International Advances in Pesticide Application
9 January 2014 – Oxford

Session 6: On target deposition

Spray retention assessment combining high-speed shadow imagery and fluorescence techniques

Mathieu Massinon, Hassina Boukhalfa and Frédéric Lebeau
m.massinon@ulg.ac.be

gembloux agro bio tech

Université de Liège

Spray retention

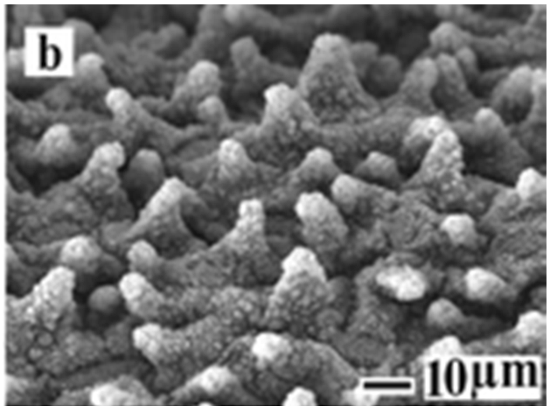
- Retention is mainly associated with droplet primary **adhesion,** while **bouncing** and **splashing** are seen as detrimental

- Impact outcomes depend on leaf surface and spray mixture properties

Leaf surface

- A **difficult-to-wet** leaf is simultaneously characterised by:
  - its **hydrophobic surface**: waxes render the surface hydrophobic
  - its **micro-topography** reducing the contact area available for droplets: veininess, hairiness: enhance the water repellency of the hydrophobic leaf surface

- Lotus effect: the water droplet static **contact angle** can exceed 150° = **superhydrophobicity**



Spray mixture

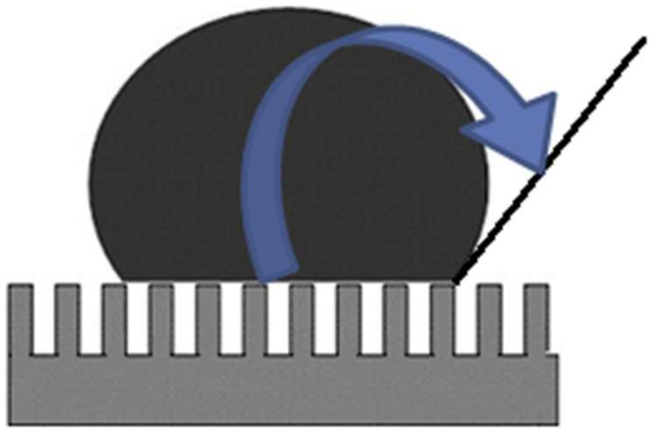
- On superhydrophobic species, **surfactants** are often used to enhance spray formulation performances by affecting the physicochemical properties of droplets, i.e. surface tension

- Surfactants are known to modify the **wetting behaviour** of the droplets on the leaf surface by increasing the spreading

