Research on Lecher IDK 90 0067 C and AD 90 01 C spray nozzles for drift reduction classification

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The nozzle types Lechler IDK 90 0067 C and AD 90 01 C were investigated to classify the drift reduction potential for downward spray applications at a liquid pressure of 3.0 bar and 3.5 bar, respectively. For the AD 90 01 C nozzles, also the drift reduction potential for upward and sideways applications was investigated at 3.5 bar. The tests followed the procedure described in the Measurement Protocol of the TCT. The uniformity of the spray distribution below a sprayer boom was tested on a patternator at the appropriate nozzle height (for these 90-degree nozzles lowered to 0.30 m). The resulting coefficient of variation (CV) was less than 10%. Measurements of droplet sizes and velocities were done using a PDPA system. For the DRD75 classification for downward spraying, the results of these droplet measurements were used in the IDEFICS spray drift model. Spray drift deposits on a standardized ditch were computed, from which the drift reductions compared to the reference situation were derived. The nozzle type IDK 90 0067 C could be classified as DRD75 at a liquid pressure of 3 bar for downward spray applications. The AD 90 01 C nozzle type could be classified as DRD50 at 3.5 bar liquid pressure for downward spray applications, based on a comparison of the drop size characteristic V_{100}. For upward and sideways spray applications, the latter nozzle type could be classified as DRD75 at 3.5 bar liquid pressure.

Keywords: drop size distribution, spray drift, drift reducing nozzles, classification

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Preface

This study on the drift-reducing properties of spray nozzles for arable crops was commissioned by Lechler GmbH, Germany. The study was supervised by Dr. Robert Heinkel (Lechler GmbH).

Summary

In this study, the nozzle types Lechler IDK 90 0067 C and AD 90 01 C were investigated to classify the drift reduction potential for downward spray applications at a liquid pressure of 3.0 bar and 3.5 bar, respectively. For the AD 90 01 C nozzles, also the drift reduction potential for upward and sideways applications was investigated at 3.5 bar. The uniformity of the spray distribution below a sprayer boom was tested on a patternator for the appropriate nozzle height (for these 90-degree nozzles lowered to 0.30 m). The resulting coefficient of variation (CV) was less than 10%. Measurements of droplet sizes and velocities were done using a PDPA system. For the DRD75 classification for downward spraying, the results of these droplet measurements were used in the IDEFICS spray drift model. Spray drift deposits on a standardized ditch were computed, from which the drift reductions compared to the reference situation were derived. According to the current classification system for drift reducing nozzles, their drift reducing capabilities must be tested at a nozzle height of 0.50 m above the crop canopy. At this nozzle height and a nozzle spacing of 0.25 m, the nozzle type IDK 90 0067 C could be classified as DRD75 at a liquid pressure of 3 bar. For downward DRD50 classification, a comparison is made of the V_{100} values from the droplet measurements for a reference nozzle and the candidate nozzle, from this comparison, the AD 90 01 C nozzle type could be classified as DRD50 at 3.5 bar liquid pressure. Similarly, for all upward and sideways applications, a comparison is done between the candidate nozzle to a class threshold nozzle, from this comparison, the AD 90 01 C nozzle type could be classified as DRD75 at 3.5 bar liquid pressure.

Therefore, the Lechler IDK 90 0067 C is eligible to be used as DRD75 nozzle at a liquid pressure of 3.0 bar in the drift-reducing technique (DRT) of ‘lowered sprayer boom’.

Similarly, the Lechler AD 90 01 C is eligible at a liquid pressure of 3.5 bar to be used as a DRD50 nozzle in the DRT class for ‘lowered sprayer boom’.

Finally, the Lechler AD 90 01 C is eligible at a liquid pressure of 3.5 bar to be used as a DRD75 nozzle in upward and sideways applications.

