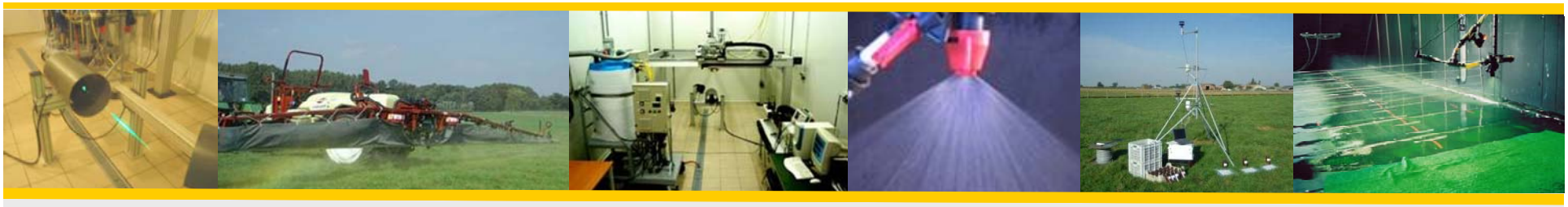


Empirical modelling of drift from ground spraying

David Nuyttens

D NUYTTENS[1], M DE SCHAMPHELEIRE[2], K BAETENS[3], & B SONCK[1]

[1] Institute for Agricultural and Fisheries Research (ILVO), Technology & Food, Agricultural Engineering

[2] Department of Crop Protection, University Ghent

[3] MeBioS, Department Biosystems, Catholic University of Leuven

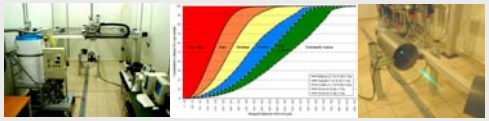
8th Annual Pesticide Stewardship Conference
Asheville, NC, February 24-27, 2008

Introduction

Spray drift
from field crop sprayers

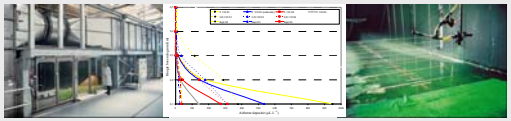
How to measure & predict?

PDPA Laser measurements



Droplet characteristics

Wind tunnel measurements



Drift potential

Reference spraying

Drift potential reduction % (*DPRP*)

indirect drift measurements

Field drift experiments

Drift values

Reference spraying

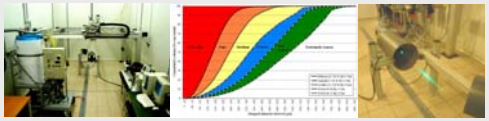
Drift reduction % (*DRP*)

direct drift measurements

Objectives

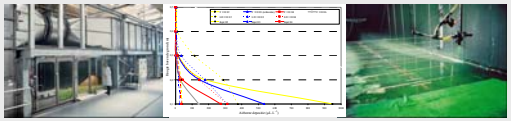
			Reference spraying		
Nozzle type	**Low-drift flat fan**		**Standard flat fan**	**Air inclusion**	
ISO nozzle size		**02**	**03**	**04**	**06**
Pressure (bar)		**2.0**	**3.0**	**4.0**	
Driving speed (km/h)	**4**	**6**	**8**	**10**	
Boom height (m)		**0.30**	**0.50**	**0.75**	
Air support		**yes**	**no**		

PDPA Laser measurements



Droplet characteristics

Wind tunnel measurements



Drift potential

Reference spraying

Drift potential reduction % (*DPRP*)

indirect drift measurements

Field drift experiments

Drift values

Reference spraying

Drift reduction % (*DRP*)

direct drift measurements

?

?

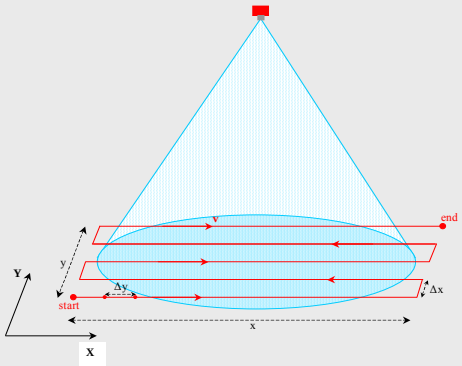
Spray application techniques

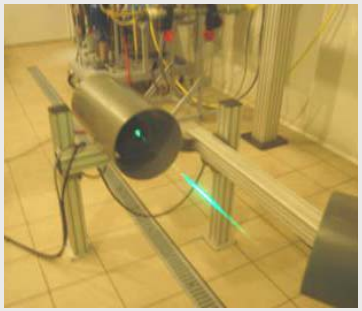
20 other spray application techniques

			Reference spraying		
Nozzle type	Low-drift flat fan		Standard flat fan	Air inclusion	
ISO nozzle size		02	03	04	06
Pressure (bar)		2.0	3.0	4.0	
Driving speed (km/h)	4	6	8	10	
Boom height (m)		0.30	0.50	0.75	
Air support		yes	no		

PDPA Laser measurements

- Materials & Methods: PDPA laser-based measuring set-up[1]
  - Climate room with temperature and humidity control system
  - Spray unit
    - Insulated spray liquid tank
    - Liquid temperature control system
    - Centrifugal pump,…
  - Automated three-dimensional positioning system
  - Phase Doppler Particle Analyzer (PDPA) laser measuring <u>droplet velocity</u> and <u>size</u>
  - 90 experiments

