Research on spray nozzles from the Teejet AIXR-110 series for drift reduction classification

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This study was carried out by the Wageningen Research Foundation (WR) business unit Agrosystems Research and was commissioned and financed by Teejet Emea BV (project number 3710.499100).

WR is part of Wageningen University & Research, the collaboration of Wageningen University and Wageningen Research Foundation.

Wageningen, December 2023

Report WPR-1280

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Holterman, H.J., D.C. de Hoog, M. Djouhri-Touri, 2023. *Research on spray nozzles from the Teejet AIXR-110 series for drift reduction classification.* Wageningen Research, Report WPR-1280. 24 pp.; 2 fig.; 5 tab.; 16 ref.

This report can be downloaded for free at https://doi.org/10.18174/643335

Seven nozzle types of the series Teejet AIXR-110 were investigated to classify their drift reduction potential for downward spray applications (at different spraying pressures). The uniformity of the spray distribution below a sprayer boom was tested on a patternator at a nozzle height of 50 cm. For all tested nozzle-pressure combinations the resulting coefficient of variation (CV) was less than 10%. Measurements of droplet sizes and velocities were carried out using a PDPA drop sizing system. For some nozzle-pressure combinations, the results of these measurements were used in the IDEFICS spray drift model, as required for a classification of DRD75 or higher. In those cases, spray drift deposits on a standardized ditch were computed, from which the drift reductions compared to the reference situation were derived. The following nozzle-pressure combinations appeared to qualify for classification as DRD50:

- AIXR 110 015 VP at 3 bar
- AIXR 110 015 VK at 2 bar
- AIXR 110 02 VP at 3.5 bar
- AIXR 110 02 VK at 3.5 bar
- AIXR 110 03 VK at 4 bar
- AIXR 110 04 VK at 5 bar
- AIXR 110 05 VK at 6 bar

Next, the following nozzle-pressure combinations appeared to qualify for classification as DRD75:

- AIXR 110 03 VK at 2 bar
- AIXR 110 04 VK at 2 bar
- AIXR 110 05 VK at 3 bar

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

Chamber of Commerce no. 09098104 at Arnhem
VAT NL no. 8065.11.618.B01

Report WPR-1280

Photo cover: Sergey Semenov (pexels.com)

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Preface

This study on the drift-reducing properties of spray nozzles for arable crops was commissioned by Teejet Emea BV, the Netherlands. The study was supervised by Mr. P. Lenaers (Teejet Emea BV).

Summary

In this study, seven nozzle types of the series Teejet AIXR-110 were investigated to classify their drift reduction potential for downward spray applications (at different spraying pressures). The uniformity of the spray distribution below a sprayer boom was tested on a patternator for the appropriate nozzle height (default height 0.50 m). For all nozzle types, at appropriate liquid pressures, the resulting coefficient of variation (CV) was less than 10%. Measurements of droplet sizes and velocities were carried out using a PDPA drop sizing system. For some nozzle-pressure combinations, the results of these measurements were used in the IDEFICS spray drift model, as required for a classification of DRD75 or higher. In those cases, spray drift deposits on a standardized ditch were computed, from which the drift reductions compared to the reference situation were derived. The following nozzle-pressure combinations in this study appear to qualify for classification as DRD50:

- AIXR 110 015 VP at 3 bar
- AIXR 110 015 VK at 2 bar
- AIXR 110 02 VP at 3.5 bar
- AIXR 110 02 VK at 3.5 bar
- AIXR 110 03 VK at 4 bar
- AIXR 110 04 VK at 5 bar
- AIXR 110 05 VK at 6 bar

Next, the following nozzle-pressure combinations in this study appear to qualify for classification as DRD75:

- AIXR 110 03 VK at 2 bar
- AIXR 110 04 VK at 2 bar
- AIXR 110 05 VK at 3 bar

1 Introduction

The Environmental Activities Decree (MinI&W, 2022) 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; TCT, 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.

The Measurement Protocol prescribes that a nozzle type can have a DRD50 classification at a certain liquid pressure when the V_{100} value (defined in Annex 1) of that nozzle-pressure combination is less than half the V_{100} value of a given reference nozzle. To apply for higher DRD classes, spray drift simulations have to be carried out to show the drift reductions correspond to the requested DRD level.

