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MeBiOS

Leaf surface topography affecting the dynamic impact behaviour of spray droplets

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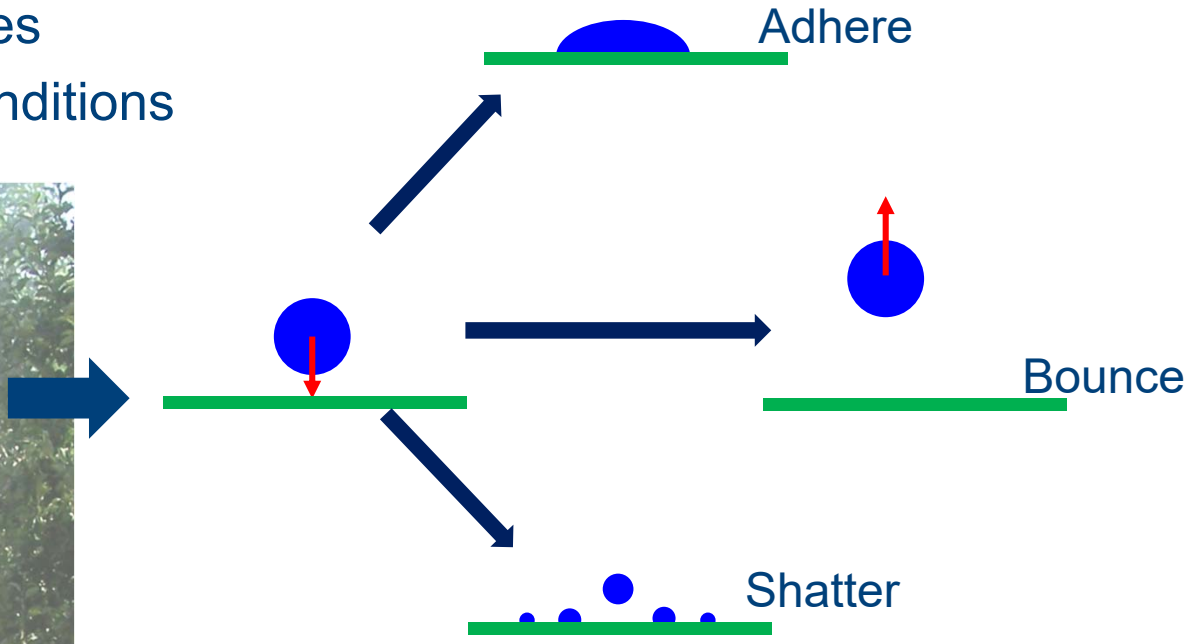
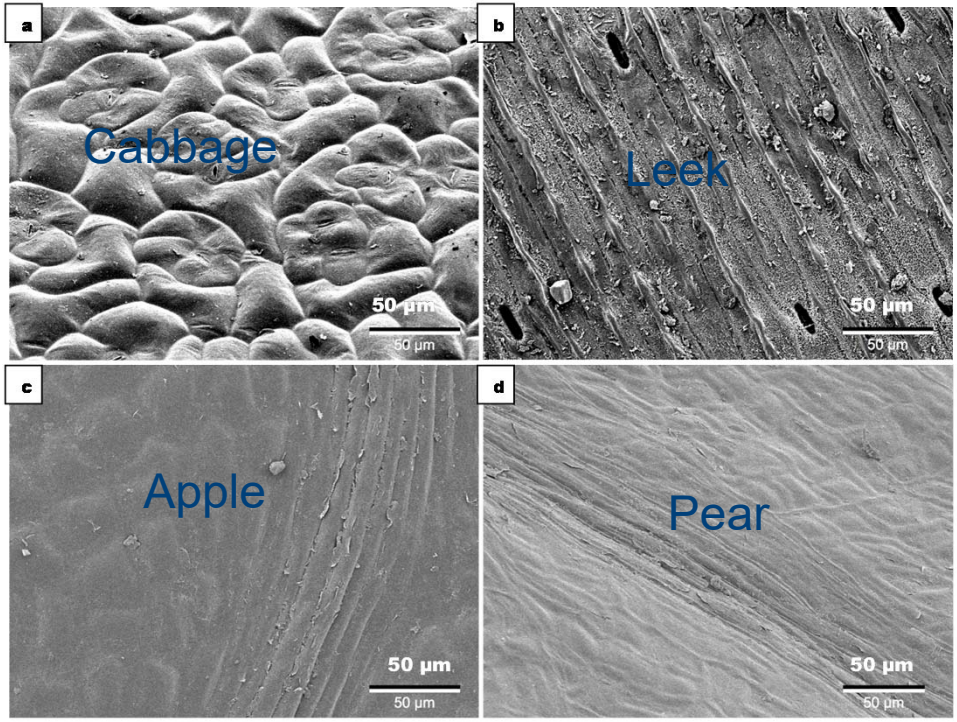
- Spraying
  - Application system
  - Liquid formulation
  - Surface properties
  - Micro climate conditions



