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Characterization of agricultural sprays using laser techniques

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Summary

The characteristics of agricultural sprays belong to the most critical factors affecting spray drift, deposition on plants, spray coverage and biological efficacy. Hence, within the framework of a research project about agricultural spray drift, a measuring set-up for the characterisation of spray nozzles using a Phase Doppler Particle Analyser (PDPA) was developed. This set-up is able to measure droplet sizes and velocities based on light-scattering principles. It is composed of different parts i.e.: a climate room, a spray unit, a three-dimensional automated positioning system and an Aerometrics PDPA 1D system.

In total, 32 nozzle-pressure combinations have been tested. From the results, the importance of the nozzle type and size on the droplet size and velocity spectra is clear. In future, the results will be linked with the drift potential of different nozzle pressure combinations (based on field measurements) and used as an input for a Computational Fluid Dynamics spray drift model.

Key words: Agricultural sprays, Phase Doppler Particle Analyser, Spray droplet characteristics, driftability

Introduction

The droplet size (and velocity) spectra are important criteria in the application of pesticides. They affect the structure of the spray deposit. In addition, the characteristics of droplets determine their driftability (Taylor et al., 2004). Furthermore, droplet size may influence the biological efficacy of the applied pesticide as well as environmental hazards. Hence, the ideal nozzle pressure combination will maximise spray efficiency for depositing and transferring a lethal dose to the target, while minimising off-target losses such as spray drift and user exposure.

Over the last years, several techniques using laser instrumentation have been developed to determine droplet characteristics like laser diffraction (Malvern laser) (Barnett and Matthews, 1992; Buttler Ellis and Bradley, 2002), the optical area probe technique (Particle Measuring System) (Combellack et al., 2002) and Phase Doppler Particle Analyzer (Aerometrics) (Farooq et al., 2001). In this paper, a detailed description of a recently developed PDPA measuring set-up is presented along with some results.

Materials and Methods

Measuring set-up

A detailed description of the PDPA laser-based measuring set-up is already given by Nuyttens et al. (2005). The spray unit consists of different parts i.e.: an insulated spray liquid tank with a volume of 100 litres and a fluid level control system, a liquid temperature control system, a mechanical and hydraulic mixing system, a vertical in-line centrifugal pump and a pressure regulator with digital pressure gauge. In case of continuous spraying, a fluid temperature range from 5°C to 50°C is feasible. In the measuring set-up the nozzle under measurement can be moved by an automated XYZ-transporter with a traverse range of 2 m by 2.2 m. With this positioning system, a defined rectangular pattern is scanned to sample the entire spray cloud at a constant scanning speed. The laser measurements are performed in an insulated climate room provided with a temperature and humidity control system. Under normal working conditions, a temperature range from 5°C to 30°C and a relative humidity range from 30% to 90% are achievable. Hence, realistic outdoor climatic conditions can be simulated.

The PDPA laser used in this research is an Aerometrics PDPA 1D system. As for the PDPA, a droplet passes through a small sampling volume, scattering light by refraction. For this 1D system, velocity measurement is limited to the dominant vertical direction. The system comprises several units i.e.: an Argon-Ion laser, a fibre drive, a fibre-optic coupler, transmitter and receiver, a Real-time Signal Analyzer (RSA) and DataVIEW-NT software. When a spherical particle crosses the measurement volume (formed by the intersecting laser beams), the rays enter the sphere at different angles. Besides, the particle has a different index of refraction than the surroundings. Hence, the rays have to travel along different optical paths with different lengths. Because of the different optical path lengths, the light waves are shifted relative to each other. These phase shifts will result in an interference pattern in the field surrounding the particle. The spacing of the interference fringes depends on the beam intersection angle. The light wavelength and the spacing are inversely proportional to the diameter of the sphere. If a particle is moving with a velocity v through the intersection of the beams, light will scatter with a frequency f_d. This frequency f_d is equal to the velocity v divided by the fringe spacing δ_f. Hence, frequency and particle velocity are related through the following relation:

$$v = f_d.\delta_f = f_d.\frac{\lambda}{2.\sin(\frac{\theta}{2})}$$

with v = velocity of the scattering particle ($m.s^{-1}$);
f_d = Doppler frequency (s^{-1});
λ = laser light wavelength (m);
θ = angle between the two laser beams (°).

The fibre-optic receiver collects the scattered light when particles pass through the measurement volume created by the optical transmitter. Photomultiplier tubes convert the light into electrical signals to be processed for velocity and size information by the Real-Time Signal Analyzer (RSA). Finally, the DataVIEW-NT software contributes to the overall ease of use of the system and gives complete control over the presentation and acquisition of the data. In figure 3, some pictures of the total measuring set-up are given.