This study deals with testing seven nozzle types from the Teejet AIXR-110 series, namely AIXR 110 015 VP, AIXR 110 015 VK, AIXR 110 02 VP, AIXR 110 02 VK, AIXR 110 03 VK, AIXR 110 04 VK and AIXR 110 05 VK, all intended for downward spray applications. The first five nozzle types of this list have recently been added to the DRD list with a DRD50 registration (TCT, 2023a), based on an interim report of the current project (De Hoog et al. 2023). For convenience and completeness, the results of that interim report have been added to the current final report (this report).

The first goal of this project is to see whether a DRD50 classification of these VP nozzle types is possible at a higher liquid pressure. A second goal of the project is to see, for the VK nozzle types, whether a DRD50 or DRD75 classification is possible and at which liquid pressure.

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 is 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 are made for nozzle-pressure combinations as agreed with the client. For a possible DRD50 classification, the measured drop size distributions are compared to those of the registered reference nozzle. For a possible DRD75 classification, the resulting droplet size distributions are 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 50, 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).

2 Methods

For seven nozzle types of the Teejet AIXR-110 series, as specified in Table 1 and shown in Figure 1, several consecutive measurements were carried out: flow rate measurements of individual nozzles, measurement of evenness of liquid distribution on a patternator, and drop size measurements. The highest liquid pressure for a DRD50 classification was estimated and a full test was carried out at this pressure. For the AIXR nozzle types of size 03, 04 and 05 the classification as DRD75 appeared possible too, at a lower pressure, as indicated in Table 1. In accordance with the Measurement Protocol, for a DRD75 classification, spray drift simulations were carried out to determine drift reduction capabilities of the nozzle-pressure combinations. According to the Measurement Protocol their drift-reducing capabilities should be tested in a standard application (0.50 m nozzle height and 0.50 m nozzle distance).

Table 1 shows that all nozzle types were tested for a DRD50 qualification, while the nozzle types with sizes 03, 04 and 05 were also tested for a DRD75 classification.

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

No.	Nozzle type	Liquid pressure [bar]	Intended DRD class	Nozzle height above crop [m]	Nozzle distance along sprayer boom [m]
1	AIXR 110 015 VP	3	50	0.50	0.50
2	AIXR 110 015 VK	2	50	0.50	0.50
3	AIXR 110 02 VP	3.5	50	0.50	0.50
4	AIXR 110 02 VK	3.5	50	0.50	0.50
5	AIXR 110 03 VK	4	50	0.50	0.50
		2	75	0.50	0.50
6	AIXR 110 04 VK	5	50	0.50	0.50
		2	75	0.50	0.50
7	AIXR 110 05 VK	6	50	0.50	0.50
		3	75	0.50	0.50

Figure 1 *Nozzle types Teejet; top row left to right: AIXR 110 015 VP, AIXR 110 015 VK, AIXR 110 02 VP, AIXR 110 02VK; bottom row left to right: AIXR 110 03 VK, AIXR 110 04 VK, AIXR 110 05 VK.*

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 0.50 m, there was room for 5 nozzles. The patternator had gutters 0.025 m wide. Combining the liquid flow through 4 of these gutters, effectively 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). Drop size measurements were carried out in 3 repetitions, resulting in 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°C and a relative humidity of 70%. The spray liquid was tap water with a temperature of 20°C. Further 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 on which the nozzle types to be examined were measured.

2.3 Spray drift computations

For the nozzle-pressure combinations for which a DRD75 classification was to be expected, the results of the measurements of droplet size distribution and droplet velocities were used as input in the drift model IDEFICS (version 1.04; October 2023). The following settings were applicable:

- location of the last nozzle 0.50 m inside the crop edge *
- crop height of 0.50 m;
- nozzle height above the crop 0.50 m;
- distance between nozzles along sprayer boom 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).