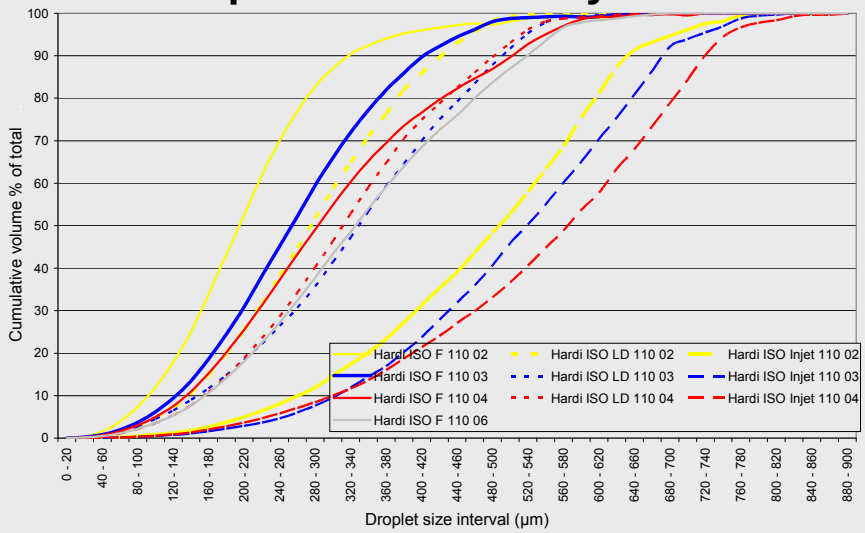


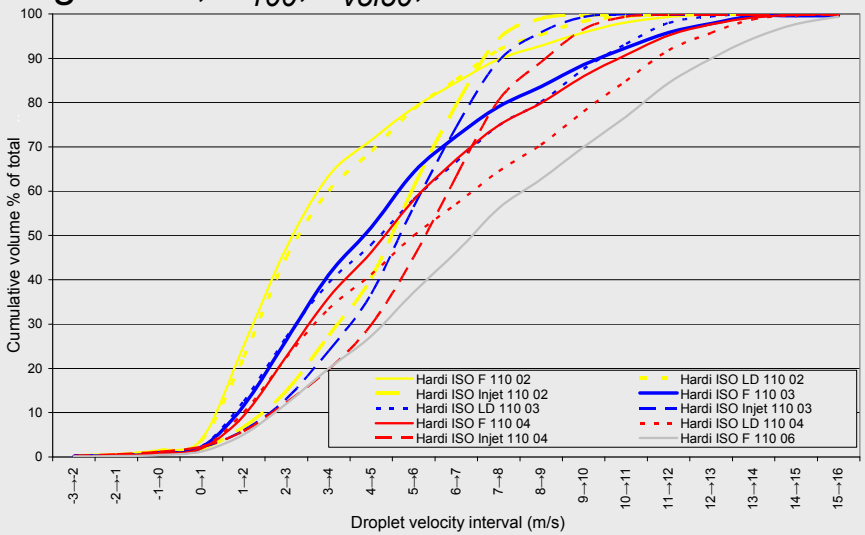


[1] Nuyttens D, De Schampheleire M, Baetens K, Sonck B**.** 2006. PDPA Laser-Based Characterisation of Agricultural Spray Nozzles. *Agricultural Engineering International: the CIGR Ejournal*. Manuscript PM 06 024. Vol. VIII. December, 2006.

PDPA Laser measurements

- Results [2]
  - **Droplet size & velocity characteristics:** e.g. *VMD*, V_{100}, v_{vol50}, …



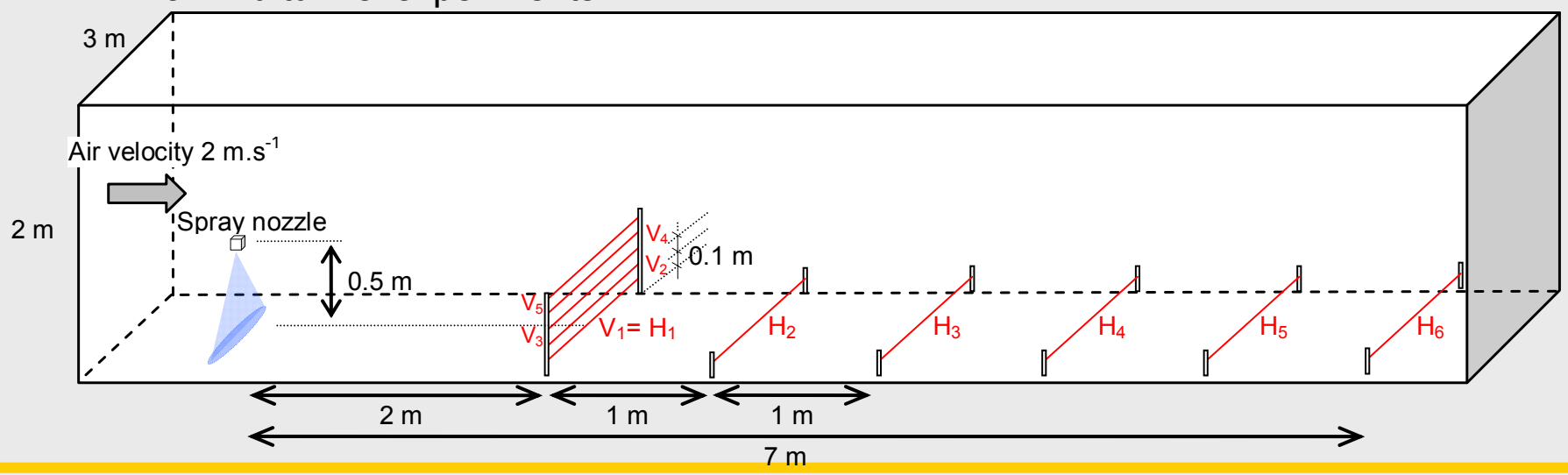


- Main conclusions [2]
  - Important effect of nozzle type and size on droplet sizes and velocities
  - Relation between droplet velocities and sizes
  - Reference nozzles are useful due to considerable variations in absolute results

[2] Nuyttens D, Baetens K, De Schampheleire M, Sonck B. 2007. Effect of Nozzle Type, Size and Pressure on Spray Droplet Characteristics. *Biosystems Engineering*. **97**(3): 333-345.