Measuring protocol

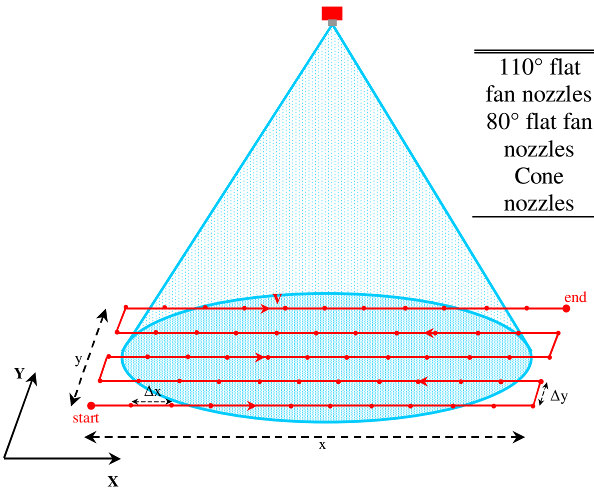
Prior to the laser measurements, the flow rate of each nozzle is tested at a pressure of 3 bar by the accredited Spray Technology Lab CLO-DVL (Beltest 259-T ISO 17025) (Goossens and

Braekman, 2003). A maximal deviation of 2.5 % is allowed compared to the prescribed nominal flow rate.

For the PDPA measurements three nozzles are selected for each nozzle-pressure combination to be tested. Each nozzle is tested three times. This makes a total of 9 measurements for each nozzle-pressure combination. Each scan yielded data for at least 10000 droplets. The BCPC reference nozzle fine-medium (Lurmark F 110 03 at 3 bar) is used as a reference nozzle to check for the repeatability of the measurements and the measuring equipment (Southcombe et al., 1997). All measurements are made spraying water with a temperature of about 20 °C at an ambient temperature of about 20 °C and a relative humidity of 60-70%. The nozzle is positioned 50 cm above the measuring point of the PDPA.

To enable the whole of the spray cone to be sampled, the nozzle was mounted on the transporter. A different scan trajectory was programmed depending on the type of nozzle i.e. 110° or 80° flat fan nozzle or cone nozzle. All measurements were carried out through the long axis of the spray cloud at a constant scan speed (Δx not applicable) (Table 1).

Table 1: *Characteristics of the scan trajectory for the different nozzle types.*



	Scan speed v ($cm.s^{-1}$)	x (m)	y (m)	Δy (m)	Measuring time (s)
110° flat fan nozzles	2.5	1.50	0.40	0.10	316
80° flat fan nozzles	1.66	1.00	0.40	0.10	324
Cone nozzles	3	1.00	1.00	0.10	400

32 nozzle-pressure combinations (288 measurements) were tested including the BCPC reference nozzles (Southcombe et al., 1997) and the nozzle-pressure combinations used in a whole series of field drift measurements (Nuyttens et al., 2005) (Table 2). Different characteristics are calculated:

- $D_{v0.1}$, $D_{v0.5}$, $D_{v0.9}$: Diameter at which a volume fraction of 10, 50, 90 percent is made up of drops with diameters smaller than this value (µm); $D_{v0.5}$ = VMD (Volume Median Diameter);
- V_{100}, V_{200}: Percentage of total volume of droplets smaller than 100, 200 µm (%);
- D_{10}, D_{20}, D_{30}: Arithmetic mean diameter, Surface mean diameter, Volumetric mean diameter (µm);
- D_{32}: Sauter mean diameter; Diameter of a drop having the same volume to surface area ratio as the total volume of all the drops to the total surface area of all the drops (µm);
- NMD: Number mean diameter; Diameter at which 50% of the number of drops is smaller than this value (µm);
- RSF: Relative Span Factor; Dimensionless parameter indicative of the uniformity of the drop size distribution defined as: $RSF = \frac{D_{v0.9} - D_{v0.1}}{VMD}$;
- V_{vol50}: Velocity at which 50 percent of the total spray volume is made up of drops with velocities smaller than this value ($m.s^{-1}$).

The reference nozzles are used to define 6 spray categories ranging from Very Fine (VF), Fine (F), Medium (M), Coarse (C), Very Coarse (VC) and Extremely Coarse (EC). This classification is based on the comparison of the droplet size spectrum ($D_{v0.1}$, VMD and $D_{v0.9}$) produced by a spray nozzle at a certain pressure with these reference spectra.