- Dynamic surface tension = variation over time of liquid surface tension

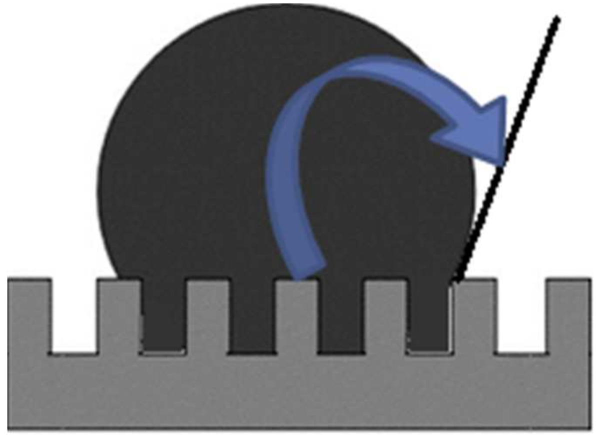
http://www.break-thru.com/

Wetting models



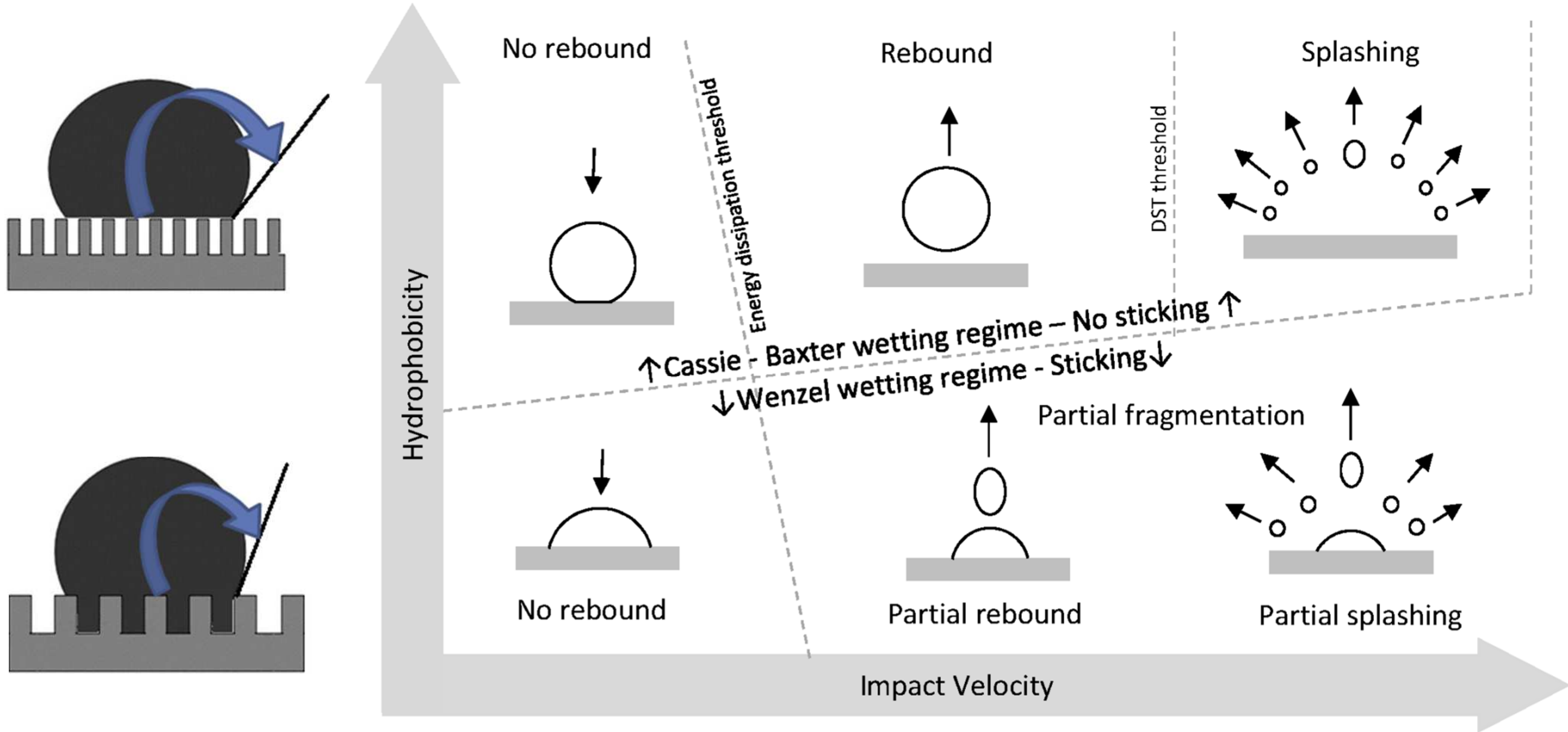
The **Cassie-Baxter** regime
(non-homogeneous wetting)