1 Introduction

The Environmental Activities Decree (MinI&W, 2023) prescribes that when a field crop is sprayed with a boom sprayer, the application technique for the entire field must be at least a 75% drift-reducing technique (DRT75). For example, a standard sprayer equipped with 75% drift-reducing nozzles (DRD75) would suffice. The requirements that must be met regarding the drop size distributions of nozzles in order to be regarded as low-drift are described in two documents: (a) "Beoordelingssystematiek emissiereducerende maatregelen open teelt" (assessment system for emission-reducing measures for field crops; MinI&M, 2017) and (b) "Measurement protocol to determine drift reduction of nozzles for downward-directed and upward/sideways-directed spraying - version 2 November 2021" (MinI&W, 2021; hereinafter simply referred to as 'Measurement Protocol'). The Measurement Protocol also specifies the measurement method to be used in order to apply for certification of a drift reducing nozzle type (i.e. to get a registration on the Dutch DRD list; TCT, 2023a). Drift-reduced nozzles can vary considerably in actual drift reduction. The 'Technische Commissie Techniekbeoordeling' (Technical Committee for Assessment of Techniques; TCT, 2023a) classifies nozzle-pressure combinations into drift reduction classes (DRD50, DRD75, DRD90, DRD95) for use in the various drift-reducing techniques (DRT; TCT, 2023b) and to determine the crop-free zone for intensively sprayed crops. Regarding nozzle types with 80-90 degree top angles, that are intended for use with lowered sprayer boom, the Measurement Protocol requires that the drift reducing capabilities of these nozzles must be tested at nozzle height of 0.50 m, yet the distance between nozzles at the sprayer boom can be 0.25 m.

This study comprises the nozzle types IDK 90 0067 C and AD 90 01 C from Lechler. The IDK 90 0067 C nozzle is already on the DRD list (TCT 2023) with a DRD50 qualification at 7 bar, in this project the goal is to see whether a higher classification is possible using a lower liquid pressure. The second part of the project involves the qualification of nozzle type AD 90 01 C both for downward spraying and for upward and sideways spraying. Applying the rule that larger nozzle types of the same series are allowed to be used at equal liquid pressure and sprayer settings, the AD 90 01 C could replace the AD 90 02 C which was already on the DRD list but its certification has not been prolonged. The project involves flow rate measurements of individual nozzles, measurement of evenness of liquid distribution on a patternator, drop size measurements and spray drift simulations to determine drift reduction capabilities. The measurement of liquid distribution on a patternator was carried out for relevant combinations of nozzle height and nozzle spacing (ISO5682-1, 2014; ISO5682-2; 2017). According to ISO 16122-2 (2015) the coefficient of variation (CV) of such a distribution should be less than 10%, which is adopted by the Measurement Protocol (MinI&W, 2021). Droplet size measurements were made for nozzle-pressure combinations as requested by the client. The resulting droplet size spectra were used in calculations with the IDEFICS spray drift model (Holterman et al., 1997) to determine the drift deposits onto the water surface of a standardized ditch, for all tested situations with a CV from the patternator measurements less than 10%. Drift deposits from the tested nozzle types are compared to those for a situation with reference nozzles, from which drift reductions can be computed. Finally, for the examined nozzle-pressure combinations the eligible classification into drift reduction classes 75, 90 and 95% is indicated, analogous to the method described by Porskamp et al. (1999), ISO22369 (2006) and the Measurement Protocol (MinI&W, 2021).

The AD 90 01 C nozzle type can also be applied for upward and sideways applications. The nozzle classification for fruit growing (Holterman et al., 2015) describes which reference and threshold nozzles are applicable for the various drift reduction classes. For the nozzle classification in fruit growing, droplet size spectra are compared to those of the threshold nozzles of the drift reduction classes to classify the nozzle types appropriately.

2 Methods

For the nozzle types Lechler IDK 90 0067 C and AD 90 01 C (Figure 1), several measurements were carried out subsequently: flow rate measurements of individual nozzles, measurement of evenness of liquid distribution on a patternator, drop size measurements. Finally, for the IDK 90 0067 C nozzles, spray drift simulations were carried out to determine drift reduction capabilities of the nozzle-pressure combination. The AD 90 01 C nozzles only qualified for DRD50 (downward) for which no spray drift simulations are required. Similarly, classifying the AD 90 01 C for upward and sideways applications requires a comparison of drop size distributions only, without spray drift simulations.

Table 1 shows the nozzle type and pressure in the test, together with their potential use. In this case, nozzle types with a top angle of 80-90 degree (such as the nozzles in this study) are intended for use at lowered sprayer boom, i.e. nozzle height is 0.30m and distance between nozzles is 0.25 m. Following the Measurement Protocol, the patternator measurements should be done according to the intended use, that is, at nozzle height of 0.30 m and nozzle spacing 0.25 m. However, the drift reducing capabilities (for DRD75 or higher) must be tested at a nozzle height of 0.50 m above the crop canopy, yet the distance between nozzles at the sprayer boom should be 0.25 m. Table 1 summarizes the nozzle types and their intended use.