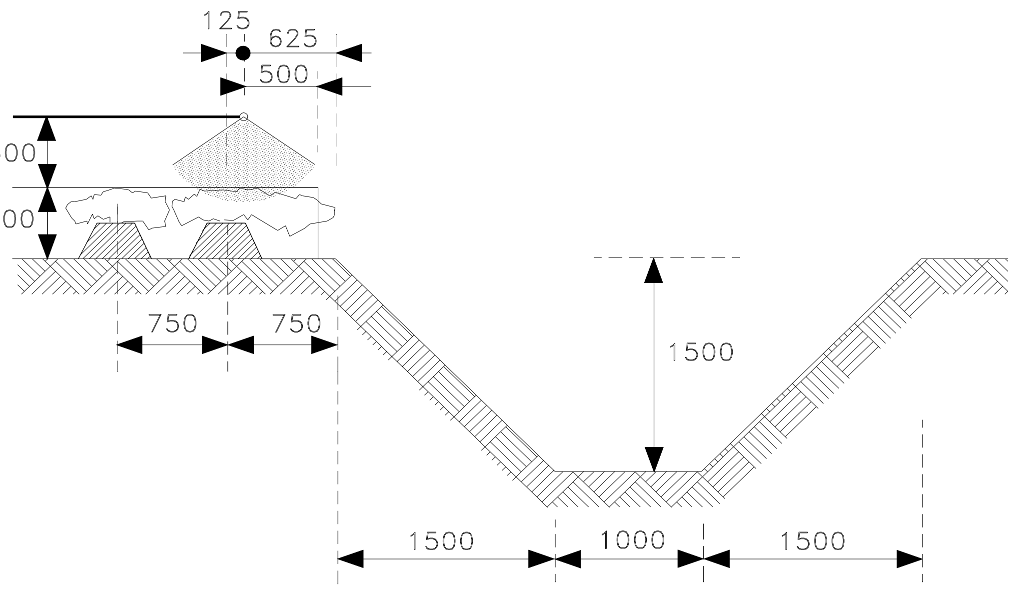

Figure 2 *Overview of the field situation for model calculations for a potato crop (dimensions in mm). In model calculations with lowered sprayer boom, nozzle heights of 300 mm were applied (after Huijsmans et al., 1997).*

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.

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 2 shows the results. In the current study only one of these three nozzles was selected for measuring the drop size distribution.

Table 2 *Measured flow rates of 10 new nozzles and selection of 3 closest to the median flow rate; for the Teejet AIXR nozzles at 3 bar liquid pressure.*

Nozzle type	Nozzle index and flow rate [ml/min]										Median	Selected nozzles
	1	2	3	4	5	6	7	8	9	10	[ml/min]	
AIXR 110 015 VP	600.0	602.5	597.5	597.5	590.0	605.0	590.0	607.5	600.0	605.0	600.0	1 2 9
AIXR 110 015 VK	600.0	600.0	605.0	600.0	597.5	597.5	592.5	600.0	600.0	605.0	600.0	1 2 4
AIXR 110 02 VP	805.0	800.0	785.0	790.0	800.0	800.0	787.5	802.5	800.0	800.0	800.0	2 5 6
AIXR 110 02 VK	785.0	787.5	790.0	787.5	787.5	787.5	787.5	790.0	787.5	785.0	787.5	2 4 5
AIXR 110 03 VK	1182.5	1207.5	1207.5	1177.5	1187.5	1192.5	1207.5	1207.5	1200.0	1202.5	1201.3	2 9 10
AIXR 110 04 VK	1580.0	1580.0	1592.5	1565.0	1607.5	1590.0	1582.5	1590.0	1587.5	1582.5	1585.0	7 9 10
AIXR 110 05 VK	1952.5	1950.0	1925.0	1945.0	1947.5	1947.5	1937.5	1945.0	1952.5	1970.0	1947.5	2 5 6

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 nozzle types were tested at the specified liquid pressure, as given in Table 3. In all cases the coefficient of variation (CV) was below 10%.

Table 3 *Coefficient of variation (CV) of spray distribution on a patternator for the nozzle types Teejet AIXR in this study, at the indicated liquid pressure, nozzle distance and nozzle height.*

Nozzle type	Pressure [bar]	Nozzle height [m]	Nozzle distance [m]	CV [%]
AIXR 110 015 VP	3	0.50	0.50	7.0
AIXR 110 015 VK	2	0.50	0.50	8.4
AIXR 110 02 VP	3.5	0.50	0.50	7.3
AIXR 110 02 VK	3.5	0.50	0.50	4.6
AIXR 110 03 VK	4	0.50	0.50	2.3
	2	0.50	0.50	7.0
AIXR 110 04 VK	5	0.50	0.50	2.7
	2	0.50	0.50	9.5
AIXR 110 05 VK	6	0.50	0.50	4.3
	3	0.50	0.50	8.0