Extreme water repellency



The **Wenzel** regime
(homogeneous wetting)
=
pinning

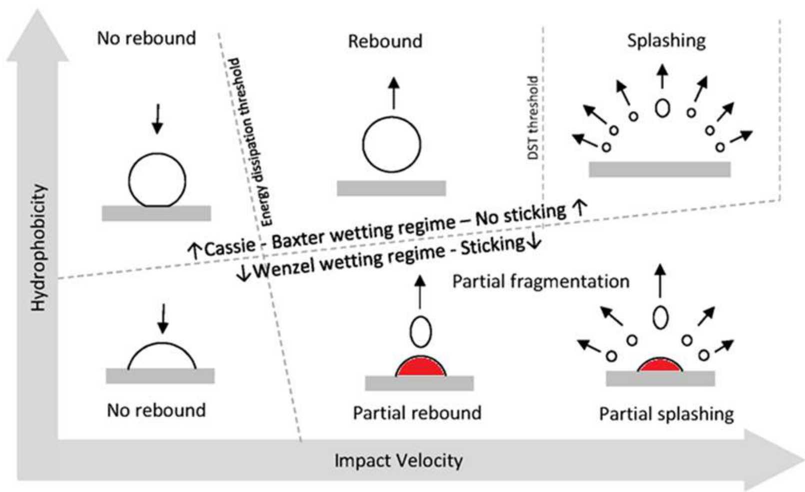
Possible impact outcomes



Transition from Cassie-Baxter to Wenzel wetting regime is possible because of high impact pressure and low DST