Table 1 *Nozzle types and pressures in this study.*

No.	Nozzle type	Liquid pressure [bar]	Nozzle height above crop [m]	Nozzle distance along sprayer boom [m]	Upward and sideways classification [y/n]
1	IDK 90 0067 C	3.0	0.30	0.25	n
2	AD 90 01 C	3.5	0.30	0.25	y

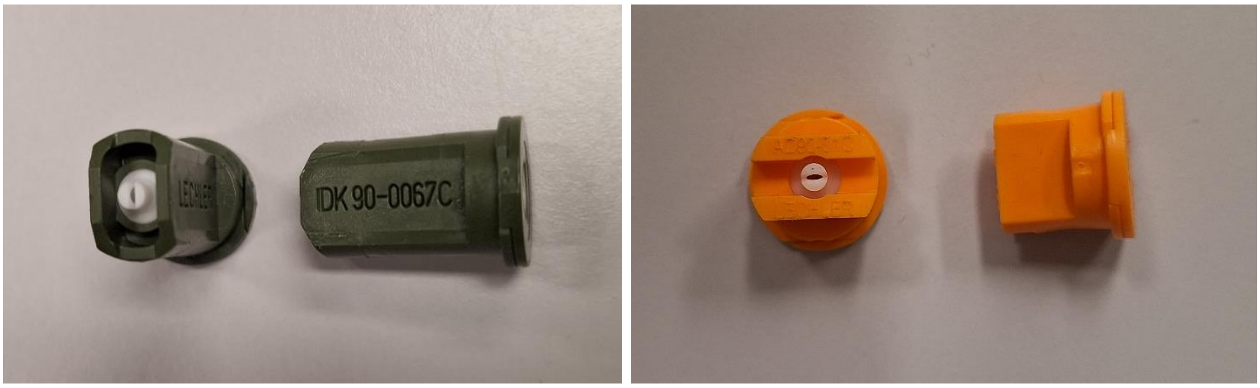

Figure 1 *Nozzle type Lechler IDK 90 0067 C (left) and AD 90 01 C (right).*

2.1 Liquid distribution measurements

In accordance with the Measurement Protocol, the evenness of the liquid distribution below a sprayer boom was tested on a patternator, for the combinations of pressure, height and nozzle distance as given in Table 1. From these distributions, the coefficient of variation (CV) was determined on a basis of 0.10 m gutter widths. According the Measurement Protocol CV should be less than 10%.

At a nozzle spacing of 0.25 m, 10 nozzles could be placed above the patternator. At a nozzle spacing of 0.50 m, there was room for 5 nozzles. The patternator had gutters 0.025 m wide. Combining the liquid flow through 4 of these gutters, the coefficient of variation (CV) based on 0.10 m gutter width could be determined. The CV was computed over a width of 1.00 m at the centre of the patternator. Only combinations that would yield a CV lower than 10% were further investigated in spray drift simulations.

2.2 Drop size measurements

The flow rates of 10 nozzles of each type were measured. The 3 nozzles with flow rate closest to the median flow rate were selected for the drop size measurements. These 3 nozzles were used in measuring the drop size distributions using the PDPA equipment (Phase-Doppler Particle Analyzer; TSI). These drop size measurements were carried out in 3 repetitions. This gave 9 measurements per nozzle-pressure combination. This has to be done only for the combinations where on a spray patternator the coefficient of variation (CV) of the liquid distribution is less than 10%. The measurement chamber was climatized to 20^{o}C and a relative humidity of 70%. The spray liquid was tap water with a temperature of 20^{o}C. The details of the PDPA measurements are described in Annex 1.

Additionally, average droplet velocities were measured at the central axis of the spray cone, as a function of droplet size and distance below the nozzle outlet. From these velocities the entrained air flows were determine, which are required input for the IDEFICS spray drift simulations.

Finally, the Fine/Medium threshold nozzle for downward spray applications (Lurmark 31-03-F110 at 3 bar liquid pressure) of the British Crop Protection Council class classification (BCPC, Southcombe et al., 1997) was measured the same way. This reference nozzle is referred to as BCPC-F/M. The drop size distribution of the reference nozzle was measured on the same days as the nozzle types to be examined were measured.