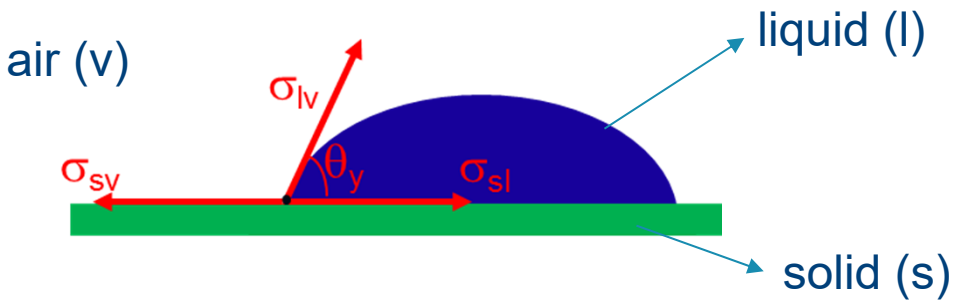
- Leaf surface topology



Scanning electron microscopy

Surface roughness and contact angle

- Young equation describes the balance at the three-phase contact of solid, liquid and vapor:



$$\sigma_{sv} = \sigma_{sl} + \sigma_{lv}\cos(\theta_y)$$

- Idealised surface: homogeneous and smooth

Surface roughness and contact angle

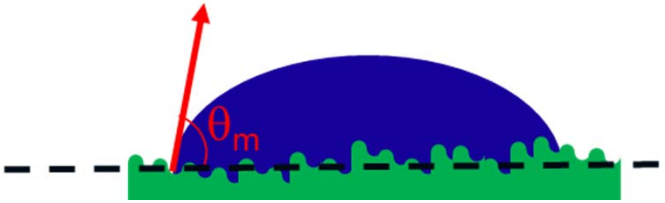
- Real surface

$$\theta_m \neq \theta_y$$

- Wenzel regime

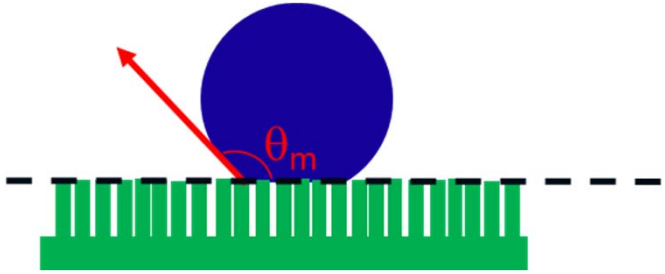
$$\cos(\theta_m) = r.\cos(\theta_y)$$

$$r = \frac{actual\ area}{\text{projected } area}$$



- Cassie-Baxter regime