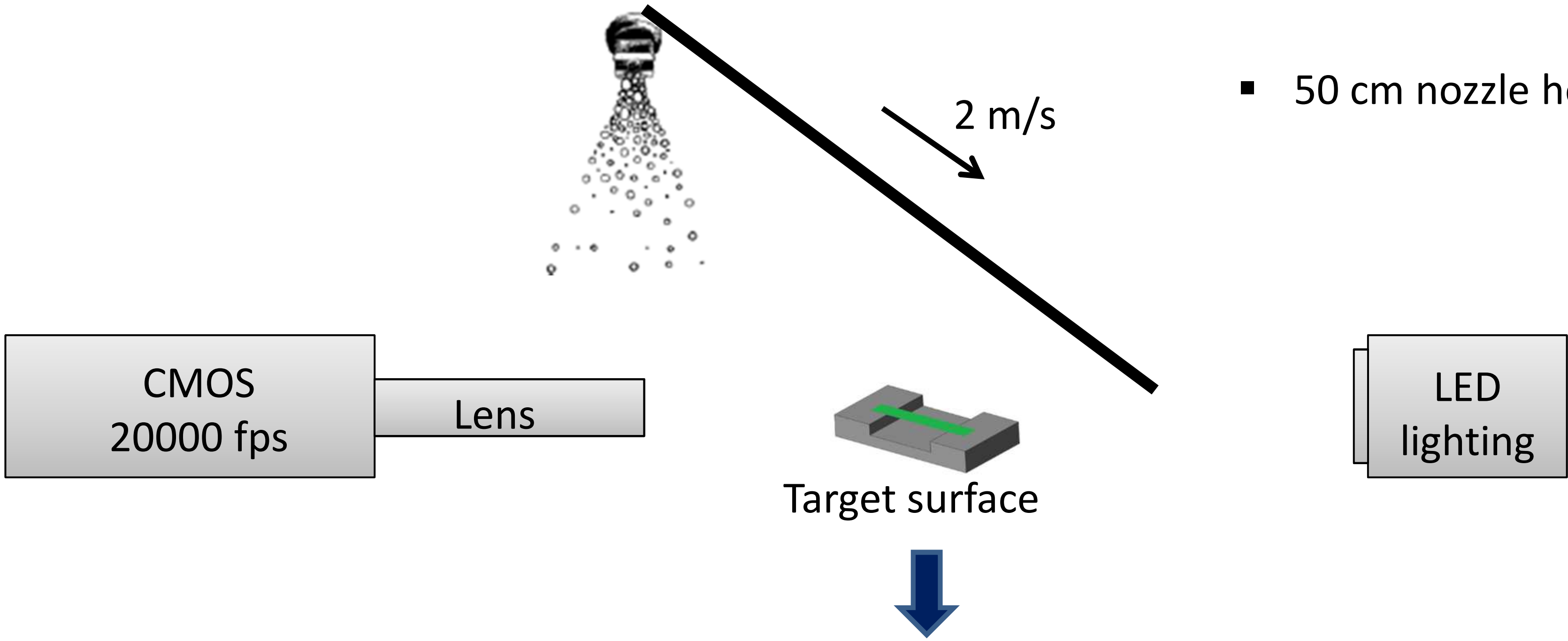
Objectives

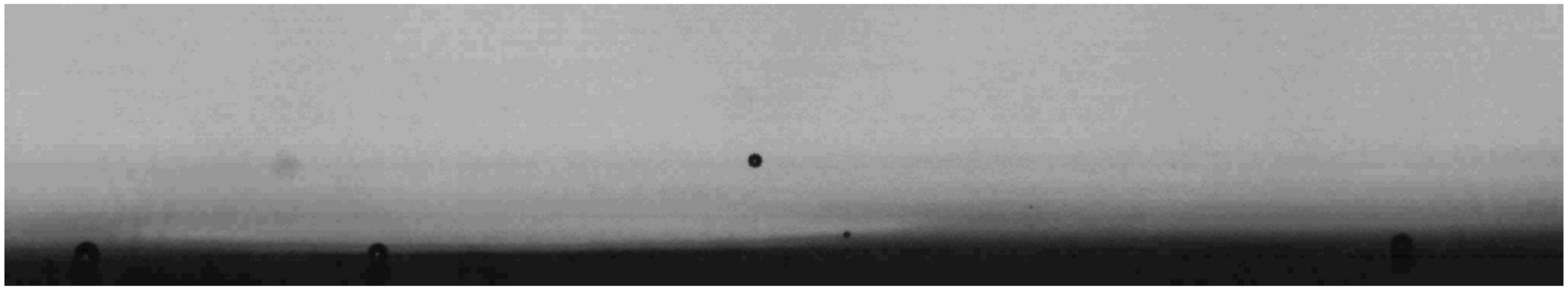
- The aims of the study are dual
  - Propose a **methodology** for characterising spray impact on leaves relying on the simultaneous observation of droplet impacts by high speed imaging and fluorescent tracer analysis of deposits
  - **Quantify** the amount remaining on a leaf after primary impact of droplets in Wenzel's wetting regime on horizontal barley leaves



Dynamic test bench

- 50 cm nozzle height

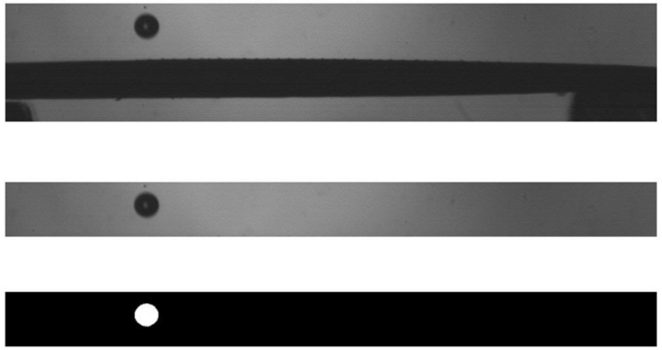




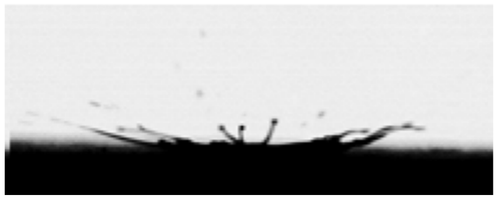
High speed imaging

image processing

1) Digital image: ROI above the leaf
2) Background soustraction
3) Image binarisation
4) Droplet detection and identification
5) Droplet size