2.3 Spray drift computations

The results of the measurements of droplet size distribution and droplet velocities were used as input in the drift model IDEFICS (version 1.02; August 2022). According to the Measurement Protocol, for classification as drift-reducing nozzles the spray drift simulations a nozzle height of 0.50 m above the crop is required. This also includes nozzle types with top angles of 80-90 degree which are intended for use with a lowered sprayer boom (nozzle height 0.30 m above the crop) and with a nozzle distance of 0.25 m.

Furthermore, the following settings were applicable:

- location of the last nozzle 0.50 m inside the crop edge *;
- crop height of 0.50 m;
- forward speed of the sprayer 1.67 m/s (= 6.0 km/h);
- sprayer travelling parallel to the crop edge;
- wind direction perpendicular to the (downwind) crop edge;
- wind speed 3 m/s (at 2 m height);
- relative humidity 60%;
- air temperature 15°C;
- neutral atmospheric stability (no thermal effects).

* This is based on a situation with a potato crop where the last ridge is located at 0.75 m from the ditch inlet; at a nozzle spacing of 0.50 m, the outer nozzle is at 0.125 m downwind from the centre of the last ridge; typically, the crop canopy extends up to the inlet. In the calculations with IDEFICS, to correct for a sloping crop canopy edge, the distance from the last nozzle to the crop edge was rounded to 0.50 m (see Figure 2).

Full-field simulations were performed in fivefold, with 30,000 droplets per nozzle, for 14 nozzles distributed over a spray treated width of 50 m. Interpolation and extrapolation for non-simulated nozzles allowed simulation of a full-field spray application.

The results of the model calculations gave deposition values of spray drift on consecutive ground strips with width 0.25 m, starting from the crop edge. These results were processed to average depositions on the evaluation strip 2.125-3.125 m from the last nozzle. This is the location of the water surface of the standardized ditch in the situation with a potato crop (Huijsmans et al., 1997; Figure 2).

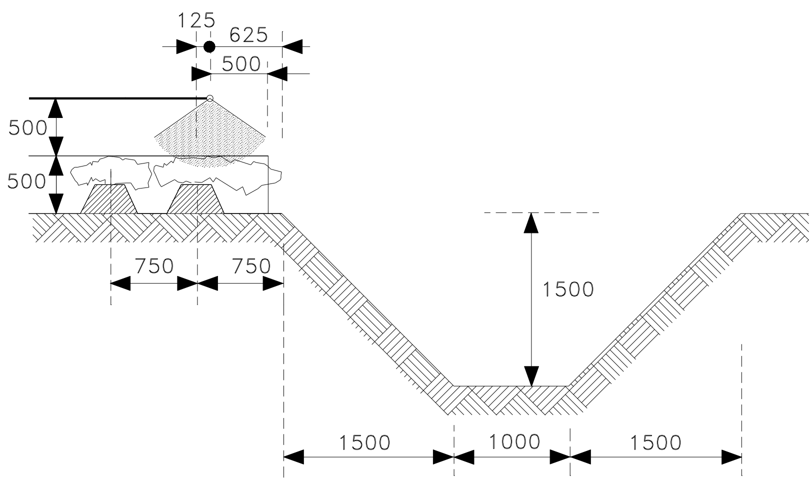

Figure 2 *Overview of the field situation for model calculations for a potato crop (dimensions in mm).*

2.4 Classification into drift reduction classes

Drift reduction was calculated by comparing the spray drift deposits for the full-field spray application with the nozzles to be tested and the deposits for the reference spray application using BCPC-F/M nozzles. Drift reduction classes with at least 50%, 75%, 90% and 95% drift reduction are distinguished. Some statistical dispersion can be expected in various steps of the evaluation process: i.e. in the determination of the average droplet size spectra (which affects the calculated spray drift) and in the results of the spray drift simulations. The repeated measurements of droplet size distributions as well as the repeated spray drift simulations greatly reduce these uncertainties. It turns out that the uncertainty in the calculated drift values is about 1%. It can be deduced that at 75% drift reduction the uncertainty is about 0.4%, at 90% about 0.2% and at 95% about 0.1%. The current classification of nozzle-pressure combinations into drift reduction classes does not take this into account. Analogous to the classifications in Germany (Ganzelmeier and Rautmann, 2000) and England (Gilbert, 2000) and the assessment of results of field tests (ISO-22369, 2006; MinI&M, 2017), the absolute values 50, 75, 90 and 95% have been used to define the limits of the reduction classes.