$$\cos(\theta_m) = a_f \cos(\theta_y + 1) - 1$$



a_f, fraction of liquid area that is in contact with the solid

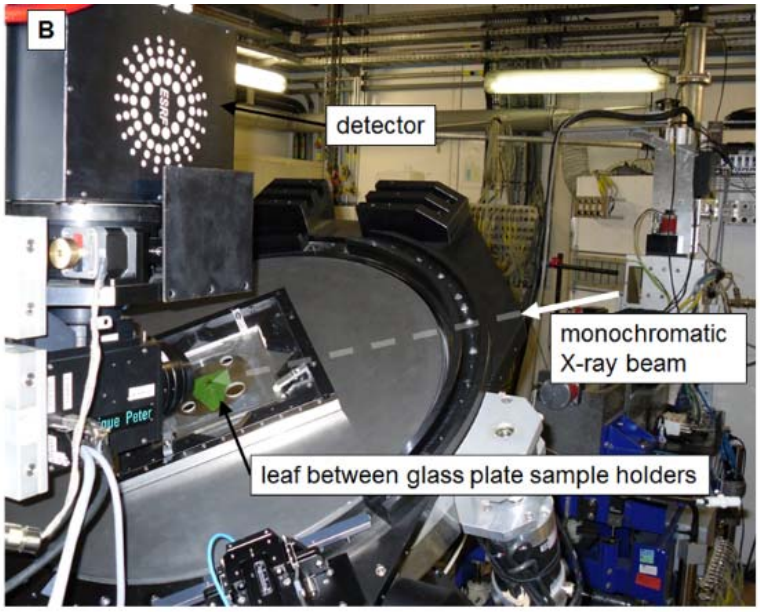
Objective

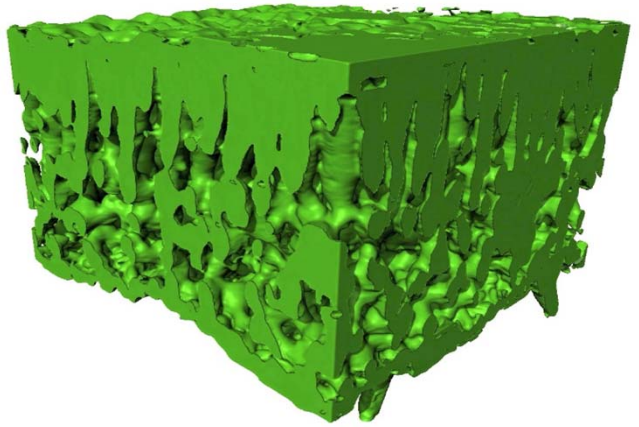
- To apply a Volume-of-Fluid CFD model for verifying
  - the effect of leaf surface topography
  - on the dynamic impact behaviour of the spray droplets on leaves
  - compared to idealised flat surfaces

(Delele et al., Soft matter, 2016)

Surface topology of leaf surface

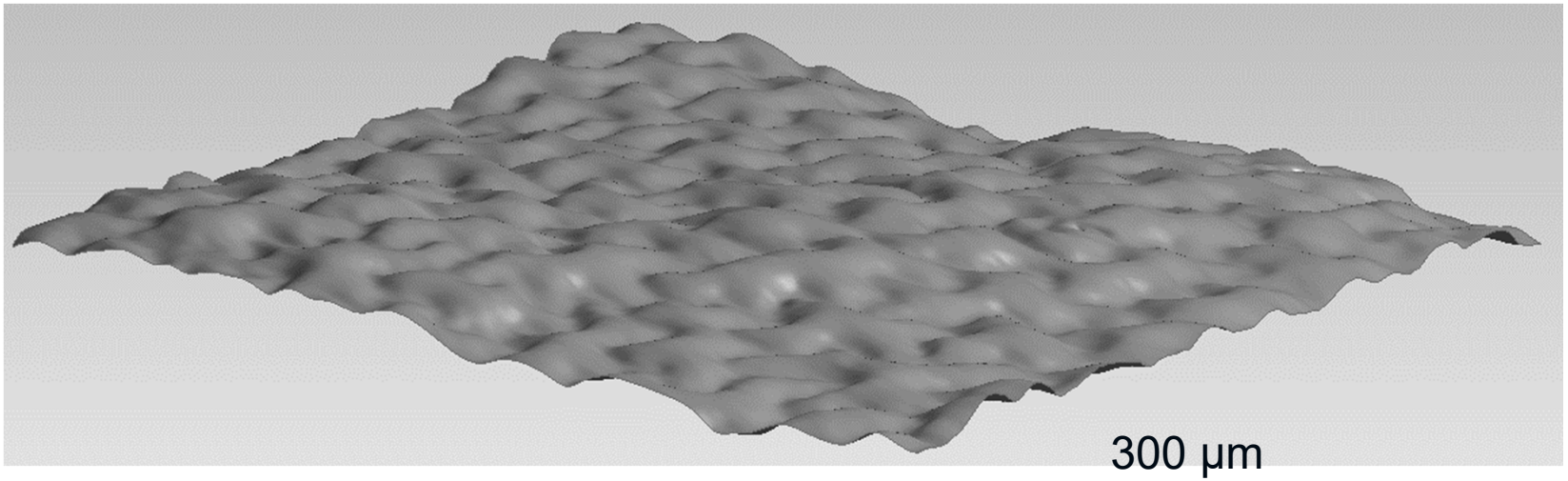
- X-ray computed laminography (ESRF, Grenoble, France)
  - 3D leaf imaging
  - 0.75 µm resolution