Table 2: *Overview of the tested nozzle–pressure combinations.*

Nozzle	Pressure (bar)	Nozzle	Pressure (bar)	Nozzle	Pressure (bar)
*Delavan 110 01**	*4.5*	Albuz API 110 06	3	Hardi ISO F110 03	2; 3; 4
*Lurmark 110 03**	3	Albuz AXI 110 02	3	Hardi ISO F 110 04	3
*Lechler 110 06**	2.0	Albuz AXI 110 04	3	Hardi ISO F 110 06	3
*TeeJet 80 08**	2.5	Albuz AXI 110 06	3	Hardi ISO LD 110	3
*TeeJet 80 15**	2.0	Albuz ADI 110 02	3	Hardi ISO LD 110	3
Albuz ATR80 blue	3	Albuz ADI 110 04	3	Hardi ISO LD 110	3
Albuz ATR80 green	3	Albuz AVI 110 02	3	Hardi ISO Injet 110	3
Albuz ATR80 orange	3	Albuz AVI 110 04	3	Hardi ISO Injet 110	3
Albuz API 110 02	3	Albuz AVI 110 06	3	Hardi ISO Injet 110	3
Albuz API 110 04	3	Hardi ISO F 110 02	3	Hardi ISO Injet 110	3

**BCPC reference nozzles*

Results and discussion

Figures 1 and 2 present the volumetric droplet size distribution and the volumetric velocity distribution cumulatively for different types and sizes of Hardi spray nozzles together with the five BCPC reference nozzles. In Table 3, an overview is given of different droplet characteristics of the tested nozzle-pressure combinations. Droplet sizes vary from a few micrometres up to some hundreds of micrometres depending on the nozzle type and size. For the same nozzle size and pressure, cone nozzles produce the finest droplet size spectrum followed by standard flat fan nozzles, low-drift flat fan nozzles and air injection nozzles (Table 3). The bigger the ISO nozzle, the bigger the droplet size spectrum. As expected, the 5 BCPC reference nozzles cover the entire range of measured droplet sizes (Fig. 1). Analogue with droplet size spectrum, each nozzle pressure combination produces a droplet velocity spectrum with velocities varying from about 0 m.s^{-1} up tot 15 m.s^{-1}. Moreover, there is a strong correlation between droplet sizes and velocities. In general, bigger droplet sizes correspond with higher droplet velocities. For air injection nozzles, droplet velocities are smaller than expected probably due to the presence of small air bubbles in the droplets which makes them less heavy.