A nozzle-pressure combination qualifies for the 50% drift reduction class if the measured V_{100} is less than 50% of the V_{100} of the reference nozzle (MinI&W, 2021). No drift simulations are required in this situation.

For the nozzle classification for upward and sideways applications, the V_{100} of the nozzle-pressure combination is compared to the V_{100} values of the threshold nozzles for drift reduction classes established in fruit growing (Holterman et al., 2015). A nozzle-pressure combination can be classified in a certain drift reduction class if the measured V_{100} is equal to or less than the V_{100} of the threshold nozzle of that class, but greater than the V_{100} of the threshold nozzle of the next higher class. The reference and threshold nozzles for fruit cultivation are listed in Table 2.

Table 2 *Reference and threshold nozzles for nozzle classification in fruit production (Holterman et al., 2015).*

Nozzle type	Liquid pressure [kPa]	threshold
Albuz Lilac (ATR 80)	700	REF
Teejet DG 80 02	700	DRD50
Albuz AVI 80 015	700	DRD75
Lechler ID 90 01	500	DRD90
Albuz TVI 80 025	700	DRD95

3 Measurements

3.1 Liquid flow rate

The flow rate of ten nozzles of each nozzle type was measured at a liquid pressure of 3 bar. Three nozzles with flow rates closest to the median flow rate were indicated, in accordance with the Measurement Protocol. Table 3 shows the results.

Table 3 *Measured flow rates of 10 new nozzles and selection of 3 closest to the median flow rate; for the Lechler nozzles at 3 bar liquid pressure.*

Nozzle type	Nozzle number and flow rate [ml/min]										Median	Selected nozzles
	1	2	3	4	5	6	7	8	9	10	[ml/min]	
IDK 90 0067 C	270.0	267.5	265.0	270.0	275.0	270.0	270.0	270.0	267.5	270.0	270.0	1 4 6
AD 90 01 C	765.0	772.5	757.5	745.0	770.0	780.0	777.5	757.5	760.0	762.5	763.8	1 9 10

3.2 Spray liquid distribution on a patternator

The liquid distribution for sprayer booms supplied with the nozzle types to be tested was measured on a spray patternator. The three nozzle types were tested at the specified liquid pressure, as shown in Table 4**.** The nozzle types were tested at nozzle distance of 0.25 m and nozzle height of 0.30 m above the patternator, according to the Measurement Protocol for lowered-boom applications. In both cases the coefficient of variation (CV) was below 10%.

Table 4 *Coefficient of variation (CV) of spray distribution on a patternator for the candidate nozzle types, at the liquid pressure, nozzle distance and nozzle height as indicated.*

Nozzle type	Pressure [bar]	Nozzle height [m]	Nozzle distance [m]	CV [%]
IDK 90 0067 C	3.0	0.30	0.25	4.8
AD 90 01 C	3.5	0.30	0.25	7.0

3.3 Drop size distribution

Drop size distributions were measured using a Phase Doppler Particle Analyzer (PDPA) as described in Annex 1. Table 5 shows the results of the drop size measurements with the PDPA system. Three nozzles of the nozzle type were measured three times, the results represent the average of 9 measurements. The results of the reference nozzle is an averages of 3 measurements. The top angle of the flat fan spray cone is required for the spray drift simulations in the IDEFICS model and is added to the table where required. The last column gives the average number of drops obtained in a single measurement. An overview of results for all drop sizing measurements is given in Annex 2.

Table 5 *Characteristic quantities of the measured drop size distributions, average droplet velocity and number of drops in each measurement. The reference nozzle BCPC-F/M is included. Measured using PDPA.*

Nozzle type	Pressure [bar]	D_{V10} [µm]	D_{V50} [µm]	D_{V90} [µm]	V_{100} [%]	v_{avg} [m/s]	Top angle [°]	Number of drops
BCPC-F/M ref (2022)	3	117.1	222.2	362.6	5.86	3.90	110	34300
IDK 90 0067 C	3	269.6	528.3	850.9	0.48	2.30	55	12800
BCPC-F/M ref (2023)	3	119.4	224.6	364.7	5.57	4.04	110	33000
Fruit reference DRD75	7	147.9	293.2	482.5	3.09	3.69	[1]	18375
AD 90 01 C	3.5	147.1	294.5	448.4	2.66	2.69	[1]	15247

[1] top angles were only measured for the nozzles were IDEFICS calculations would be executed.