Model parameters

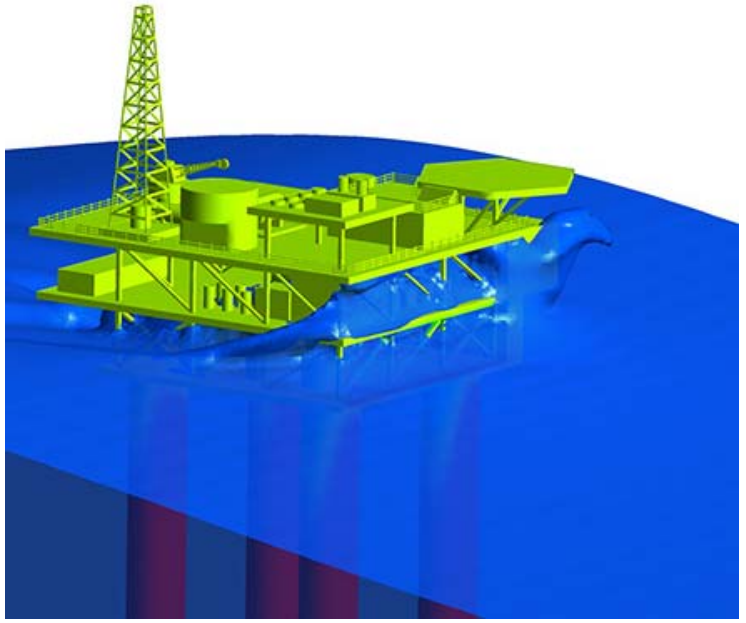
- Contact angle = 97.9º



Volume-of-Fuid modeling

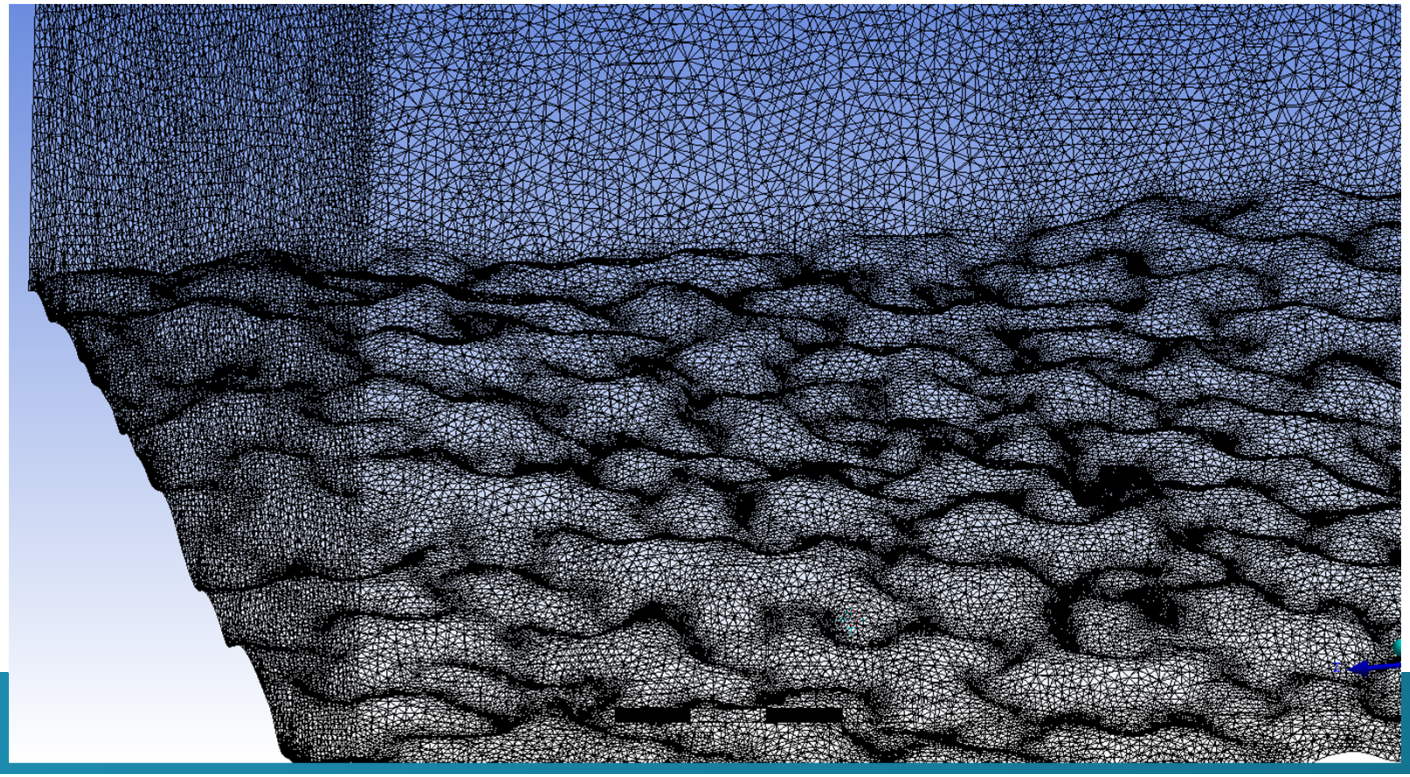
- Equations for flow of mixture of 2 fluids (air and liquid) depending on fraction of each
- Track position and shape of free surface using surface tension model
- Solve on a discrete mesh

0	0	0	0
0,75	0,4	0,05	0
1	1	0,3	0
1	1	0,4	0



Model solution

- Ansys Fluent 17.2
- 1-30 µm mesh size, 5.4 million elements
- Time step $1e^{-7}$s
- 64-bit, Intel® Core™ i7-4790 CPU, 3.60 GHz, 32 Gb RAM