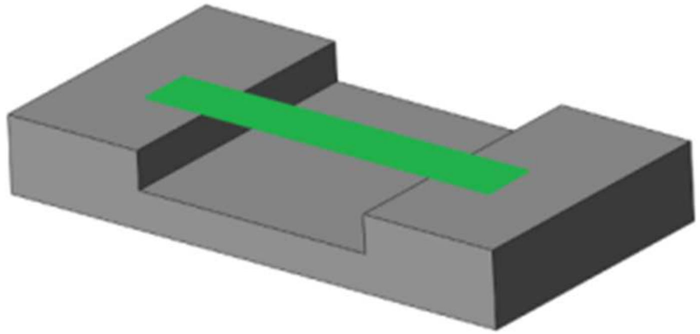


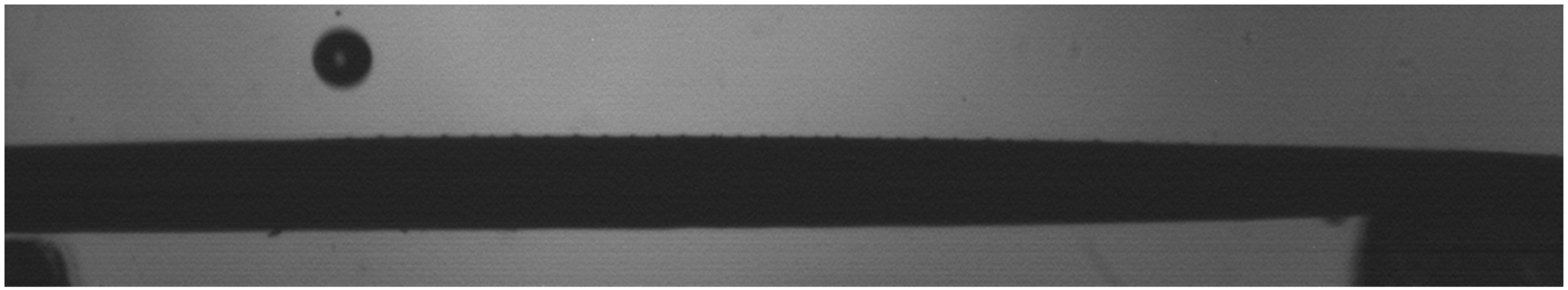
6) Droplet coordinates on 2 frames
7) Droplet velocity
8) Dimensionless Weber number *We* = $\frac{\rho V^2 d}{\sigma}$
9) Impact outcome identification according to the physical classification