3.4 Spray drift simulations and nozzle classification

The IDEFICS spray drift model was used to compute downwind spray drift deposits for a full-field treatment using a sprayer boom equipped with the Lechler IDK 90 0067 C nozzle type at the requested liquid pressure. These spray drift deposits were compared to the deposits for a reference treatment using BCPC-F/M nozzles. The field layout was standardized: crop height 0.50 m, sprayer boom 0.50 m above the crop, first (outer) nozzle positioned at 0.50 m inside the crop edge. Each simulation was carried out 5 times, to improve accuracy and allow estimation of this accuracy.

The results are shown in Table 6. They indicate that at a liquid pressure of 3 bar the nozzle type is within the class of 75% drift reducing nozzles (DRD75), for a nozzle height of 0.50 m.

Table 6 *Computed drift deposits and drift reductions at the location of the standardized ditch (1.625 – 2.625 m from the crop edge[1]), for the Lechler IDK 90 0067 nozzle at the given liquid pressure. Drift reductions are computed with respect to the drift deposits of a reference treatment with BCPC-F/M nozzles. The corresponding classification is added as well.*

Nozzle type	Pressure [bar]	Nozzle distance [m]	Nozzle height [m]	Drift deposits [%dose]	SEM [2] [%dose]	Reduc [3] [%]	Potential reduction class			
							50%	75%	90%	95%
BCPC F/M ref	3	0.50	0.50	2.081	0.017	0				
IDK 90 0067 C	3	0.25	0.50	0.319	0.001	84.7		x		

[1] this corresponds to a distance of 2.125-3.125 m from the outer nozzle.

[2] SEM = standard error of mean, based on 5 independent drift simulations for each case.

[3] Reduction is computed against the average drift deposits for a treatment using BCPC-F/M nozzles.

For a nozzle-pressure combination to qualify for the DRD50 classification, the measured V_{100} should be less than 50% of the V_{100} of the reference nozzle. The V_{100} value of the reference nozzle was 5.97% (Table 5), so the critical value would be 2.99%. The Lechler AD 90 01 C nozzle at 3.5 bar liquid pressure had a V_{100} of 2.66%, this implies that the Lechler AD 90 01 C at 3.5 bar liquid pressure qualifies for the DRD50 class for downwards applications.

3.5 Nozzle classification for upward and sideways applications

For a nozzle-pressure combination to qualify for a certain DRD classification for upward and sideways applications, the measured V_{100} should be less than the V_{100} of the reference nozzle for this class. In Table 5 it can be observed that V_{100} of the Lechler AD 90 01 C nozzle is less than V_{100} of the fruit reference DRD75 nozzle, measured on the same day. This implies that the Lechler AD 90 01 C at 3.5 bar liquid pressure qualifies for the DRD75 class for upward and sideways applications.

4 Conclusion

Classification for downward application

In this study the drift reducing capabilities of the nozzle type Lechler IDK 90 0067 C at a liquid pressure of 3 bar and the Lechler AD 90 01 C at a liquid pressure of 3.5 bar were examined. The nozzle types (in the group of nozzles with 80-90 degree top angles) are intended for use at a lowered sprayer boom. Evenness of the spray liquid distribution below a sprayer boom was tested on a patternator. The examined nozzle-pressure combination passed this test, yielding a coefficient of variation of less than 10%. In accordance with the measurement protocol, DRD50 classifications were done through a comparison of the V_{100} and higher DRD classifications were done using IDEFICS drift simulations.

For the AD 90 01 C nozzles, from the droplet spectrum measurements from the PDPA setup, the V_{100} was compared to the V_{100} of the BCPC-F/M nozzles. The V_{100} of the AD 90 01 C nozzles at 3.5 bar, the V_{100} was less than half the value of the reference BCPC-F/M nozzles and could be classified as DRD50.

For the IDK 90 0067 C nozzles, from the results of spray drift simulations the drift reductions could be determined with respect to a reference spray application using BCPC-F/M nozzles. The examined nozzle-pressure combination could be classified as 75% drift-reducing nozzle types (DRD75).