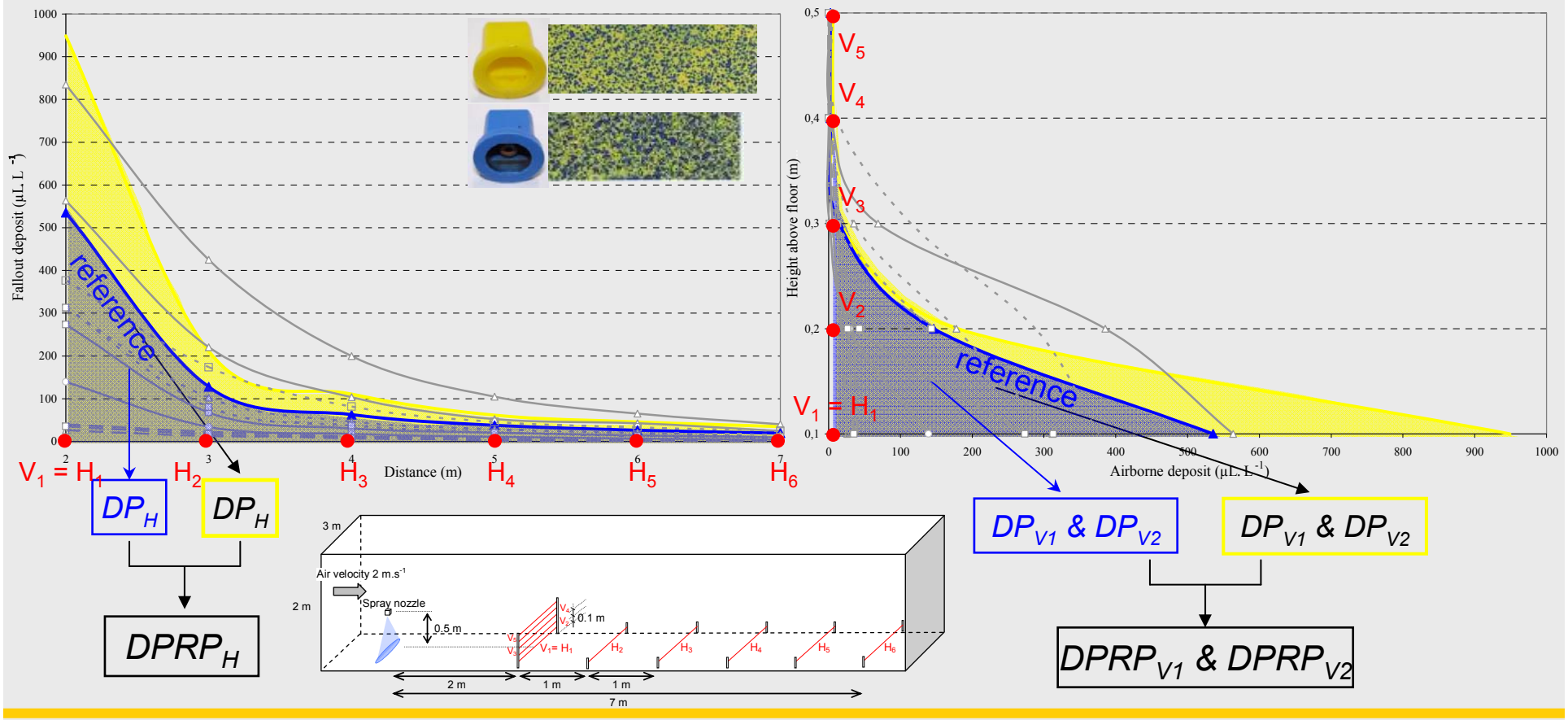
Wind tunnel measurements

- Materials & Methods
  - Silsoe Research Institute wind tunnel facility (Hardi International S/A)
  - Single and static spray nozzle (10 s spraying)
  - Uniform wind tunnel air speed of 2 $m.s^{-1}$
  - Collectors: 2 mm polythene lines → downwind spray deposits
    - 6 horizontal lines ($H_1 \rightarrow H_6$) at distances from 2 to 7 m at a nozzle height of 0.5 m
    - 5 vertical lines ($V_1 \rightarrow V_5$): at a distance of 2 m at nozzle heights from 0.1 to 0.5 m
  - 45 wind tunnel experiments



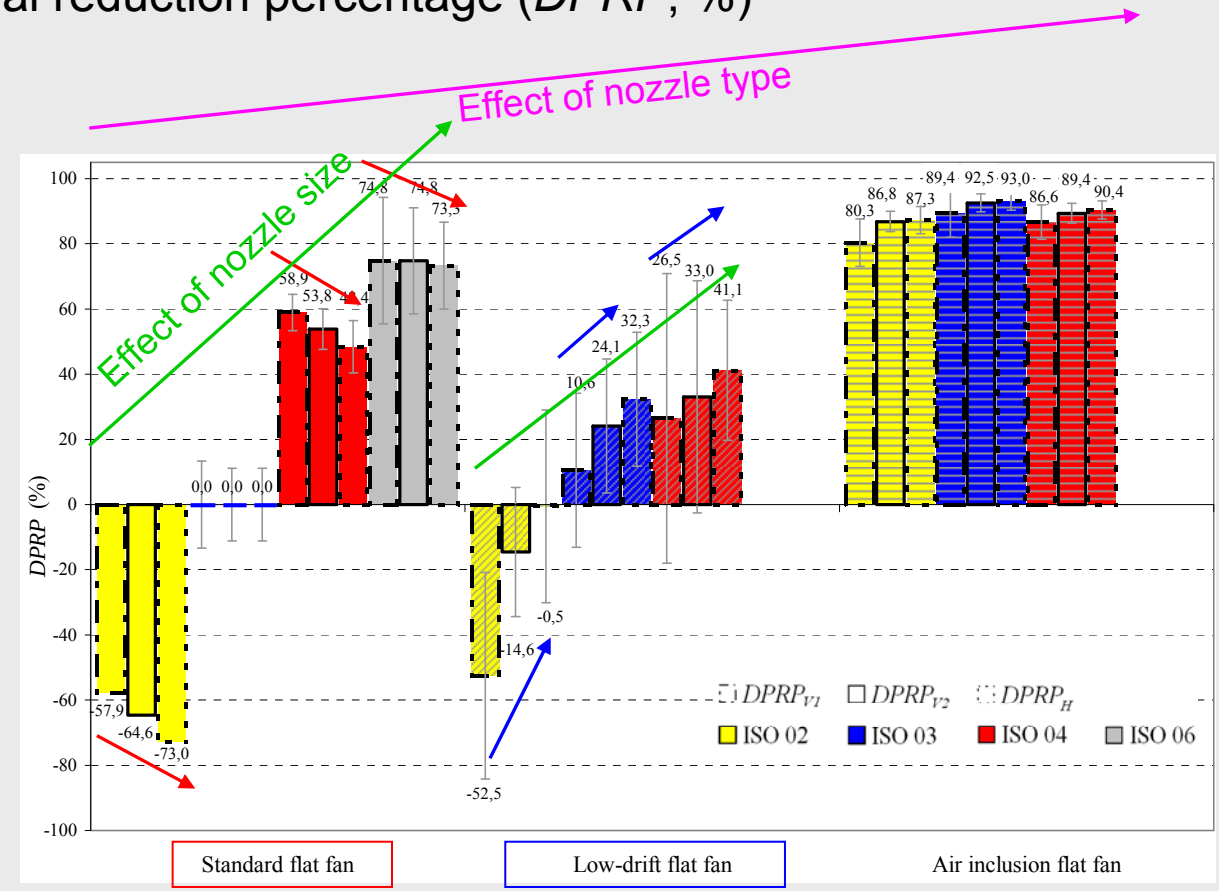
Wind tunnel measurements

- Drift potential reduction percentage (*DPRP*, %)
  - *DPRP* values calculated following 3 approaches → $DPRP_H$, $DPRP_{V1}$, $DPRP_{V2}$



Wind tunnel measurements

- Drift potential reduction percentage (*DPRP*, %)