3.3 Drop size distribution

Drop size distributions were measured using a Phase Doppler Particle Analyzer (PDPA) as described in Annex 1. Table 4 shows the results of the drop size measurements with the PDPA system. Three selected nozzles (Table 2) of each nozzle type were measured three times, the results represent the average of 9 measurements. The results of the reference nozzle is an average of 18 measurements, which represents an average over the days at which the different Teejet AIXR nozzles were measured. For nozzle-pressure combinations that could qualify for a DRD75 classification, 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. This involves the AIXR 03, 04 and 05 nozzle sizes at the lower liquid pressure. For cases qualifying for DRD50 no top angle is required, since no spray drift simulations have to be carried out. 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 4 *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	3	115.8	220.1	359.7	6.13	3.97	110	33800
AIXR 110 015 VP	3	170.6	351.1	556.3	1.74	2.38	[1]	11700
AIXR 110 015 VK	2	192.9	404.1	675.3	1.15	2.01	[1]	10900
AIXR 110 02 VP	3.5	167.7	335.4	525.7	1.84	2.98	[1]	14300
AIXR 110 02 VK	3.5	172.7	348.8	575.7	1.72	2.66	[1]	13400
AIXR 110 03 VK	4	181.7	364.9	586.8	1.59	3.04	[1]	14200
AIXR 110 03 VK	2	238.0	473.7	760.7	0.69	2.46	106	13600
AIXR 110 04 VK	5	171.9	351.2	568.3	1.93	3.67	[1]	23100
AIXR 110 04 VK	2	249.6	492.9	779.6	0.56	2.87	110	14900
AIXR 110 05 VK	6	170.1	352.8	587.4	1.97	4.31	[1]	29100
AIXR 110 05 VK	3	224.5	458.9	747.0	0.82	3.57	114	15000

[1] measurement of top angles not required for the nozzle-pressure combinations qualifying for DRD50.

3.4 DRD50 nozzle classification

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 BCPC-F/M was 6.13% (Table 4), so the critical value would be 3.06%. All tested nozzle-pressure combinations shown in Table 4 represent a V_{100} value less than this critical value and therefore are eligible for at least a DRD50 classification. Note that some combinations are intended for a higher classification (DRD75), which will be discussed in the next paragraph.

3.5 Spray drift deposition and nozzle classification

A nozzle classification of DRD75 or higher requires the computation of spray drift reduction using a spray drift model (according to the Measurement Protocol). 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 Teejet AIXR nozzle types in this study, for three nozzle-pressure combinations as mentioned in Table 1. These spray drift deposits were compared to the deposits for a reference treatment using BCPC-F/M nozzles on the sprayer boom. The field layout was standardized: crop height 0.50 m, nozzles height 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 simulation accuracy and allow estimation of this accuracy.

The results are shown in Table 5. They indicate that the tested nozzle-pressure combinations all are within the class of 75% drift reducing nozzles (DRD75).

Table 5 *Computed drift deposits and drift reductions at the location of the standardized ditch (1.625 – 2.625 m from the crop edge[1]), for Teejet AIXR nozzle types at the given liquid pressures. For crop height of 0.50 m and an outer nozzle position 0.50 m inside the crop edge. 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	0.5	0.5	2.136	0.011	0				
AIXR 110 03 VK	2	0.5	0.5	0.482	0.005	77		x		
AIXR 110 04 VK	2	0.5	0.5	0.397	0.003	81		x		
AIXR 110 05 VK	3	0.5	0.5	0.504	0.005	76		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.

4 Conclusion

In this study the drift reducing capabilities of various nozzle types of the Teejet AIXR 110 series were examined. Some nozzle-pressure combinations were tested for a drift reduction of 50% (DRD50), while other cases were tested for a 75% drift reduction (DRD75). Evenness of the spray liquid distribution below a sprayer boom was tested on a patternator. The examined nozzle-pressure combinations passed this test, yielding a coefficient of variation of less than 10%. For a DRD50 classification only the drop size distributions (in particular the V_{100} value) had to be compared to that of the reference nozzle BCPC-F/M. For a DRD75 classification spray drift simulations were carried out. From the results of these simulations the drift reductions could be determined with respect to a reference spray application using BCPC-F/M nozzles.

