

## Measuring the Contact Area on Lotus and Rice Leaves by using Image Analysis

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This research work describes an image analysis technique for measuring the contact area of papillose epidermal cells (PEC) and epicuticular wax (EW) of lotus (*Nelumbo nucifera*) and rice (*Oryza sativa*) leaf with water drops. These leaf surfaces are superhydrophobic, which means that their static contact angles are greater than 150° and their sliding angles (SA) are less than 10° [1]. It is the well-known “Lotus effect” [2]. A water drop on a superhydrophobic self-cleaning surface is like a fakir on his bed of nails, the contact area between the water drop and the underlying solid is considerably reduced, resulting in very low adhesion forces. These drops are known as “fakir droplets” (figure 1) [3]. The surface of the lotus leaf is uniformly textured with 10 µm size protrusions or bumps (figure 2). Superposed we find a dense epicuticular wax layer which is a second scale of texture generally submicrometric. The wax crystals have a tubule shape (figure 3). Similar case occurs with rice leaves but the difference is that the wax crystals have a platelet shape. As the water drops sits on the top of protrusions and epicuticular wax (i.e. figure 1), I decided to measure the area which is in contact to the water drop using an image analysis technique. ESEM images of lotus and rice leaves were obtained at two different magnifications. One at a low magnification (2400x) to see a good number of epidermal cells (i.e. figure 2) and one at a higher magnification (50000x) to get only epicuticular wax crystals (i.e. figure 3). The contact area would be the white regions of these images, which are equivalent to the higher regions of the topography. The percentage of the total contact area of the digitized images was calculated using the JMicroVision 1.22 software. A minimum gray level ( $U_{\min}$ ) was chosen manually. For selecting this value, which would depend on the image studied, an interactive property of the JMicrovision software was used. This property permits to see how much contact area is being covered as the  $U_{\min}$  value is modified. In many cases, the  $U_{\min}$  value corresponds to inflexion points of the spectral curve of the image analyzed. So, all the objects which had a gray level between the  $U_{\min}$  and the  $U_{\max}$  (255 units, completely white) were considered the areas where the drop sat. In the present case the  $U_{\min}$  values were between 150 and 160 units. Figure 4 shows the contact areas (red line boundaries) for the lotus leaf seen in figure 2, using  $U_{\min}$  equals to 160 units. After the  $U_{\min}$  value was selected and the total contact area calculated, two new gray level minima different in  $\pm 5$  units from the first one were considered. Using these two new levels, two new contact areas were calculated. These values gave us the possibility of estimating the error made as a function of the  $U_{\min}$  chosen. Table I shows the contact areas obtained after analyzing lotus and rice ESEM images at two different magnifications. It is worth noticing that similar contact areas are found between PEC and EW for the same species, which probably means that a fractal concept is underneath the two scales of texture. These are preliminary studies on two species. The next step is to extend these analyses to more species and in a more complete way.

### References

- [1] Z. Guo and W. Liu, Plant Science. 172 (2007) 1103-1112.
- [2] A. Solga et al. Bioinsp. Biomim. 2 (2007) S126-S134. [3] D. Quéré. Nat. Mater. 1 (2002) 14-5

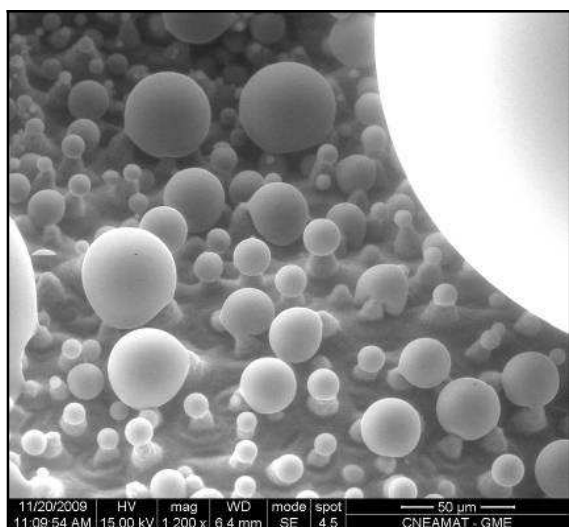


Figure 1. ESEM image of a Lotus leaf with water micro-drops on its surface.

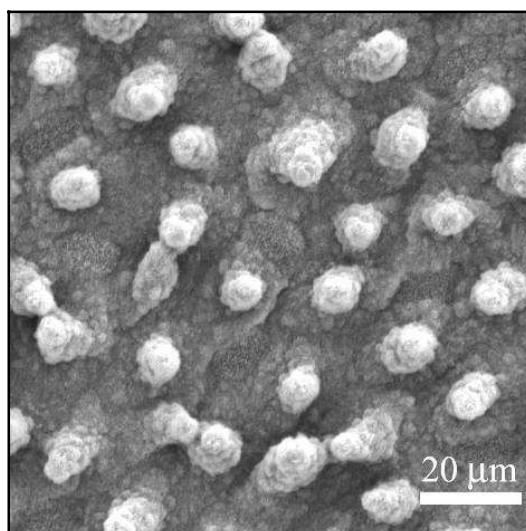


Figure 2. ESEM image of a lotus leaf (2400x). Papillose cells are seen.

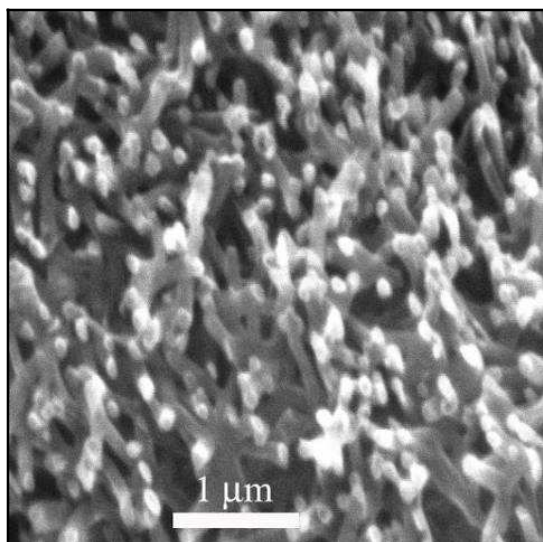


Figure 3. ESEM image of a lotus leaf (50000x). The epicuticular wax is observed.

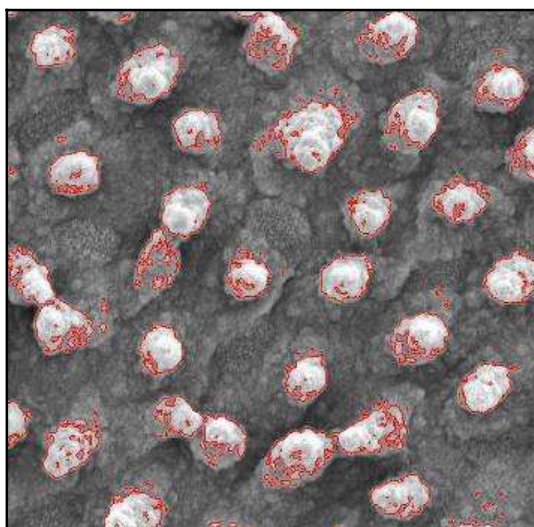


Figure 4. Red line boundaries show the contact area considered in figure 2.

Table I: Contact Area values. PEC: papillose epidermal cells. EW: epicuticular wax.

Species	Contact Area (%)	
	PEC	EW
Lotus ( <i>Nelumbo nucifera</i> )	18 ± 3	17 ± 4
Rice ( <i>Oryza sativa</i> )	22 ± 3	16 ± 4