$DPRP_{V1} > DPRP_{V2} > DPRP_H$ $DPRP_{V1} < DPRP_{V2} < DPRP_H$

Field drift measurements

- Materials & Methods [3]
  - 108 field drift measurements according to ISO 22 886
  - Spray liquid & spray drift collectors
    - Fluorescent tracer Brilliant Sulfo Flavine (BSF, 3 $g.l^{-1}$) + Surfactant Tween 20 (0.1%)
    - Machery – Nachel filter paper (type 751, 0.25 m x 0.25 m)
      - 24 drift collectors (3 collector lines) at distances from 0.5 to 20 m
  - Meteorological measurements
    - Wind speed & direction at 1.50 m & 3.25 m (ultrasonic)
    - Temperature and relative humidity at 1.25 m & 2.15 m
    - Turbulence intensity, dewpoint temperature, atmospheric stability, solar radiation

  - Sprayer
    - Hardi Commander Twin Force trailed field sprayer with 27 m boom, a nozzle spacing of 0.50 m and a tank volume of 3200 litres

[3] Nuyttens D, De Schampheleire M, Baetens K, Sonck B. 2007. The influence of operator controlled variables on spray drift from field crop sprayers. *Transactions of the ASABE*. 50(4):1129-1140.

Field drift measurements

- Reference spraying: 32 experiments at a wide range of climatological conditions [3]
  - Validated non-linear statistical drift prediction equation

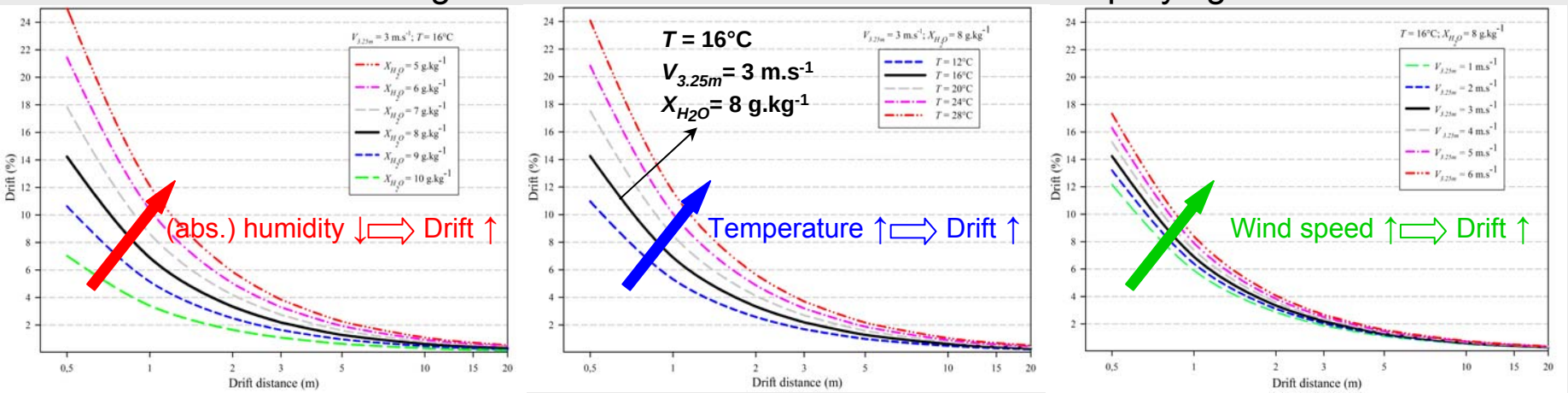
Temperature

$$drift_{\%} = (drift\_dist)^{-1.05} \times (13.00 + 0.50 V_{3.25m} + 0.40 \times T - 1.74 \times X_{H_2O})$$

$R^2 = 0.84$

Drift distance — Wind speed — Absolute humidity

  - Effect of climatological conditions on drift for the reference spraying



[3] Nuyttens D, De Schampheleire M, Baetens K, Sonck B. 2007. The influence of operator controlled variables on spray drift from field crop sprayers. *Transactions of the ASABE*. 50(4):1129-1140.

Field drift measurements

- Reference spraying
  - Validated non-linear statistical drift prediction equation [3]

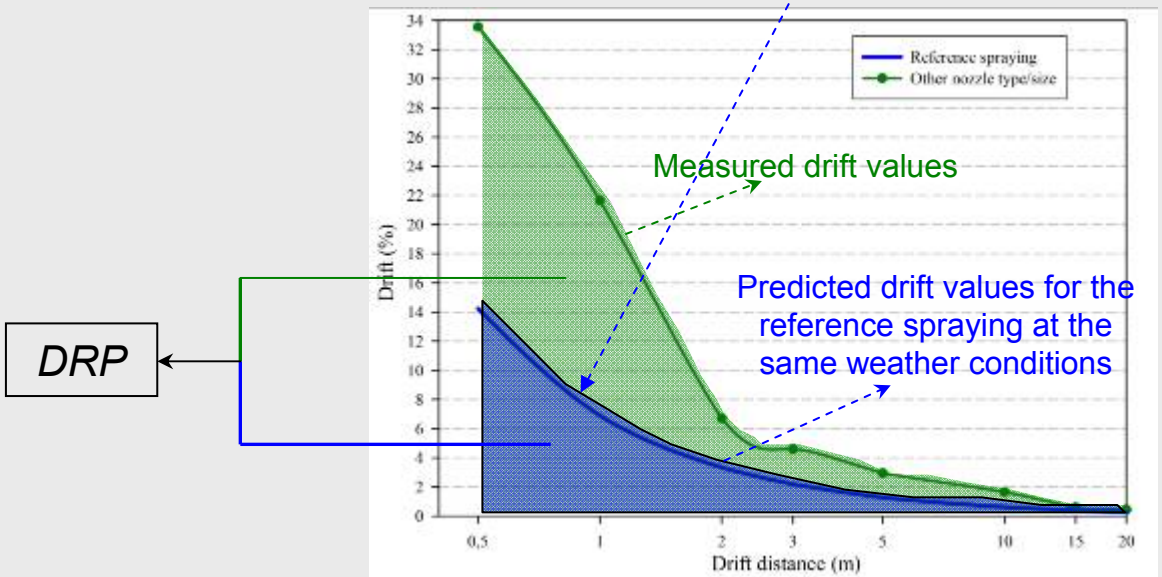
Temperature

$$drift_{\%} = (drift\_dist)^{-1.05} \times (13.00 + 0.50.V_{3.25m} + 0.40 \times T - 1.74 \times X_{H_2O})$$