Classification for downward application
To summarize the results, the following nozzle-pressure combinations in this study appear to qualify for classification as DRD50:
- AIXR 110 015 VP at 3 bar *
- AIXR 110 015 VK at 2 bar *
- AIXR 110 02 VP at 3.5 bar *
- AIXR 110 02 VK at 3.5 bar *
- AIXR 110 03 VK at 4 bar *
- AIXR 110 04 VK at 5 bar
- AIXR 110 05 VK at 6 bar

The combinations marked with * were added to the DRD list recently (TCT, 2023a), based on an interim report of the current project (De Hoog et al. 2023).

Next, the following nozzle-pressure combinations in this study appear to qualify for classification as DRD75:
- AIXR 110 03 VK at 2 bar
- AIXR 110 04 VK at 2 bar
- AIXR 110 05 VK at 3 bar

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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.

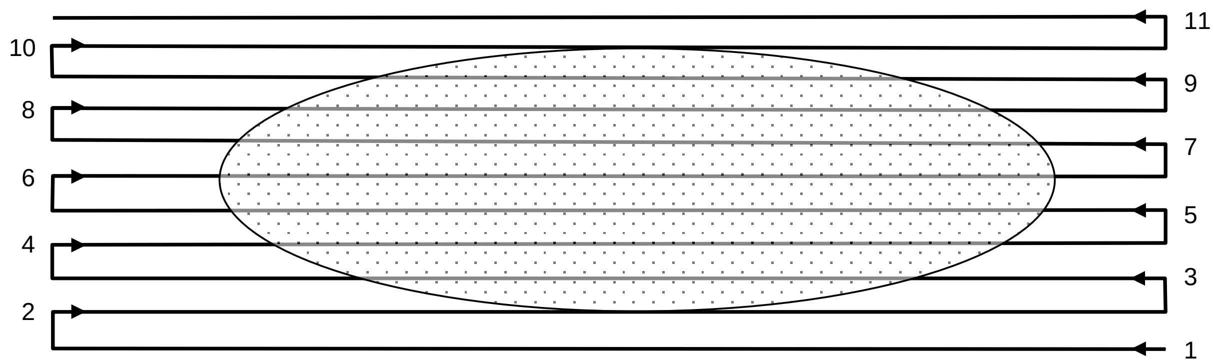

Figure A.1 *Pattern of paths along which the tested nozzle was moved to obtain the drop size distribution averaged over the cross-sectional area of the spray cone in a horizontal plane 0.30 m below the nozzle. Length of the paths and distance between parallel paths were adjusted to fit the cross-section 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

In Table A.1 an overview is given of drop size measurements for the reference nozzle type BCPC-F/M, on the same dates on which the Teejet AIXR nozzles were measured. These reference measurements were combined to the drop size spectrum of the BCPC-F/M to be used in the IDEFICS spray drift simulations.

In Table A.2 through A.11 an overview is given of drop size measurements for the Teejet AIXR 110 nozzle types at the indicated liquid pressures. The averaged drop size spectra were used in the IDEFICS spray drift simulations.

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 dates on which the Teejet AIXR nozzles were tested.*

Run	Date	D_{V10} [µm]	D_{V50} [µm]	D_{V90} [µm]	V_{100} [%]	v_{avg} [m/s]	Droplet count
1	6-9-2023	113.0	219.7	378.0	6.68	3.80	36600
2		117.4	219.1	369.1	5.78	3.90	33000
3		117.0	218.8	353.0	5.93	3.94	33000
4	21-9-2023	113.4	216.7	349.8	6.48	3.94	38100
5		115.6	219.4	364.1	6.13	3.97	35500
6		116.3	219.3	355.7	5.94	3.96	35300
7	3-10-2023	116.7	220.2	354.6	5.87	4.05	32500
8		120.2	227.1	364.8	5.42	4.07	30700
9		119.3	226.8	366.7	5.51	4.06	31600
10	04-10-2023	114.2	217.9	366.2	6.46	3.92	35100
11		114.9	217.6	352.2	6.30	3.94	34200
12		114.4	218.9	355.4	6.44	3.89	33500
13	17-10-2023	120.9	226.7	378.7	5.31	3.97	30300
14		115.8	219.4	355.9	6.09	4.14	30800
15		113.1	219.8	358.7	6.67	3.96	33700
16	02-11-2023	115.1	220.6	360.6	6.32	4.13	35300
17		115.2	217.5	349.8	6.18	3.94	34100
18		112.1	216.3	341.8	6.90	3.95	35900
	average	**115.8**	**220.1**	**359.7**	**6.13**	**3.97**	**33800**