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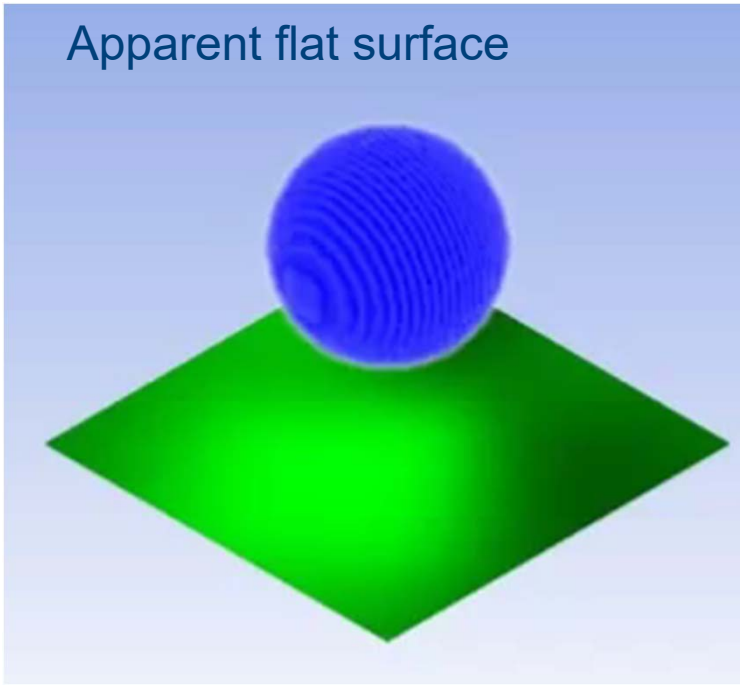
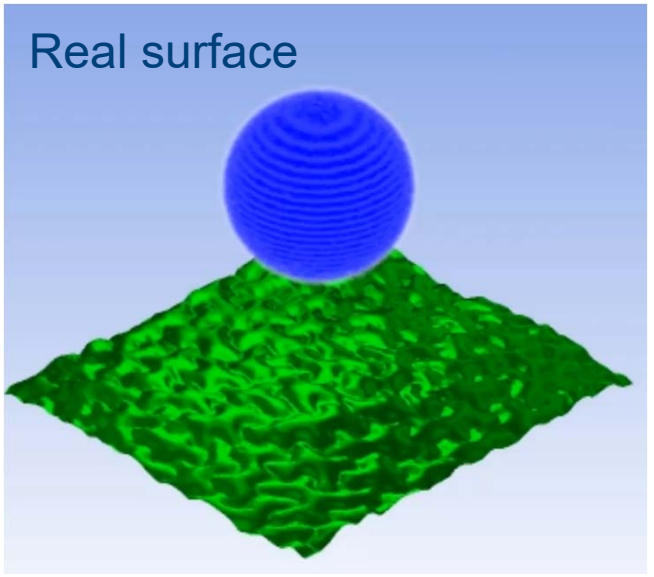
Results

