the approximate area of each Urticaceae and smooth leaf.

We measured relative water retention of each leaf type by mounting each leaf on a clipboard at an angle of 45°, spraying the leaf surface five times with a spray bottle and waiting 15 s for water to drain. We calculated water retention as the difference between wet and dry mass, divided by leaf area. To determine whether hairiness influenced water retention we used a one-way ANOVA. We used Tukey-Kramer post hoc comparison of means to determine differences among leaf groups. We also compared water retention to hairiness of each leaf and analyzed the relationship with a linear regression.

We established five 20 m transects at both high elevation (1795-1810 m) and low elevation (1535-1545 m), choosing areas with relatively constant elevation along the main trail. We counted the number of Urticaceae plants within 0.5 m on either side of each transect. We kept our elevation constant by taking altimeter readings at the beginning and end of each transect. We calculated the mean density of plants per m^2 at each elevation and tested for a difference using a Student's t-test.

RESULTS

High elevation Urticaceae leaves had greater hair density [124.8 ± 3.4 hairs/cm^2 (mean ± SE)] than low elevation Urticaceae leaves (24.8 ± 3.4) or smooth leaves (0.0).

High elevation Urticaceae leaves retained significantly more water on their surfaces [74.5 ± 2.8 mL water/m^2 (mean ± SE)] than either the low elevation Urticaceae leaves (43.8 ± 2.8) or smooth leaves (35.3 ± 2.8) (Fig. 1; $F = 54.38$, $df = 2$, $P < 0.001$). High elevation Urticaceae water retention was higher than both low elevation Urticaceae and smooth leaves, but there was no significant difference between low elevation Urticaceae and smooth leaves (Tukey-Kramer HSD $\alpha = 0.05$). Hairiness explained 64% of the variation in water retention among leaf types (Fig 2; $df = 13$, $P < 0.001$).

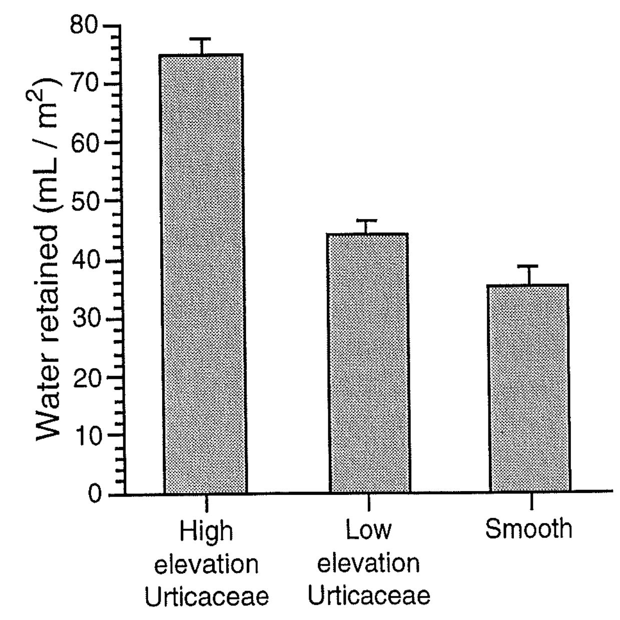

FIG. 1. Water retention (mean ± SE) on leaf surfaces of three different leaf types in Monteverde, Costa Rica. Water retention = (Wet mass - dry mass) / (Surface area of leaf).