Table A.2 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 015 VP 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	6-9-2023	172.2	355.3	569.7	1.62	2.37	11300
2	2		174.6	351.9	563.4	1.59	2.33	10600
3	9		170.5	352.4	554.1	1.69	2.45	12500
4	9		165.6	347.6	549.7	1.95	2.45	12900
5	2		176.7	360.2	550.1	1.63	2.38	11200
6	1		167.0	350.0	544.4	1.91	2.31	12300
7	1		169.7	345.7	550.4	1.73	2.39	11600
8	2		167.2	351.2	576.9	1.94	2.29	11300
9	9		171.9	345.7	548.3	1.56	2.47	11200
		average	**170.6**	**351.1**	**556.3**	**1.74**	**2.38**	**11700**

Table A.3 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 015 VK at 2 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	6-9-2023	195.7	422.8	715.4	1.10	2.03	10400
2	2		188.6	385.6	607.0	1.14	2.02	10700
3	4		196.6	404.1	678.1	1.07	2.07	10200
4	4		190.7	391.0	640.1	1.14	2.00	10800
5	2		192.9	399.9	633.1	1.13	2.00	10300
6	1		189.5	410.0	739.6	1.28	1.96	11500
7	1		198.9	422.9	740.5	1.09	2.03	10600
8	2		191.1	397.8	644.4	1.26	2.03	11400
9	4		191.7	403.2	679.3	1.17	1.99	11800
		average	**192.9**	**404.1**	**675.3**	**1.15**	**2.01**	**10900**

Table A.4 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 02 VP 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	2	21-09-2023	174.2	345.1	532.5	1.54	2.99	12700
2	5		167.5	336.0	506.5	1.76	2.96	14700
3	6		165.0	330.9	529.3	1.94	3.03	14700
4	6		169.0	335.3	518.8	1.89	3.03	15100
5	5		162.5	332.1	544.5	2.17	2.94	16200
6	2		168.9	340.7	542.4	1.85	2.92	13900
7	2		170.4	345.4	530.8	1.71	2.93	13100
8	5		163.3	324.3	507.9	1.98	2.95	14900
9	6		168.8	329.0	519.0	1.71	3.04	13800
		average	**167.7**	**335.4**	**525.7**	**1.84**	**2.98**	**14300**

Table A.5 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 02 VK 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	2	3-10-2023	175.7	346.4	564.2	1.67	2.72	12800
2	4		168.1	335.9	532.6	1.76	2.69	14000
3	5		176.9	364.7	608.3	1.63	2.56	12900
4	5		178.7	367.5	598.9	1.57	2.62	12200
5	4		166.0	332.6	561.2	1.89	2.68	14900
6	2		170.8	343.4	546.0	1.78	2.69	13600
7	2		173.4	347.4	590.4	1.73	2.64	13500
8	4		167.8	338.5	576.9	1.93	2.68	14900
9	5		177.4	362.4	603.2	1.54	2.65	12000
		average	**172.7**	**348.8**	**575.7**	**1.72**	**2.66**	**13400**

Table A.6 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 03 VK at 4 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	2	3-10-2023	183.0	367.0	587.7	1.57	3.00	14000
2	9		172.6	358.3	562.4	2.04	2.96	16100
3	10		183.0	373.1	632.1	1.52	3.01	13900
4	10		186.3	375.1	620.8	1.54	3.05	13700
5	9		179.0	351.9	565.9	1.62	3.03	14200
6	2		182.8	362.8	597.9	1.44	3.06	13200
7	2		184.3	364.8	570.5	1.45	3.09	13700
8	9		180.8	357.8	553.4	1.55	3.12	14200
9	10		183.8	373.0	590.0	1.58	3.05	14500
		average	**181.7**	**364.9**	**586.8**	**1.59**	**3.04**	**14200**