Barley leaves

- Indoor grown
- Excised leaves: 10mm x 3mm

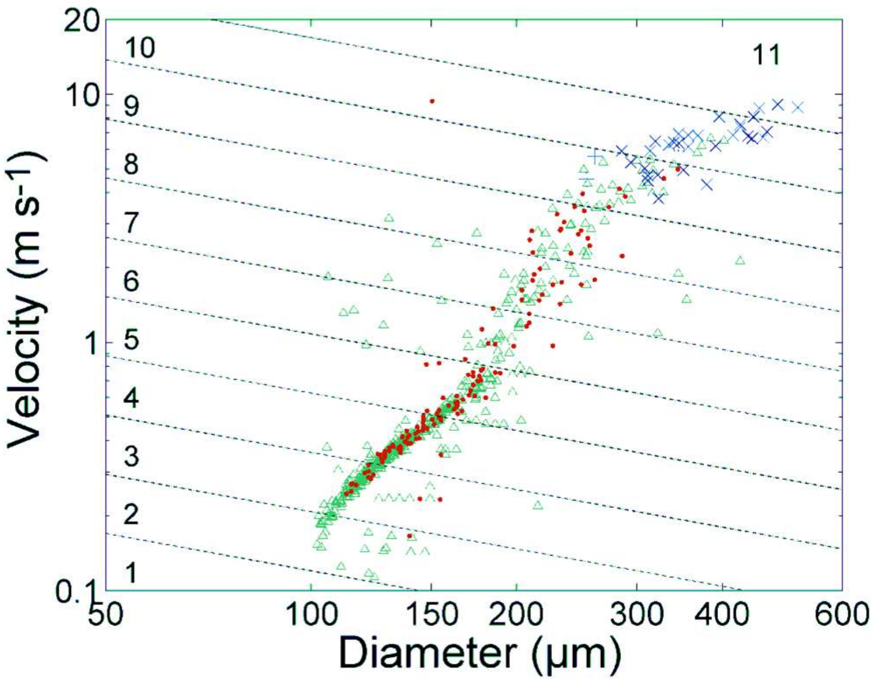


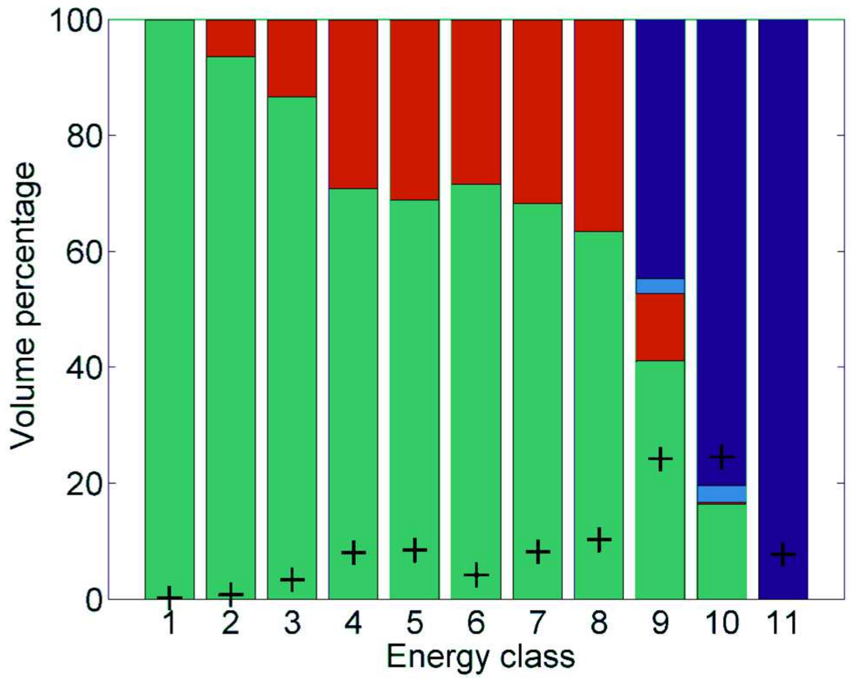


High speed imaging

data analysis: energy classes

- Tap water + 0.2g/L fluorescein on barley leaf
- XR11003VK @2bars 160 L/ha , 10 sprayings