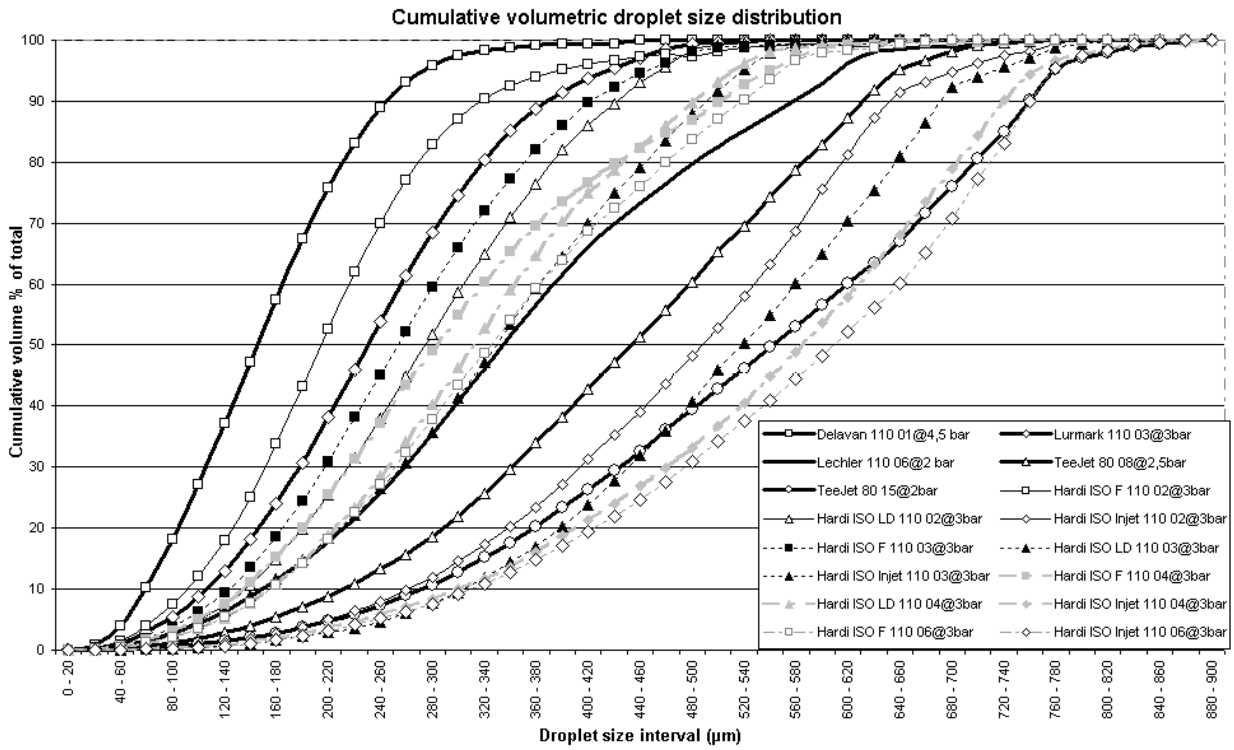


Figure 1: Cumulative volumetric droplet size distribution for different Hardi nozzles and the 5 BCPC reference nozzles.

Table 3: Droplet characteristics (average ± standard deviation) of 32 nozzle-pressure combinations.