$R^2 = 0.84$

Drift distance — Wind speed — Absolute humidity

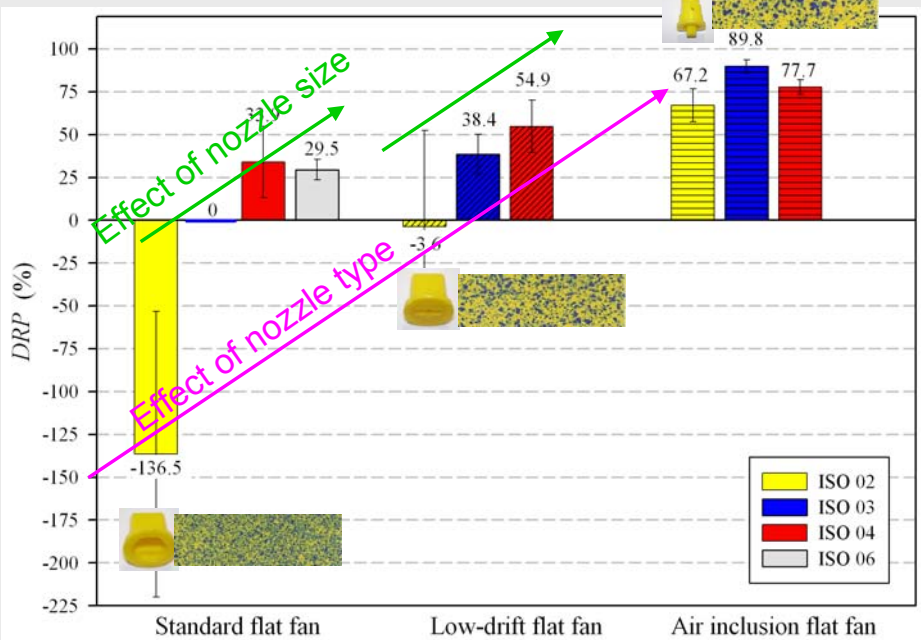
- Drift reduction potential of the different other spray application techniques (*DRP*, %)



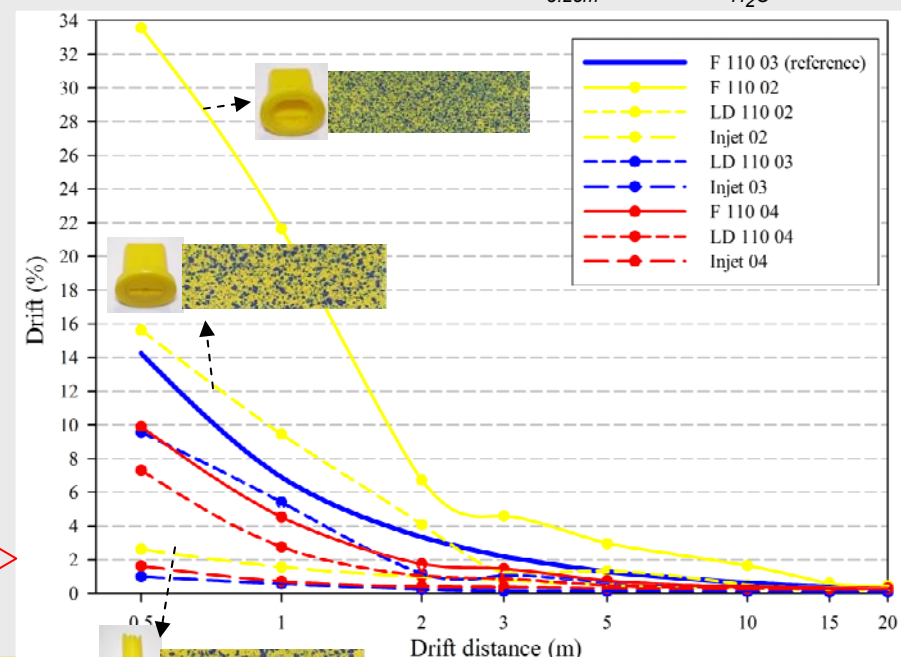
[3] Nuyttens D, De Schampheleire M, Baetens K, Sonck B. 2007. The influence of operator controlled variables on spray drift from field crop sprayers. *Transactions of the ASABE*. 50(4):1129-1140.

Field drift measurements

- Other spray application techniques
  - Effect of nozzle type & size

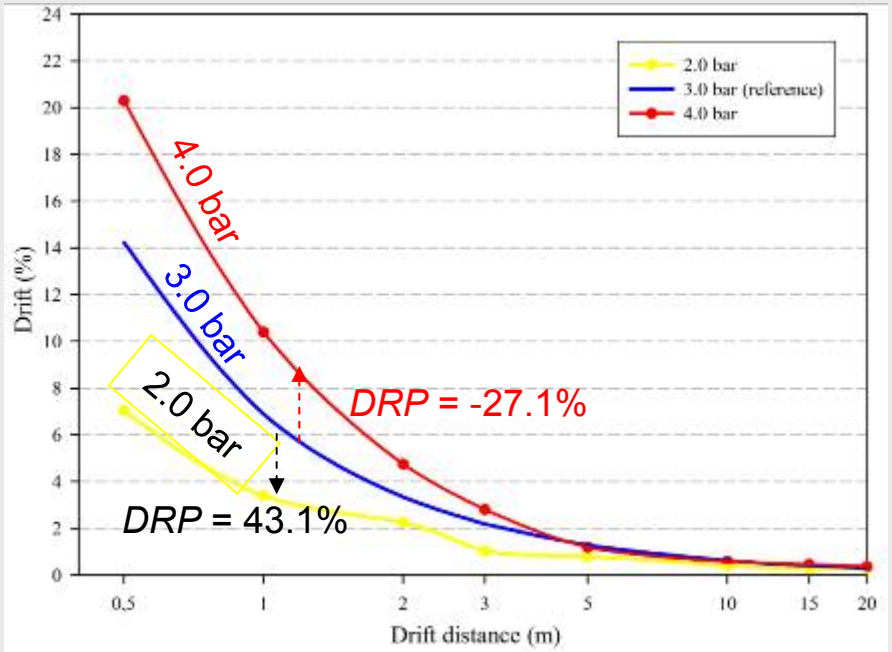


Standard meteorological conditions:
T= 16°C, $V_{3.25m}$= 3 m.s^{-1}, X_{H_2O}= 8 g.kg^{-1}