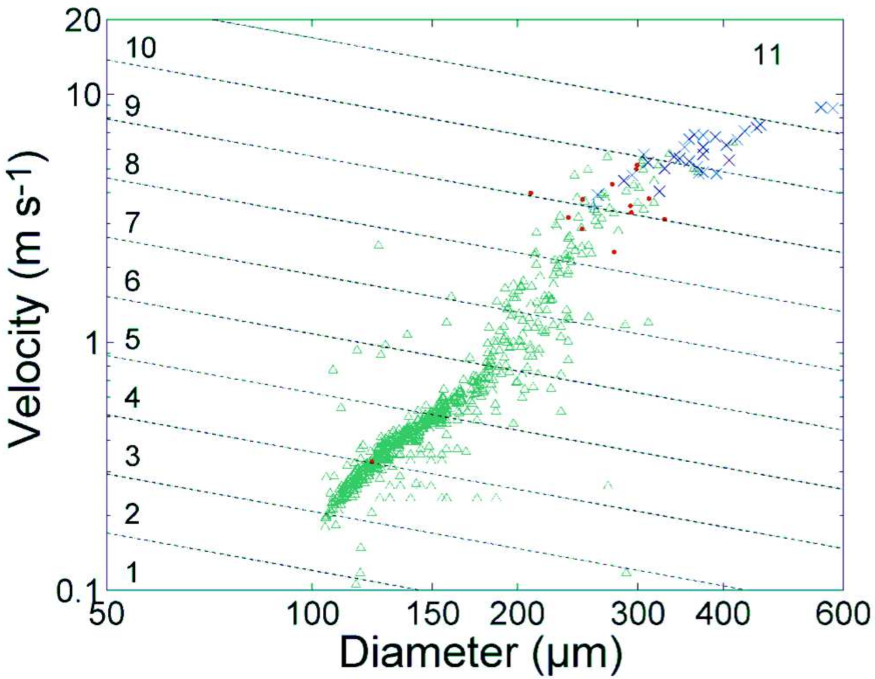


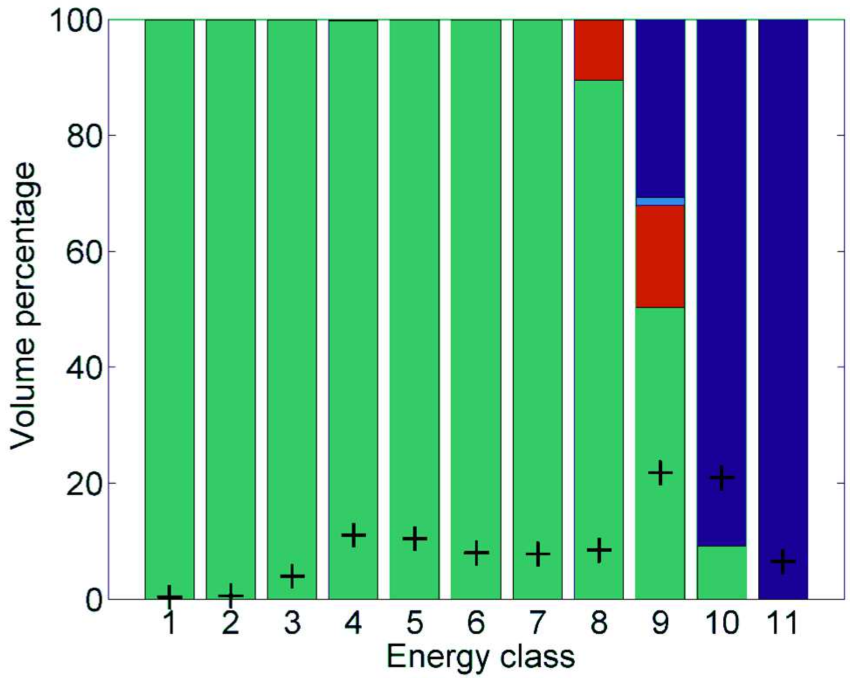


High speed imaging

data analysis: energy classes

- Tap water + 0.1%v/v Break-Thru S240 + 0.2g/L fluorescein on barley leaf
- XR11003VK @2bars 160 L/ha, 10 sprayings