To conclude, the following nozzle-pressure combinations in this study appear to qualify for classification for downward spray application for use with lowered boom:

- IDK 90 0067 C at 3 bar as DRD75;
- AD 90 01 C at 3.5 bar as DRD50.

Classification for upward and sideways application

Nozzle classification for upward and sideways applications is based on the droplet size distribution; the V_{100} of the candidate nozzles is compared to the V_{100} of the threshold nozzles in fruit growing. For the AD 90 01 C the threshold nozzle for 75% drift reduction applies. The following nozzle pressure combination in this study appears to qualify for classification:

- AD 90 01 C at 3.5 bar as DRD75 for upward and sideways applications.

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Annex 1 PDPA drop size measurements

The droplet size spectrum of spray nozzles was determined with a Phase Doppler Particle Analyzer (PDPA, TSI). The spray liquid was tap water with a temperature of 20°C. The climate chamber was set to a temperature of 20°C and a relative humidity of 70%. During the measurement, the nozzle position described a trajectory of 11 parallel paths (Figure A.1). The length of the paths and the distance between paths were set in such a way that the paths covered the total spray pattern well. The moving speed of the nozzle along the paths was adjusted in such a way that at least 10,000 drops were measured per measurement. The nozzle height was 0.30 m above the measuring plane. The measurement height above the floor was 0.70 m.

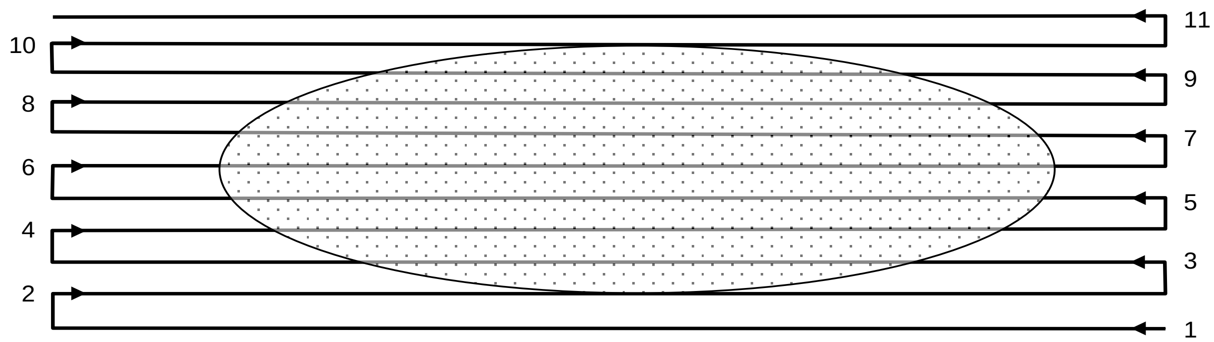

Figure A.1 *Pattern of paths along which the tested nozzle was moved to obtain the drop size distribution averaged over the cross-sectional area of the spray cone in a horizontal plane 0.30 m below the nozzle. Length of the paths and distance between parallel paths were adjusted to fit the cross-section of the spray. Path no. 6 crosses the centre of the spray.*

The PDPA settings were:

• Laser power at measuring point	25 mW
• Focus front lens of transmitter	1000 mm
• Focus front lens of detector	1000 mm
• Expander/contractor	contractor
• Detection angle	40°
• Detector voltage	540 V
• Signal threshold	50 mV
• Measuring range	5 - 1250 μm
• Diameter resolution	2,4 μm
• Probe Volume Correction	yes

The laser power was checked at the start of each measurement and adjusted if necessary. The proper coupling of the laser beams into the glass fibers of the so-called 'fiber drive' was also checked before each measurement, since this fiber connection is sensitive to temperature changes and vibrations. In all cases the laser power in the measurement point was the major quantity to keep constant: this power was kept constant at the stated value of 25 mW.

The results of the drop sizing measurements are presented as D_{V10}, D_{V50}, D_{V90} and V_{100}. These quantities are defined as follows:

- D_{V10} [μm]: 10% of the spray volume consists of droplets with a diameter less than D_{V10};
- D_{V50} [μm] = VMD [μm] (Volume Median Diameter): 50% of the spray volume consists of droplets with a diameter less than D_{V50};
- D_{V90} [μm]: 90% of the spray volume consists of droplets with a diameter less than D_{V90};
- V_{100} [%]: volume fraction of the spray consisting of droplets with diameter less than 100 μm.