Nozzle type	Pressure (bar)	Nominal flow rate (l/min)	BCPC*	Dv0.1 (µm)	VMD (µm)	Dv0.9 (µm)	V100 (%)	V200 (%)	D10 (µm)	D20 (µm)	D30 (µm)	D32 (µm)	NMD (µm)	Vvol50 (m/s)
Delavan 110 01	4.5	0.45	VF/F	79.7 ± 4.3	165.4 ± 8.0	263.5 ± 7.5	18.3 ± 2.4	67.4 ± 3.9	71.3 ± 3.8	85.2 ± 4.3	99.6 ± 4.4	136.3 ± 5.2	59.6 ± 3.3	1.7 ± 0.2
Lurmark 110 03	3	1.18	F/M	127.2 ± 10.2	251.0 ± 14.0	389.1 ± 20.3	5.5 ± 1.2	30.8 ± 4.6	92.7 ± 5.7	117.5 ± 7.1	141.8 ± 8.3	206.7 ± 11.8	68.6 ± 3.5	3.9 ± 0.5
Lechler 110 06	2	1.93	M/C	170.8 ± 10.7	355.0 ± 10.7	573.5 ± 19.5	2.7 ± 0.3	14.4 ± 1.9	108.6 ± 2.9	143.9 ± 4.8	180.7 ± 6.1	285.1 ± 10.4	74.7 ± 1.6	4.4 ± 0.3
TeeJet 80 08	2.5	2.88	C/VC	231.8 ± 12.5	453.0 ± 17.2	630.5 ± 7.3	1.2 ± 0.2	7.0 ± 1.0	139.4 ± 5.9	187.8 ± 8.3	234.5 ± 9.7	365.4 ± 13.5	89.8 ± 2.8	9.6 ± 0.2
TeeJet 80 15	2	4.9	VC/EC	292.7 ± 7.1	561.8 ± 8.3	757.4 ± 4.7	0.6 ± 0.1	3.7 ± 0.4	164.1 ± 7.5	227.1 ± 8.5	285.8 ± 8.4	452.7 ± 7.2	99.3 ± 5.9	6.6 ± 0.3
Albuz ATR80 blue	3	1.94	M	150.1 ± 5.2	298.6 ± 14.0	474.4 ± 33.5	3.2 ± 0.7	21.0 ± 1.7	114.7 ± 18.1	142.7 ± 15.3	170.9 ± 11.6	246.4 ± 5.7	88.6 ± 23	3.5 ± 0.2
Albuz ATR80 green	3	1.41	M	137.5 ± 9.4	256.2 ± 7.2	409.0 ± 12.2	3.9 ± 1.2	28.6 ± 2.2	113.2 ± 14.3	137.0 ± 13.4	160.0 ± 11.6	218.8 ± 6.9	92.1 ± 18.5	2.6 ± 0.2
Albuz ATR80 orange	3	0.78	F	109.9 ± 7.0	191.1 ± 5.3	286.5 ± 9.1	7.5 ± 2.0	55.2 ± 3.0	97.7 ± 6.8	114.7 ± 6.9	130.1 ± 6.2	167.5 ± 4.8	85.1 ± 10.1	1.2 ± 0.2
Albuz API 110 02	3	0.8	F	106.0 ± 4.9	208.3 ± 6.2	325.8 ± 8.4	8.7 ± 1.0	45.9 ± 3.2	81.4 ± 2.3	101.6 ± 3	121.5 ± 3.4	173.7 ± 5.1	62.3 ± 1.9	2.1 ± 0.2
Albuz API 110 04	3	1.6	M	129.9 ± 5.9	263.6 ± 5.7	424.7 ± 13.1	5.4 ± 0.6	28.4 ± 1.7	85.7 ± 2.8	112.2 ± 3.5	139.2 ± 3.7	214.1 ± 5.1	61.2 ± 1.9	3.5 ± 0.4
Albuz API 110 06	3	2.4	M	157.1 ± 6.6	315.4 ± 3.9	508.5 ± 18.4	3.3 ± 0.4	18.5 ± 1.3	97.0 ± 5.2	129.7 ± 6.1	162.6 ± 5.8	255.6 ± 4.3	66.2 ± 3.6	4.8 ± 0.3
Albuz AXI 110 02	3	0.8	F	104.0 ± 4.1	207.0 ± 5.0	330.0 ± 6.2	9.2 ± 1.0	46.6 ± 2.4	77.2 ± 1.7	97.6 ± 2.2	117.8 ± 2.7	171.8 ± 4.7	58.5 ± 2.2	1.6 ± 0.2
Albuz AXI 110 04	3	1.6	M	139.5 ± 6.5	265.5 ± 7.3	416.9 ± 16.5	4.2 ± 0.4	26.1 ± 2.3	97.9 ± 2.5	125.1 ± 3.1	151.4 ± 3.6	221.7 ± 6.1	70.7 ± 2.0	3.5 ± 0.3
Albuz AXI 110 06	3	2.4	M	154.1 ± 10.6	302.2 ± 6.9	476.0 ± 7.1	3.3 ± 0.5	19.7 ± 2.4	99.8 ± 5.4	131.4 ± 6.9	162.4 ± 7.5	247.9 ± 8.9	69.0 ± 3.8	5.1 ± 0.5
Albuz ADI 110 02	3	0.8	M	182.7 ± 16.4	341.7 ± 22.0	492.0 ± 9.7	2.1 ± 0.5	13.2 ± 2.8	110.1 ± 8.6	149.0 ± 12.1	184.4 ± 14.0	282.5 ± 18.9	70.3 ± 3.8	2.7 ± 0.2
Albuz ADI 110 04	3	1.6	M	181.6 ± 15.4	351.1 ± 23.3	509.9 ± 41.2	1.8 ± 0.5	13.3 ± 3.0	119.3 ± 15.2	157.9 ± 17.2	193.2 ± 18.4	289.5 ± 21.3	83.5 ± 13.0	3.0 ± 0.6