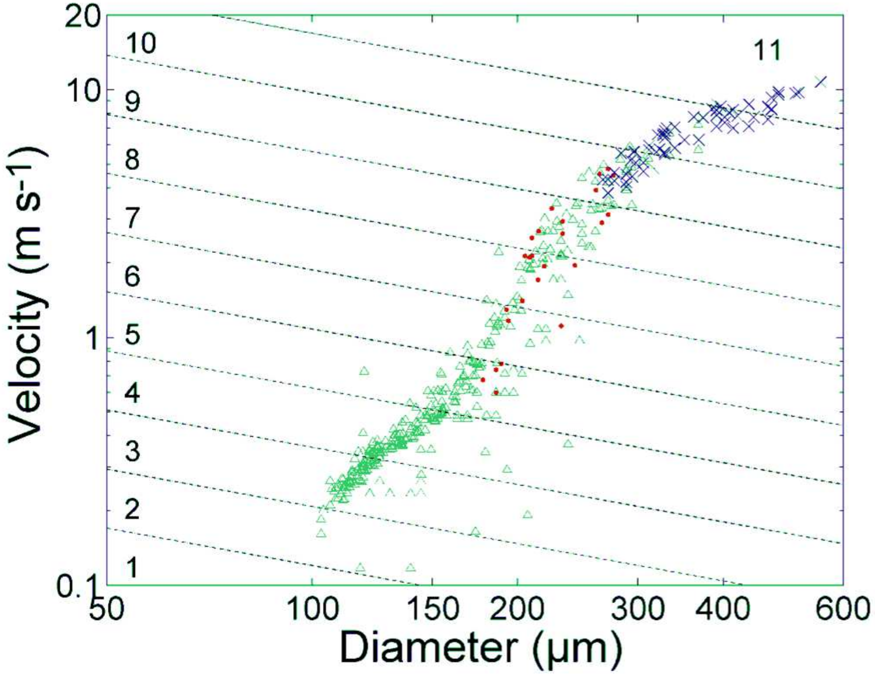


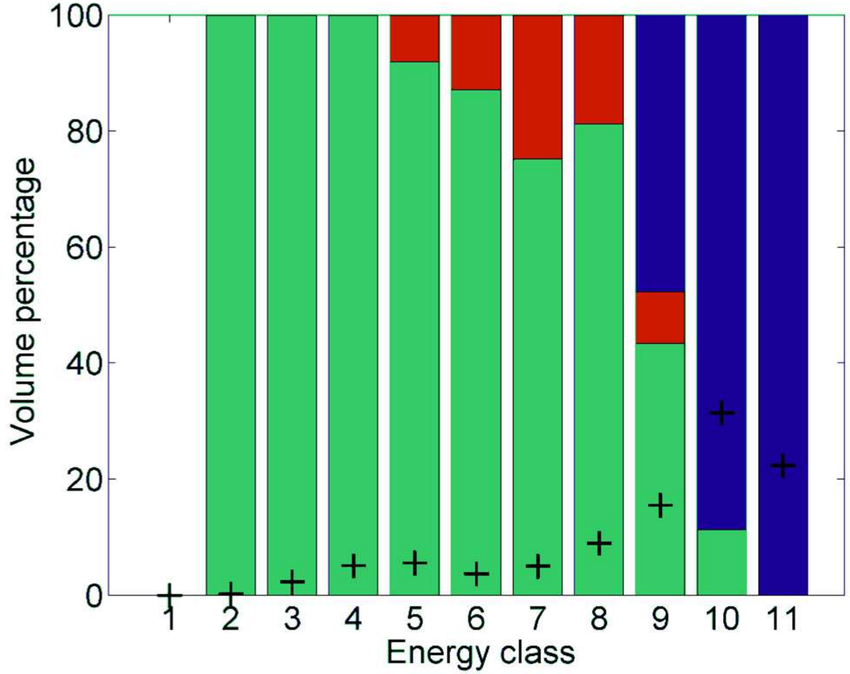


High speed imaging

data analysis: energy classes

- Tap water + 0.25%v/v Li-700 + 0.2g/L fluorescein on barley leaf
- XR11003VK @2bars 160 L/ha, 10 sprayings





Retention: tap water < Li-700 < Break-Thru S240

DST: tap water > Li-700 > Break-Thru S240

High speed imaging

data processing: evaporation

- Because of evaporation, fluorescein concentrations in droplets increase
- Correction of the measured volume is required for making correlation between the two techniques
- This was achieved by resolving equations for the droplet transport, heat and mass transfer (according to Guella 2008, International Journal of Thermal Sciences 47 886–898)

Spray retention

comparison between techniques

		Tap water		Break Thru S240		Li700	
Technique	Volume (µl/0.3 cm²)	Av.	StD	Av.	StD	Av.	StD
High speed imaging	Observed volume[1]	**0,34**	**0,11**	**0,34**	**0,08**	**0,33**	**0,08**
	Adhesion	0,14	0,08	0,19	0,05	0,12	0,05
	Rebound C-B	0,05	0,04	0,01	0,01	0,01	0,01
	Splashing C-B	0,00	0,01	0,00	0,00	0,00	0,00
	Splashing W	0,15	0,09	0,13	0,06	0,20	0,08
Spectrophotometry	Retention	**0,22**	**0,12**	**0,27**	**0,05**	**0,22**	**0,08**

[1] Total volume of droplets landing on the leaf increased to account for evaporation.

$$Retention = Adhesion + K * Splashing\ Wenzel$$

K = % of droplet volume splashing in Wenzel regime that remains on the leaf due to pinning

Spray retention

pinning percentage

Spraying	Tap water		Break Thru S240		Li700	
	% Sp. W ret. K	Retention / Ret. img.	% Sp. W ret. K	Retention / Ret. img.	% Sp. W ret. K	Retention / Ret. img.
1	44,40	1,03	66,80	1,12	56,40	1,04
2	71,90	0,91	42,00	0,96	39,00	0,87
3	14,40	1,07	67,30	1,01	68,10	1,05
4	38,00	1,18	70,50	1,13	32,70	1,15
5	48,20	1,17	63,70	1,04	50,80	1,07
6	29,80	0,67	36,50	0,92	74,30	0,83
7	5,00	1,13	30,00	1,10	45,30	1,52
8	83,90	1,00	46,60	1,08	43,40	0,62
9	57,00	0,75	91,40	0,70	36,20	1,10
10	62,40	0,99	70,20	0,96	37,00	0,90
Average	**45,50**	**0.99**	**58.50**	**1.00**	**48.32**	**1.02**
StD	**24,74**	**0,17**	**18,99**	**0,13**	**14,05**	**0,24**

Conclusions

- Depending on the spray mixture, droplets fragmented in Wenzel regime accounted for 28-46% of retention at first impact, with a clear ranking as a function of DST
- This contribution is not negligible and should be considered when modelling spray retention processes, especially on early growth stages and when using low-drift nozzles with surfactants (larger droplets more likely to splash)
- The coexistence of impact outcomes for the same impact energy is also important to be considered in retention models

High speed imaging

results: volume percentages

- Ten trials

Mixture	V_{tot} (μl)	% Ad	% R CB	% Sp CB	% Sp W	VMD	Drops number
Water	3.44	41.6	14.2	1.1	43.0	317	627
Water + Break Thru S240	3.35	58.0	2.4	0.3	39.4	272	736
Water + Li 700	3.31	35.6	4.3	0	60.1	328	448