- 200 µm and 2 m/s $\mathrm{We} = \frac{\rho D V^2}{\sigma} = 11$

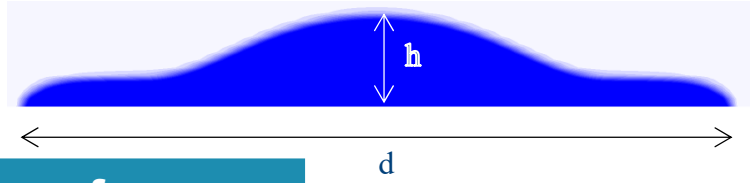




300 µm

- θ_m = 97.9°
- r = 1.57
- θ_y = 95.1°

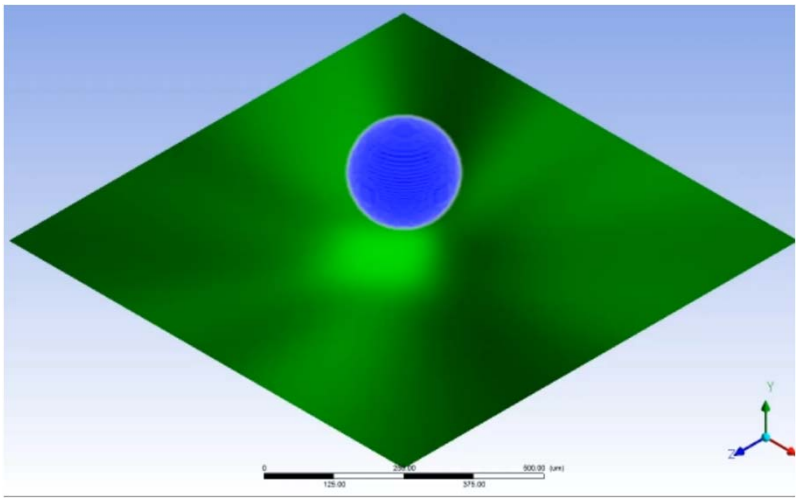
- Comparison



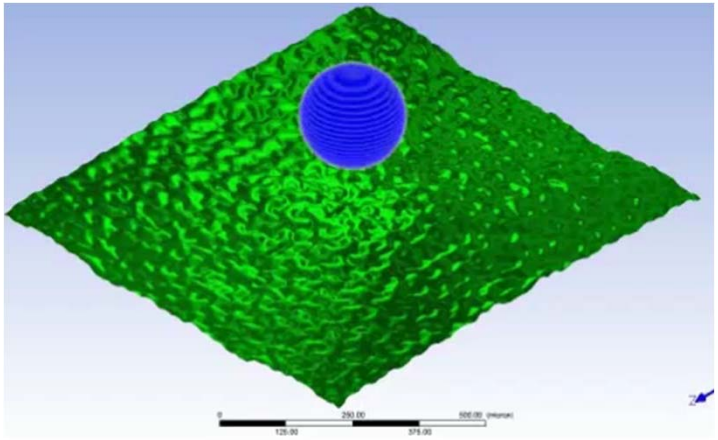
Parameter	Flat surface	Real surface
Symmetry	Yes	No
Maximum spread factor ($\frac{d}{D}$)	1.9	1.6