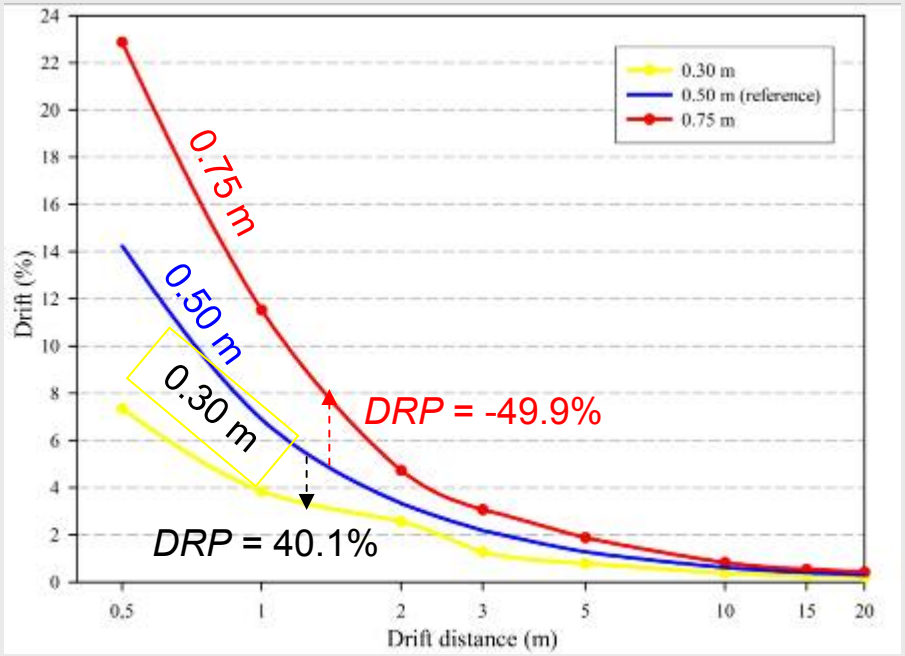


Field drift measurements

- Other spray application techniques
  - Effect of spray pressure



  - Effect of spray boom height



  - Effect of driving speed
    - 8 km/u → 6 km/u: *DRP* = 52.9%
    - 8 km/u → 4 km/u: *DRP* = 35.3%

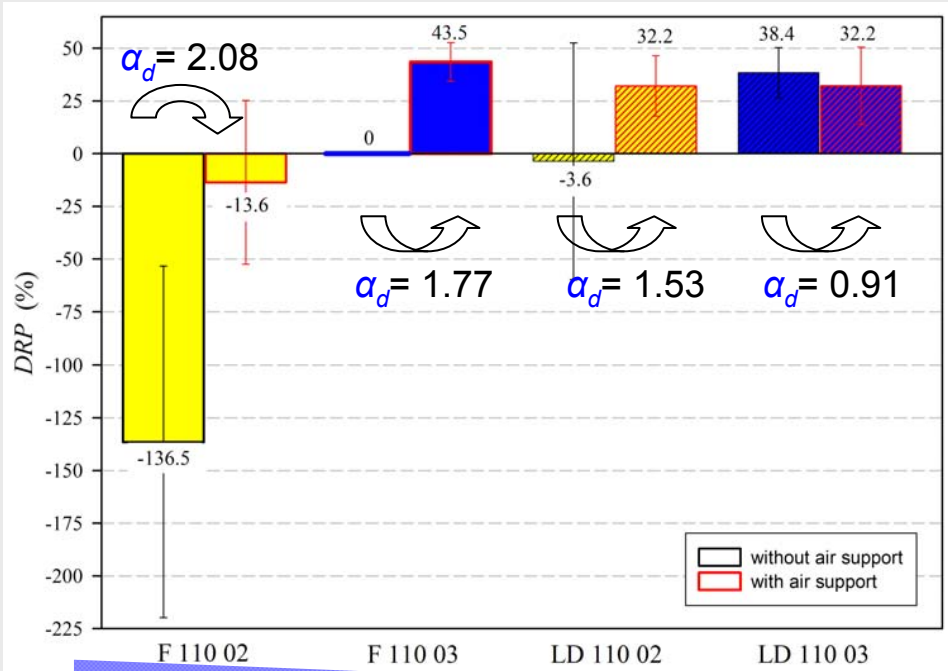
    } Less drift

    - 8 km/u → 10 km/u: no significant effect

Field drift measurements

- Other spray application techniques
  - Air support

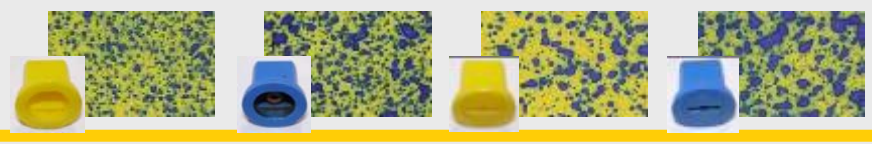
$$\alpha_d = \frac{\text{Drift without air support}}{\text{Drift with air support}}$$



α_d

$D_{v0.5}$ (µm) 214.2 273.6 294.9 348.2

R^2=0.95

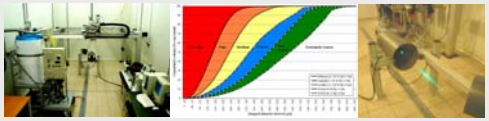


Comparison of drift assessment means

?

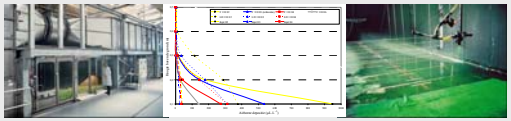
?

PDPA Laser measurements



Droplet characteristics

Wind tunnel measurements



Drift potential

Reference spraying

Drift potential reduction % (*DPRP*)

indirect drift measurements

?