Albuz AVI 110 02	3	0.8	C	242.4 ± 19.9	450.4 ± 23.7	589.4 ± 10.7	0.7 ± 0.3	5.9 ± 1.6	158.8 ± 20.7	210.2 ± 23.2	254.3 ± 23.0	372.8 ± 20.3	111.1± 20.6	4.5 ± 0.2
Albuz AVI 110 04	3	1.6	VC	280.3 ± 10.5	526.5 ± 9.1	684.8 ± 10.7	0.5 ± 0.1	3.9 ± 0.7	164.3 ± 12.2	227.1 ± 13.3	281.2 ± 12.6	431.3 ± 9.4	103.4± 11.3	5.3 ± 0.2
Albuz AVI 110 06	3	2.4	VC	276.2 ± 9.9	524.8 ± 10.0	684.0 ± 7.0	0.5 ± 0.1	4.1 ± 0.5	159.7 ± 11.4	221.4 ± 12.5	275.3 ± 11.9	426.0 ± 7.6	98.7 ± 9.6	5.5 ± 0.2
Hardi ISO F 110 02	3	0.8	F	112.5 ± 10.7	214.2 ± 7.9	343.9 ± 29.9	7.4 ± 1.8	43.2 ± 4.0	83.7 ± 6.9	105.4 ± 8.4	126.2 ± 9.1	181.1 ± 10.9	64.1 ± 5.6	2.4 ± 0.3
Hardi ISO F110 03	4	1.39	F	117.5 ± 5.5	246.5 ± 6.7	426.0 ± 28.0	6.6 ± 0.9	33.5 ± 2.6	93.2 ± 3.2	115.2 ± 4.1	138.7 ± 4.5	201.2 ± 6.3	71.8 ± 2.6	3.8 ± 0.8
Hardi ISO F 110 03	3	1.2	M	144.1 ± 8.9	273.6 ± 10.9	421.9 ± 21.3	3.7 ± 0.7	24.5 ± 2.9	96.0 ± 5.9	125.3 ± 6.8	152.9 ± 6.8	227.9 ± 8.2	67.9 ± 5.1	3.9 ± 0.4
Hardi ISO F110 03	2	0.98	M	131.2 ± 16.5	265.4 ± 28.2	399.3 ± 17.8	5.3 ± 2.1	28.7 ± 8.5	97.1 ± 10.9	122.7 ± 13.4	148 ± 15.5	215.5 ± 21.2	72.8 ± 5.7	3.3 ± 0.5
Hardi ISO F 110 04	3	1.6	M	154.9 ± 7.7	303.4 ± 10.3	518.3 ± 34.1	3.0 ± 0.4	20.1 ± 1.8	98.7 ± 2.6	131.2 ± 4.0	163.1 ± 5.3	252.1 ± 9.9	67.7 ± 2.1	4.6 ± 0.2
Hardi ISO F 110 06	3	2.4	M	176.1 ± 7.3	345.1 ± 5.5	538.7 ± 10.9	2.2 ± 0.3	14.2 ± 1.4	107.1 ± 3.2	144.9 ± 4.5	181.2 ± 5.1	283.3 ± 6.9	70.8 ± 2.6	6.6 ± 0.2
Hardi ISO LD 110 02	3	0.8	M	157.4 ± 7.6	294.9 ± 9.7	440.0 ± 16.2	2.9 ± 0.4	19.9 ± 2.3	107.8 ± 4.6	139.0 ± 5.7	168.1 ± 6.0	245.8 ± 7.8	76.2 ± 3.0	2.6 ± 0.1
Hardi ISO LD 110 03	3	1.2	M	169.8 ± 18.9	348.2 ± 14.1	509.3 ± 8.4	2.7 ± 0.8	14.8 ± 3.2	116.7 ± 10.5	150.8 ± 13.9	185.1 ± 15.2	279.0 ± 17.4	82.5 ± 5.4	4.4 ± 0.4
Hardi ISO LD 110 04	3	2.4	M	175.1 ± 3.7	331.2 ± 6.4	499.2 ± 11.9	2.1 ± 0.2	14.5 ± 0.9	117.3 ± 3.0	152.9 ± 3.6	186.1 ± 4.1	275.9 ± 5.7	81.7 ± 3.3	5.2 ± 0.4
Hardi ISO Injet 110 02	3	0.8	VC	281.6 ± 16	506.8 ± 27	644.7 ± 34.2	0.5 ± 0.1	3.7 ± 0.5	181.1 ± 13.8	240.3 ± 13.8	290.0 ± 13.9	422.7 ± 20.4	122.1± 17.9	4.6 ± 0.0
Hardi ISO Injet 110 03	3	1.2	VC	324.3 ± 11.2	537.4 ± 16.9	689.1 ± 8.2	0.3 ± 0.1	2.2 ± 0.5	216.2 ± 23.2	281.2 ± 22	332.3 ± 19.6	464.8 ± 12.4	152.6 ± 35.4	4.8 ± 0.1
Hardi ISO Injet 110 04	3	1.6	EC	321.3 ± 18.6	584.0 ± 23.2	733.5 ± 16.6	0.3 ± 0.1	2.8 ± 0.6	198.4 ± 14.5	267.0 ± 17.8	325.0 ± 18.7	481.4 ± 19.7	134.4 ± 13.8	5.6 ± 0.1
Hardi ISO Injet 110 06	3	2.4	EC	331.2 ± 12.6	610.0 ± 21.2	758.3 ± 15.7	0.3 ± 0.1	2.3 ± 0.4	209.2 ± 13.3	280.5 ± 15.1	340.0 ± 15.5	499.5 ± 16.3	146.0 ± 17.0	5.9 ± 0.3