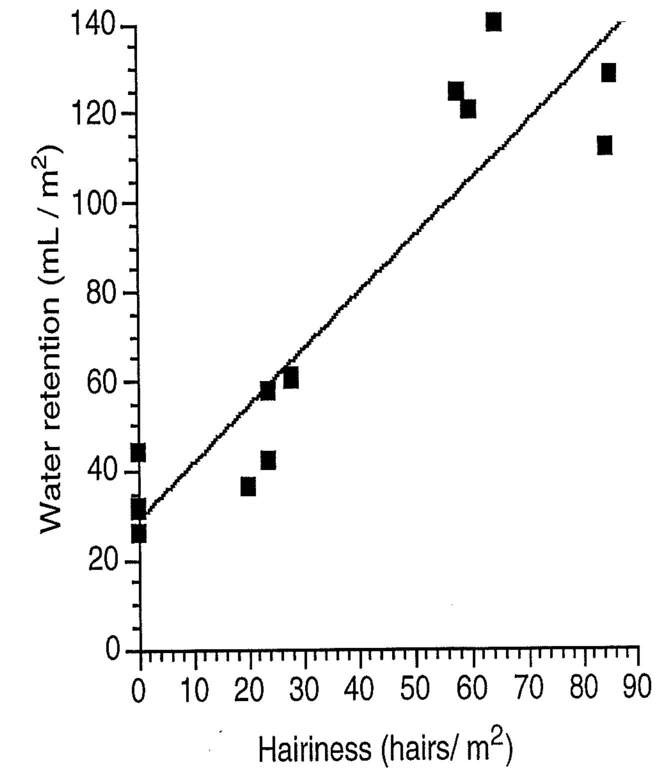

FIG. 2. Water retention as a function of leaf hairiness in Monteverde, Costa Rica.

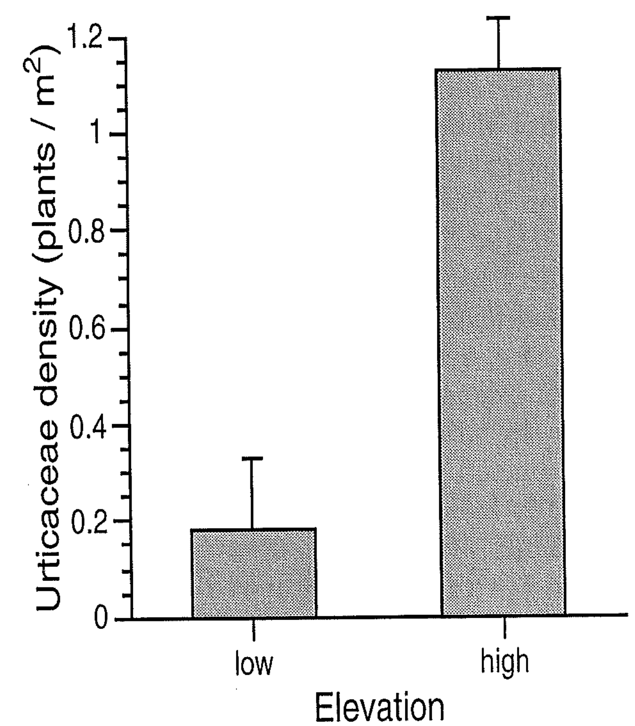

FIG. 3. The number of plants per m^2 (mean ± SE) at low elevation (~1500 m) andhigh elevation (~1800 m) in Monteverde, Costa Rica.

We found that the density of Urticaceae plants was significantly greater at our high elevation site [1.03 ± 0.15 plants/m^2 (mean ± SE)] than our low elevation site (0.18 ± 0.10 plants/m^2) (Fig. 3; $t = 3.49$, df = 8, $P = 0.01$).

Discussion

The hairier, high elevation Urticaceae leaves held significantly more water than the low elevation Urticaceae leaves or the smooth leaves, supporting our prediction. The low elevation Urticaceae did not retain significantly more water than the smooth leaves. However, across all leaves tested, the amount of water retained was proportional to the number of hairs/cm^2 (Fig. 3). The water retained on the leaf surface may stress the physical structure of the plant, by bending or breaking leaf petioles. Leaves may compensate for the extra weight of retained water by developing a stronger petiole structure.

Contrary to our prediction, we found higher densities of Urticaceae plants at high elevation than at low elevation. This may be due to increased wind exposure at high elevations (Nadkarni and Wheelwright 2000) that may increase evapotranspiration rates, dry leaf surfaces, and reduce the need for an efficient water shedding system. Therefore, despite higher precipitation and greater exposure to clouds at high elevation, water shedding may not be as important as we expected. Additionally, Urticaceae are typically fast-growing, high light demanding plants. Therefore, their abundance may depend primarily on light availability. Our high elevation site had more light gaps, which may permit higher abundances of these fast-growing species.

The hairs on Urticaceae also protect the leaves from herbivory. Therefore, there may be a tradeoff between defense against herbivory and the plant's ability to shed water. Hairy Urticaceae leaves may be better competitors at exposed high elevations, if herbivore pressure is high. We suggest that further studies investigate the relationship between how herbivory, plant structure and water retention affect distributional patterns.

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