Annex 2 Measurements of droplet sizes

Table A.1 *Overview of the drop size characteristics for the BCPC-F/M threshold nozzle at 3 bar liquid pressure; measured using PDPA at the same date on which the Lechler IDK 90 0067 C nozzles were measured.*

Run	Date	D_{V10} [µm]	D_{V50} [µm]	D_{V90} [µm]	V_{100} [%]	v_{avg} [m/s]	Droplet count
1	27-9-2022	117.7	224.3	361.6	5.73	3.96	33840
2		116.4	222.7	370.0	5.95	3.84	35317
3		117.0	219.5	356.3	5.91	3.91	33873
	average	**117.1**	**222.2**	**362.6**	**5.86**	**3.90**	**34343**

Table A.2 *Overview of the drop size characteristics for the BCPC-F/M threshold nozzle at 3 bar liquid pressure; measured using PDPA at the same date on which the Lechler AD 90 01 C nozzles were measured.*

Run	Date	D_{V10} [µm]	D_{V50} [µm]	D_{V90} [µm]	V_{100} [%]	v_{avg} [m/s]	Droplet count
1	28-9-2023	120.6	225.4	366.2	5.39	4.01	32930
2		118.4	224.3	364.3	5.72	4.00	33344
3		119.3	224.2	363.7	5.59	4.10	32726
	average	**119.4**	**224.6**	**364.7**	**5.57**	**4.04**	**33000**

Table A.3 *Overview of the drop size characteristics for the Fruit Reference DRD75 threshold nozzle at 7 bar liquid pressure (Albuz AVI 80 015); measured using PDPA at the same date on which the Lechler AD 90 01 C nozzles were measured.*

Run	Nozzle index	Date	D_{V10} [µm]	D_{V50} [µm]	D_{V90} [µm]	V_{100} [%]	v_{avg} [m/s]	Droplet count
1	4	28-9-2023	142.4	283.2	462.8	3.53	3.57	20283
2	6		149.0	290.3	486.8	2.93	3.85	18263
3	9		152.3	306.0	497.8	2.80	3.66	16578
		average	**147.9**	**293.2**	**482.5**	**3.09**	**3.69**	**18375**

Table A.4 *Overview of the drop size characteristics for nozzle type Lechler IDK 90 0067 C at 3 bar liquid pressure; measured using PDPA.*

Run	Nozzle index	Date	D_{V10} [µm]	D_{V50} [µm]	D_{V90} [µm]	V_{100} [%]	v_{avg} [m/s]	Droplet count
1	1	27-9-2022	265.5	520.6	869.4	0.49	2.33	13452
2	4		271.9	517.1	836.9	0.45	2.29	11622
3	6		271.5	530.2	855.6	0.48	2.26	12533
4	6		278.4	540.6	864.1	0.41	2.33	11364
5	4		272.1	529.4	843.9	0.43	2.37	12223
6	1		267.5	527.3	839.0	0.50	2.38	14065
7	1		257.9	504.0	808.8	0.56	2.28	14254
8	4		273.5	539.5	877.3	0.44	2.29	12458
9	6		268.4	546.2	862.9	0.53	2.21	13258
		average	**269.6**	**528.3**	**850.9**	**0.48**	**2.30**	**12803**

Table A.5 *Overview of the drop size characteristics for nozzle type Lechler AD 90 01 C at 3.5 bar liquid pressure; measured using PDPA.*

Run	Nozzle index	Date	D_{V10} [µm]	D_{V50} [µm]	D_{V90} [µm]	V_{100} [%]	v_{avg} [m/s]	Droplet count
1	1	28-9-2023	152.9	300.2	460.5	2.15	2.74	13227
2	9		143.5	288.1	436.7	2.86	2.68	16267
3	10		146.6	295.2	444.1	2.93	2.68	16297
4	10		148.8	301.3	467.3	2.48	2.73	14871
5	9		144.9	290.1	450.0	2.71	2.70	15722
6	1		146.9	293.4	455.0	2.69	2.67	15505
7	1		147.3	291.9	430.6	2.52	2.65	13622
8	9		145.7	292.2	443.5	2.79	2.67	16209
9	10		146.9	298.1	448.2	2.83	2.66	15507
		average	**147.1**	**294.5**	**448.4**	**2.66**	**2.69**	**15247**

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