* BCPC nozzle classification: VF = Very Fine; F = Fine; M = Medium; C = Coarse; VC = Very Coarse; XC = Extremely Coarse

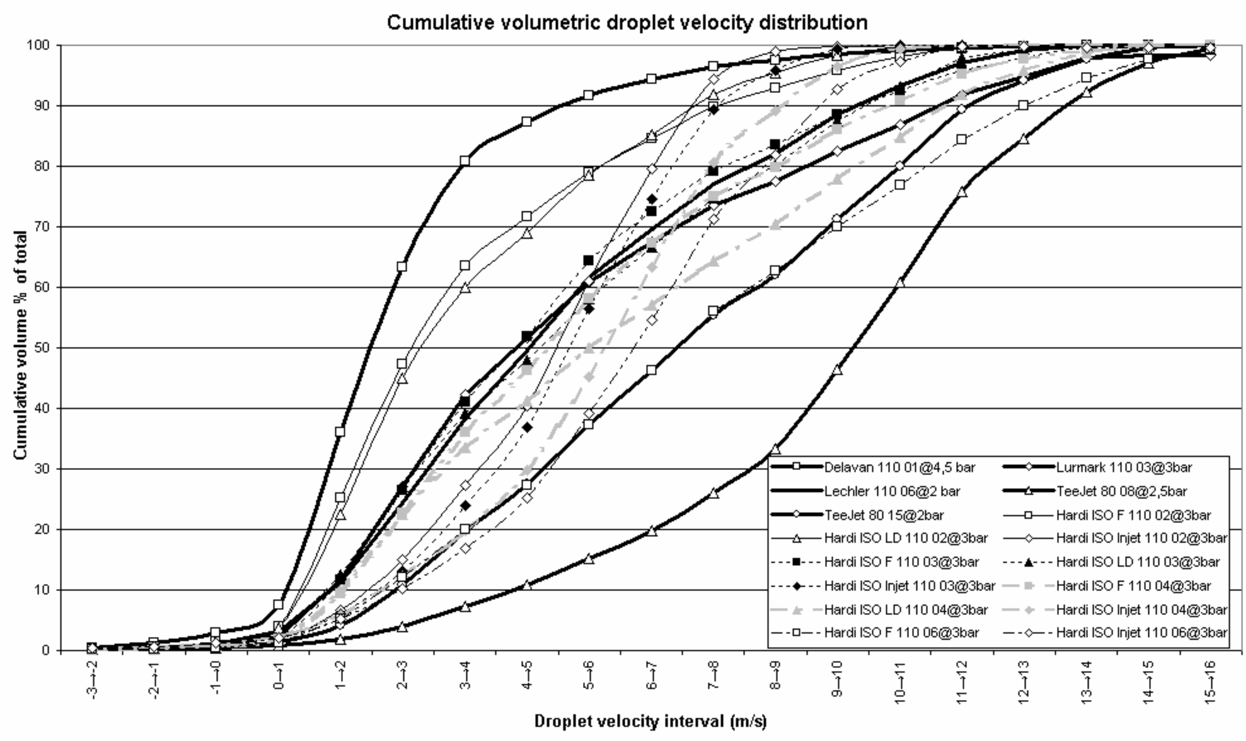


Figure 2. Cumulative volumetric droplet velocity distribution for different Hardi nozzles and the 5 BCPC reference nozzles

Different characteristics have already been measured by other researchers using different techniques. For the BCPC reference nozzle, 17 references ($D_{v0.1}$, VMD and $D_{v0.9}$) were found in total (Western et al., 1989; Barnett & Matthews, 1992; Miller et al., 1995; Hewitt et al. 1998; Porskamp et al., 1999; Womac, 1999; Nilars et al., 2000; Womac, 2000; Herbst, 2001; Powell et al., 2002; Van De Zande et al., 2002). The spreading of these measurements is presented in Figure 3 together with our measuring results.