Maximum recoiling height ($\frac{h}{D}$)	1.7	1.1
Outcome	Bounce	Adhere

- 200 µm and 10 m/s $\mathrm{We} = \frac{\rho D V^2}{\sigma} = 274$

Flat surface



Real surface

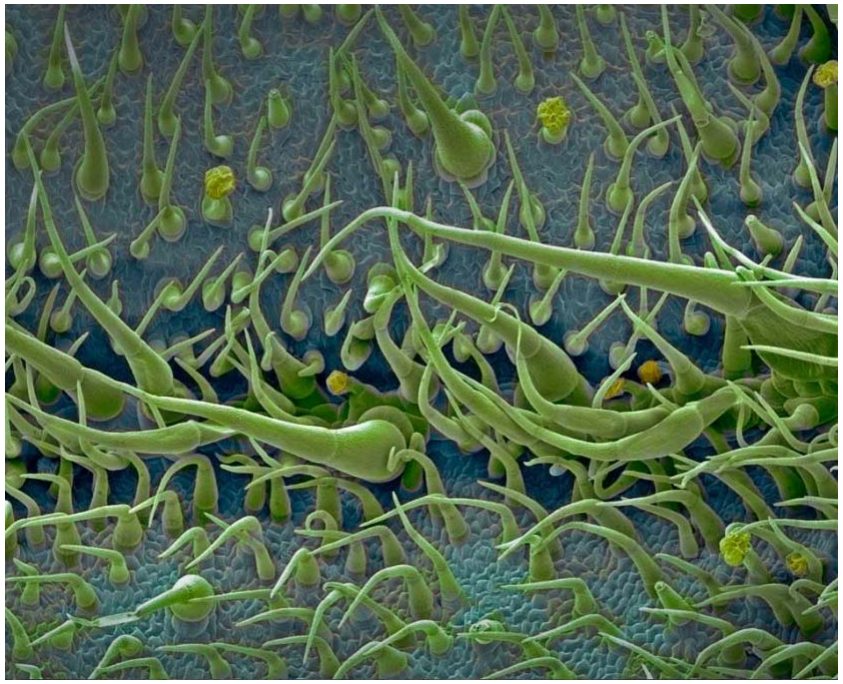


500 µm

- Comparison

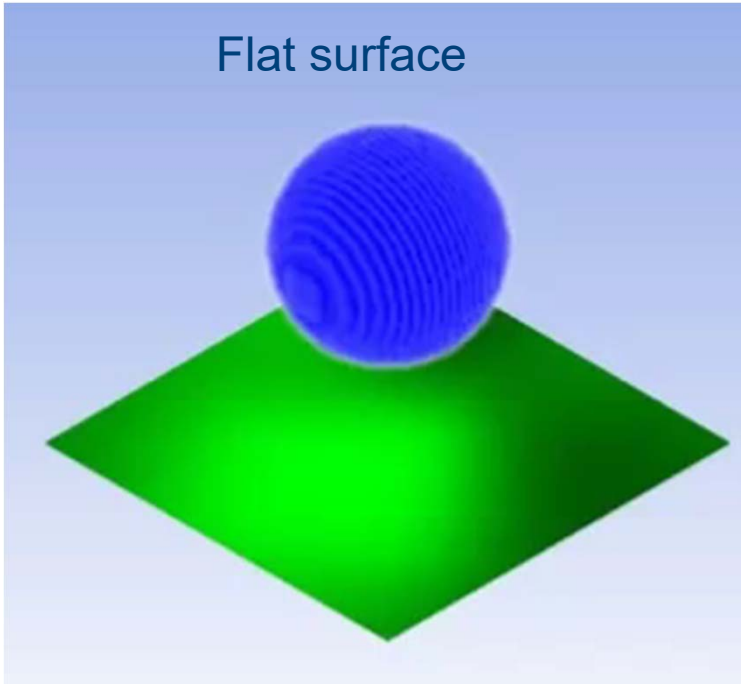
Parameter	Flat surface	Real surface
Fingers	Short	long
No of secondary droplets	17	25