Field drift experiments

Drift values

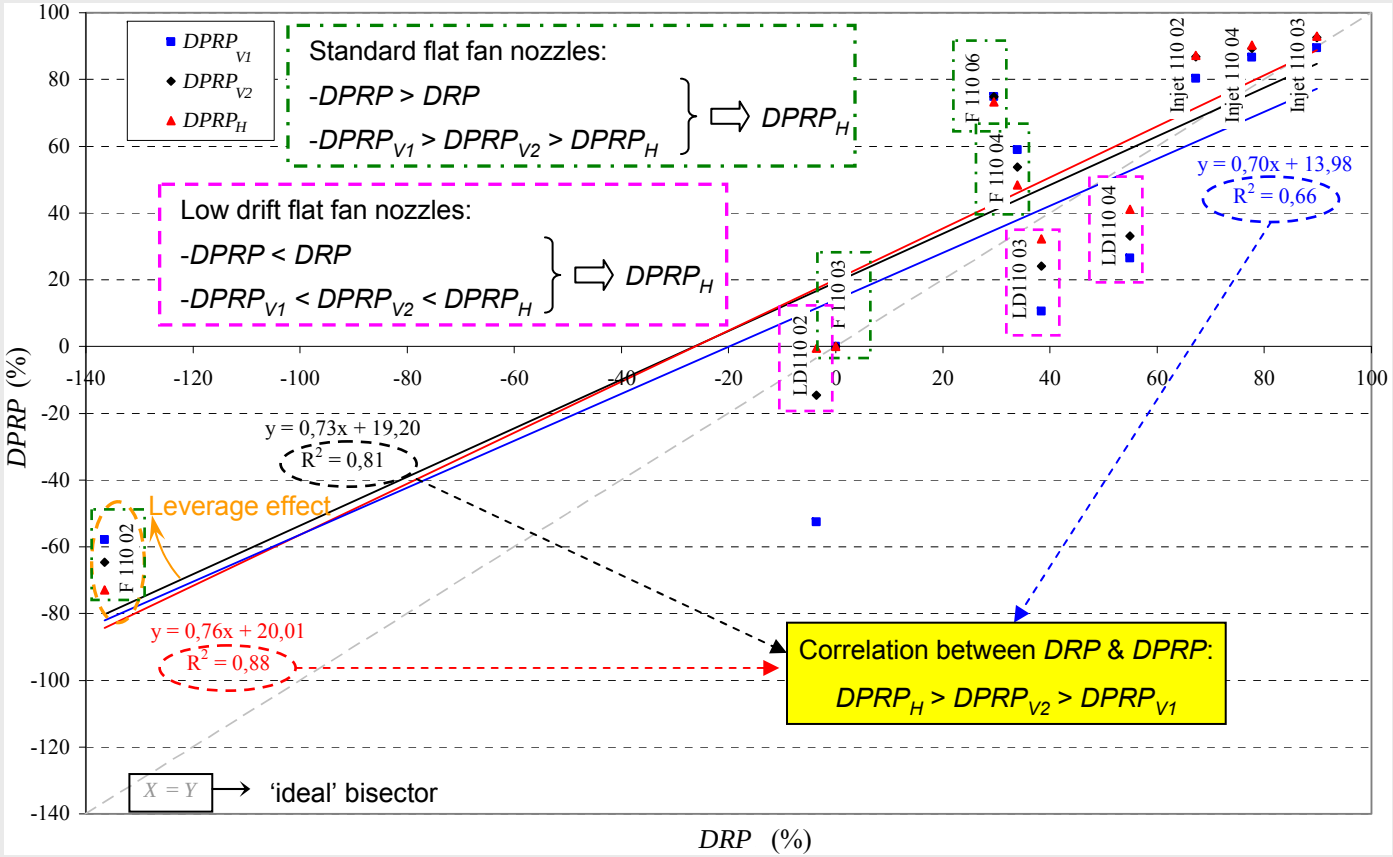
Reference spraying

Drift reduction % (*DRP*)

direct drift measurements

Comparison of drift assessment means

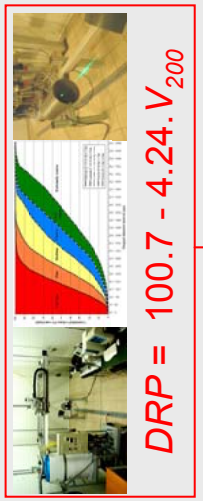
- Wind tunnel experiments (*DPRP*) & field drift experiments (*DRP*)



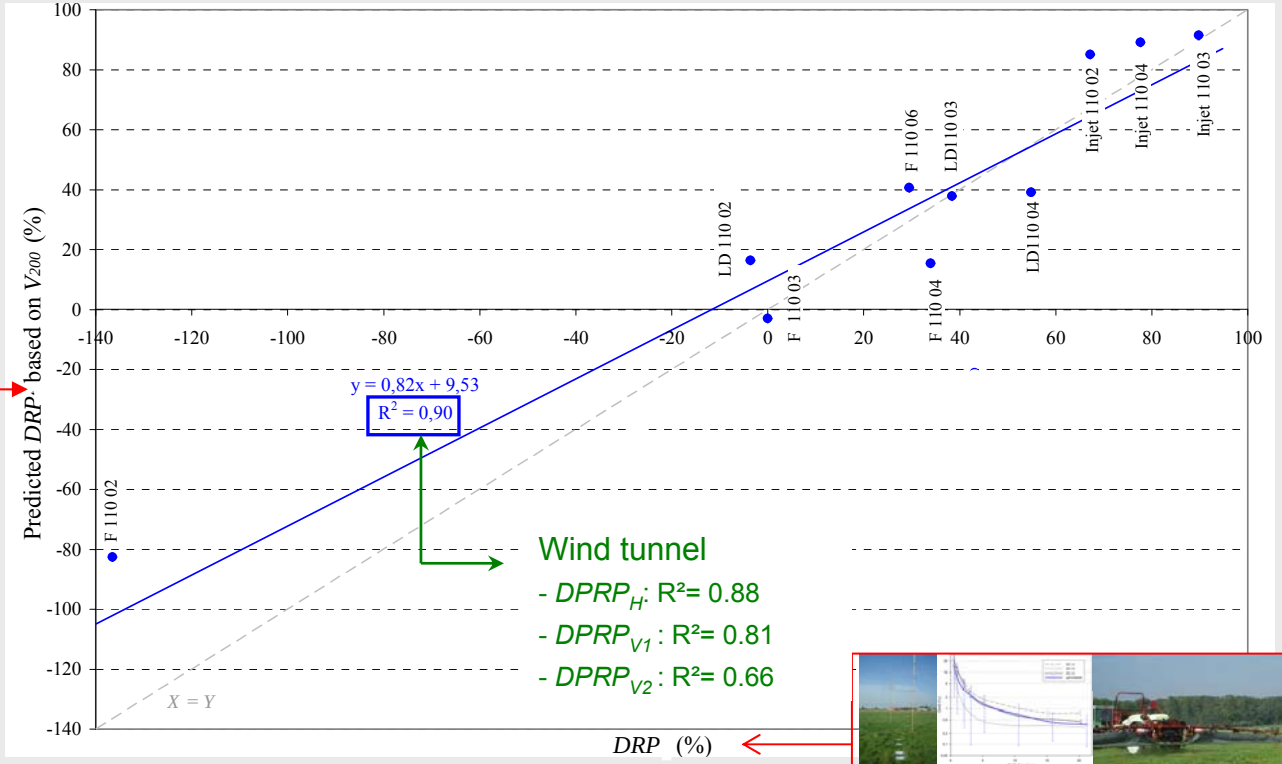
Comparison of drift assessment means

- PDPA laser measurements (≠ droplet characteristics) & field drift experiments (*DRP*)
  - First-order linear regressions: $DRP = a_0 + b_0.X$ ⇨ $DRP = 100.7 - 4.24.V_{200}$ ($R^2 = 0.90$)