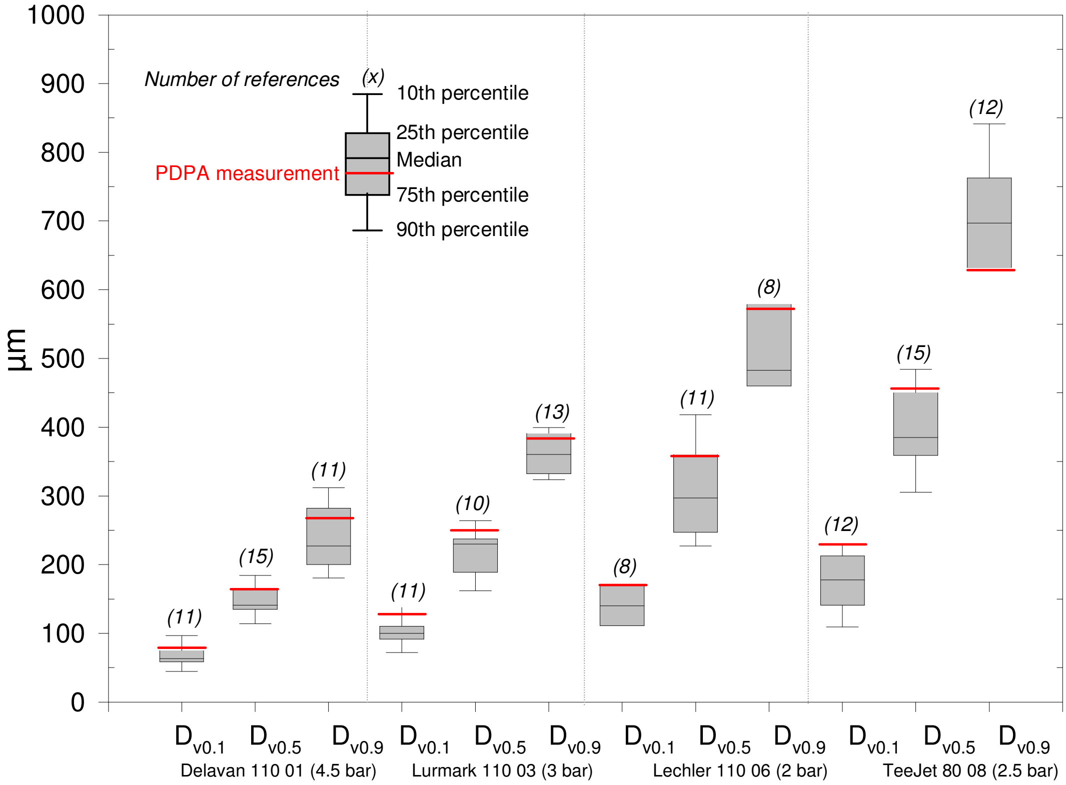


Figure 3. Spreading of measuring results from different researches on BCPC reference nozzles.

It is clear that absolute results differ significantly depending on settings and type of measuring equipment. Differences increase with droplet size. This confirms the need for (BCPC) reference nozzles to classify sprays. In table 4, the BCPC classification for the tested nozzle-pressure combinations is compared with the results of 5 other investigations, also using laser techniques but not considering droplet size class 'extremely coarse'. Despite the wide range of absolute measurements (Fig. 3), classification was identical in 73% of the cases. This quite uniform classification confirms the usefulness of these reference nozzles.

Table 4: *Comparison of BCPC nozzle classification with different other investigations.*

Nozzle type	Pressure (bar)	PDPA Laser	I	II	III	IV	V
Delavan 110 01	4.5	**VF/F**		F			
Lurmark 110 03	3	**F/M**		M			
Lechler 110 06	2	**M/C**		C			
TeeJet 80 08	2.5	**C/VC**		C			
TeeJet 80 15	2	**VC/EC**		VC			
Albuz ATR80 blue	3	**M**					
Albuz ATR80 green	3	**M**					
Albuz ATR80 orange	3	**F**					
Albuz API 110 02	3	**F**		F			F
Albuz API 110 04	3	**M**		M			F/M
Albuz API 110 06	3	**M**		C			M/C
Albuz AXI 110 02	3	**F**		F			F
Albuz AXI 110 04	3	**M**		M			F/M
Albuz AXI 110 06	3	**M**		C			M/C
Albuz ADI 110 02	3	**M**		M			
Albuz ADI 110 04	3	**M**		C			

Nozzle type	Pressure (bar)	PDPA Laser	I	II	III	IV	V
Albuz AVI 110 02	3	**C**		VC			
Albuz AVI 110 04	3	**VC**		VC			
Albuz AVI 110 06	3	**VC**		VC			
Hardi ISO F 110 02	3	**F**	F	F	M	F	F
Hardi ISO F110 03	4	**F**	M	M			F
Hardi ISO F 110 03	3	**M**	M	M	M	M	F
Hardi ISO F110 03	2	**M**	M	M			F/M
Hardi ISO F 110 04	3	**M**	M	M	M	M	F/M
Hardi ISO F 110 06	3	**M**	C	C	C	C	M/C
Hardi ISO LD 110 02	3	**M**	M	M	M	M	
Hardi ISO LD 110 03	3	**M**	C	M	M	C	
Hardi ISO LD 110 04	3	**M**	C	C	M	C	
Hardi ISO Injet 110 02	3	**VC**	VC	VC			
Hardi ISO Injet 110 03	3	**VC**	VC	VC			
Hardi ISO Injet 110 04	3	**EC**	VC	VC			
Hardi ISO Injet 110 06	3	**EC**	VC	VC			

I: Hardi nozzles product guide
II: Huygebaert et al., 2004
III: Nillars et al., 2000 Aerometrics
IV: Nillars et al., 2000 Dantec
V: BCPC nozzle card

italic: BCPC reference nozzles

VF: Very Fine
F: Fine
M: Medium
C: Coarse
VC: Very Coarse
EC: Extremely Coarse
Non classified

Conclusion

Within the framework of a research project about agricultural spray drift, a measuring set-up for the characterisation of spray nozzles using a Phase Doppler Particle Analyser (PDPA) was developed and a measuring protocol was set up. This PDPA is capable of producing huge amounts of useful and informative data, but absolute results differ depending on settings and type of measuring equipment. From the results, the importance of the nozzle type and size on the droplet size and velocity spectra is clear. In future, results will be linked to the drift potential of different nozzle-pressure combinations and used as an input for a Computational Fluid Dynamics spray drift model.

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