Table A.7 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 03 VK at 2 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	2	03-10-2023	238.8	470.4	738.0	0.62	2.50	12600
2	9		237.2	473.7	760.2	0.75	2.42	14700
3	10		239.0	483.3	790.6	0.64	2.44	13700
4	10		247.1	506.3	830.4	0.74	2.42	13900
5	9		232.0	460.4	723.2	0.70	2.44	14100
6	2		234.2	462.4	752.3	0.66	2.49	13300
7	2	04-10-2023	238.2	475.3	734.9	0.67	2.47	13600
8	9		232.5	459.0	750.0	0.79	2.45	15400
9	10		243.0	472.5	766.8	0.63	2.51	10900
		average	**238.0**	**473.7**	**760.7**	**0.69**	**2.46**	**13600**

Table A.8 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 04 VK at 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	7	17-10-2023	177.6	361.8	573.6	1.70	3.75	21700
2	9		167.0	336.9	535.4	2.08	3.66	24200
3	10		173.3	362.6	592.0	1.99	3.65	22800
4	10		172.0	357.3	567.7	2.03	3.62	23300
5	9		168.9	338.3	547.3	1.96	3.73	23900
6	7		172.6	347.3	553.4	1.87	3.67	21800
7	7		173.9	356.8	576.5	1.90	3.74	22900
8	9		167.0	338.9	554.5	1.99	3.62	25400
9	10		175.0	361.0	614.6	1.86	3.58	21600
		average	**171.9**	**351.2**	**568.3**	**1.93**	**3.67**	**23100**

Table A.9 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 04 VK at 2 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	7	17-10-2023	246.3	480.9	753.2	0.57	2.83	14600
2	9		243.2	473.0	754.3	0.62	2.92	16000
3	10		261.2	523.5	818.8	0.45	2.88	13200
4	10		257.7	514.8	827.1	0.56	2.76	14400
5	9		242.5	480.1	771.6	0.60	2.91	15900
6	7		247.6	496.0	771.0	0.58	2.84	14800
7	7		251.3	494.9	779.8	0.56	2.88	15000
8	9		244.5	475.7	764.0	0.56	2.92	16100
9	10		252.0	496.9	776.5	0.54	2.86	14100
		average	**249.6**	**492.9**	**779.6**	**0.56**	**2.87**	**14900**

Table A.10 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 05 VK at 6 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	2	17-10-2023	168.9	349.3	569.2	1.95	4.37	28800
2	5		170.5	351.6	580.3	2.00	4.31	29800
3	6		171.8	357.8	599.2	1.89	4.26	27800
4	6		169.6	360.2	618.0	2.08	4.21	29500
5	5		172.1	356.1	608.5	1.83	4.31	28800
6	2		168.6	349.9	574.6	2.04	4.33	30500
7	2		167.9	346.4	577.6	2.09	4.36	30400
8	5		170.7	346.4	571.7	1.89	4.35	28900
9	6		170.9	357.5	587.2	1.92	4.33	27600
		average	**170.1**	**352.8**	**587.4**	**1.97**	**4.31**	**29100**

Table A.11 *Overview of the drop size characteristics for nozzle type Teejet AIXR 110 05 VK 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	2	02-11-2023	221.4	449.4	737.7	0.88	3.55	16100
2	5		225.5	461.5	748.1	0.85	3.58	15900
3	6		221.7	467.5	762.1	0.92	3.51	14500
4	6		228.0	459.5	743.4	0.80	3.56	14400
5	5		222.0	448.4	708.3	0.86	3.59	14900
6	2		226.7	451.1	756.4	0.76	3.58	14800
7	2		228.9	463.6	742.8	0.78	3.60	15700
8	5		221.8	459.1	754.4	0.77	3.64	14800
9	6		224.6	469.7	769.4	0.74	3.48	13800
		average	**224.5**	**458.9**	**747.0**	**0.82**	**3.57**	**15000**

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Report WPR-1280

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The mission of Wageningen University & Research is "To explore the potential of nature to improve the quality of life". Under the banner Wageningen University & Research, Wageningen University and the specialised research institutes of the Wageningen Research Foundation have joined forces in contributing to finding solutions to important questions in the domain of healthy food and living environment. With its roughly 30 branches, 7,600 employees (6,700 fte) and 13,100 students and over 150,000 participants to WUR's Life Long Learning, Wageningen University & Research is one of the leading organisations in its domain. The unique Wageningen approach lies in its integrated approach to issues and the collaboration between different disciplines.