    ≠ Droplet characteristics



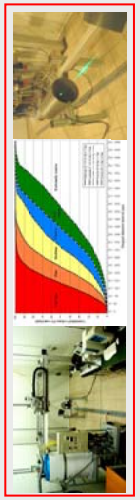
$DRP = 100.7 - 4.24.V_{200}$

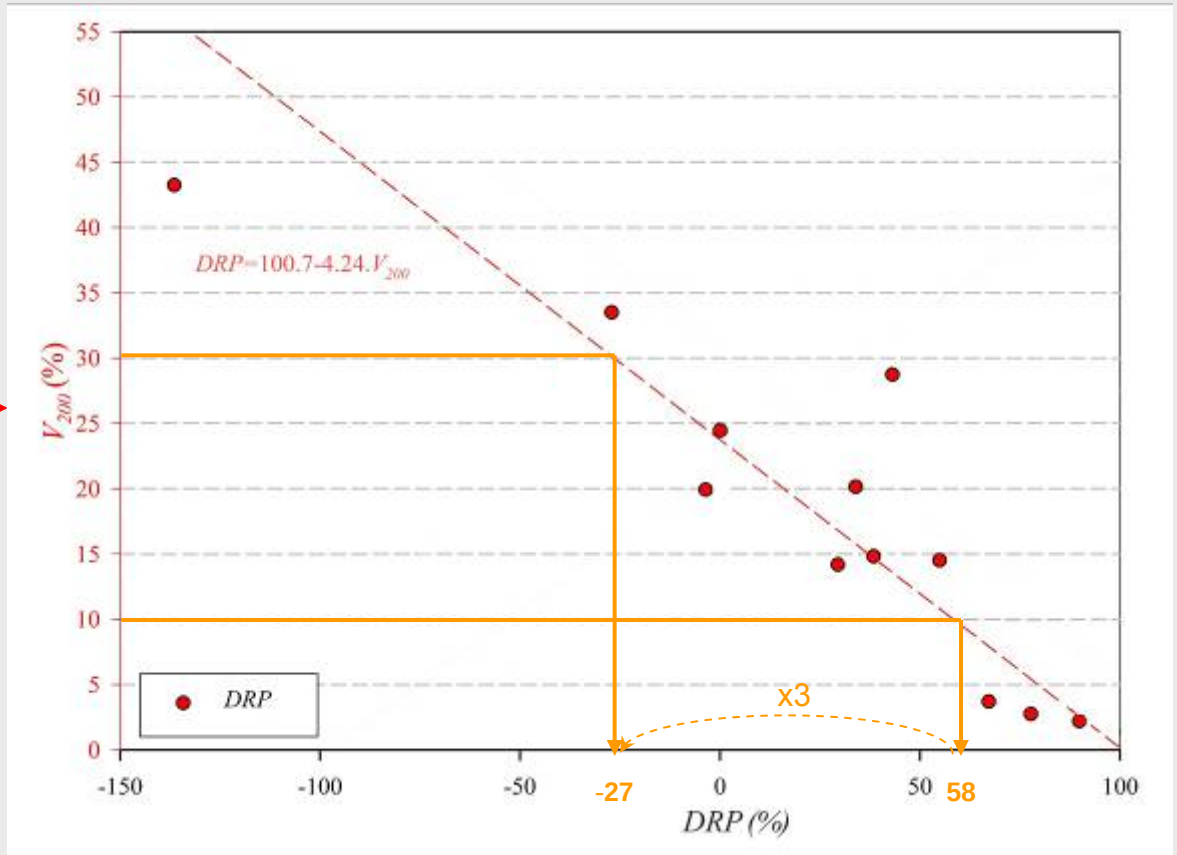


$drift_{\%} = (drift\_dist)^{-1.05} \times (13.00 + 0.50 V_{3.25m} + 0.40 \times T - 1.74 \times X_{H_2O})$

Comparison of drift assessment means

- PDPA laser measurements (≠ droplet characteristics) & field drift experiments (*DRP*)



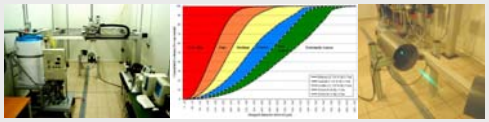


  - Multiple linear regression: no improvement

Conclusions

indirect drift measurements

PDPA Laser measurements

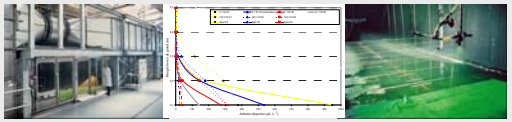


Reference spraying

Other spray applications

Droplet characteristics

Windtunnel measurements



Reference spraying

Other spray applications

DP

DP

DPRP

Field drift experiments

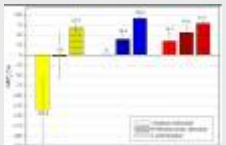
Reference spraying

Other spray applications

$drift_{1\%} = (drift\_dist)^{-1.05} \times (13.00 + 0.50.V_{3.25m} + 0.40 \times T - 1.74 \times X_{H_2O})$

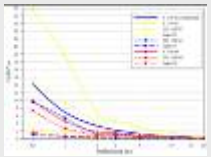
Drift data + meteo

DRP



$drift_{1\%} = (drift\_dist)^{-1.05} \times (13.00 + 0.50.V_{3.25m} + 0.40 \times T - 1.74 \times X_{H_2O})$

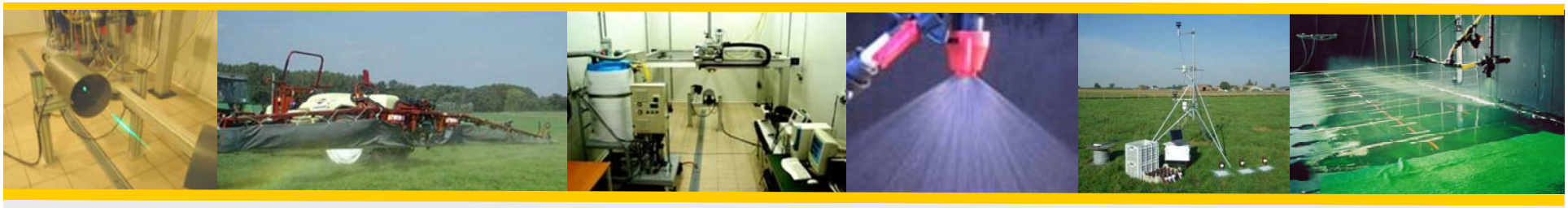
Drift values as a function of spray application technique & meteo



$DRP = 100.7 - 4.24.V_{200}$

$DPRP_H$

direct drift measurements



Thank you for your attention!

Nuyttens D. 2007. Drift from field crop sprayers: The influence of spray application technology determined using indirect and direct drift assessment means. PhD thesis nr. 772, Katholieke Universiteit Leuven. 293 pp.
available at: http://hdl.handle.net/1979/1047

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