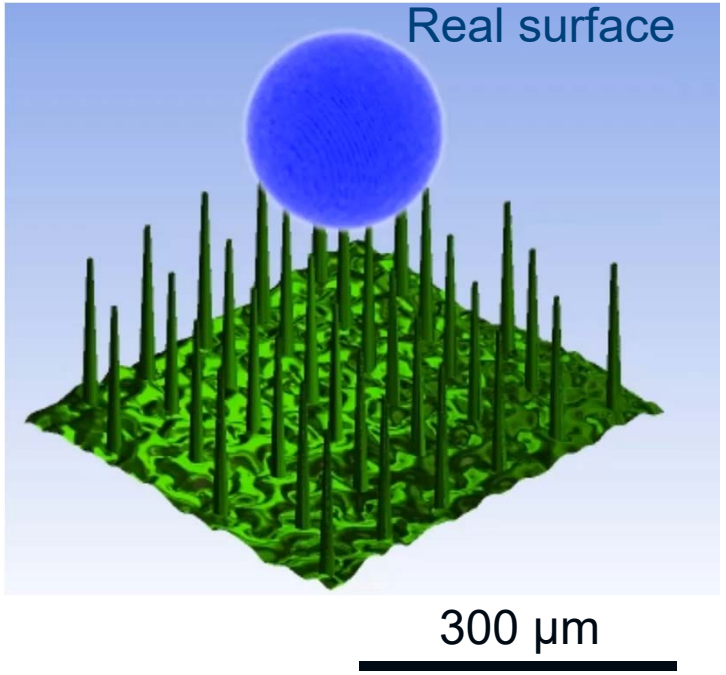
- Hair structures
  - Trichomes/hairs are fine outgrowths
  - 0.2-0.4mm
  - 149/mm^2



http://smartgrowtechnologies.com/tomatoe-trichomes/

- Leaf with hair structures
- 200 µm and 2 m/s $\mathrm{We} = \frac{\rho D V^2}{\sigma} = 11$

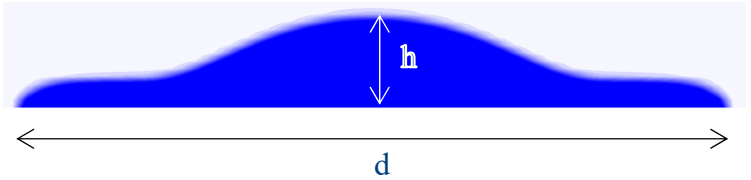




- θ_m = 97.9°

- r = 2.9
- θ_y = 92.8º

- Comparison



Parameter	Flat surface	Real surface without hair	Real surface with hair
Maximum spread factor ($\frac{\mathbf{d}}{\boldsymbol{D}}$)	1.9	1.6	1.3
Maximum recoiling height ($\frac{\mathbf{h}}{\boldsymbol{D}}$)	1.7	1.1	0.9
Outcome	Bounce	Adhere	Adhere

Conclusion

- Leaf surface topology has significant effect on drop impact
- Model leads to better understanding of impact
- Can be extended to include other factors
- The new knowledge will help in developing better spray deposition models
  - For use in computer aided design and optimization of spray application

Thank you