

Research on TeeJet AI 80 03 VS spray nozzles for drift reduction classification

M. Djouhri-Touri, D.C. de Hoog, H.J. Holterman



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In this study, the nozzle type TeeJet AI 80 03 VS is investigated to classify its drift reduction potential for downward spray applications. The uniformity of the spray distribution below a sprayer boom was tested on a patternator for the appropriate nozzle height (lowered boom: 0.30 m). The resulting coefficient of variation (CV) was less than 10% at 2 bar liquid pressure. Measurements of droplet sizes and velocities were carried out using a PDPA drop sizing system. The results of these measurements were used in the IDEFICS spray drift model, as required for a classification of DRD75 or higher. Spray drift deposits on a standardized ditch were computed, from which the drift reductions compared to the reference situation were derived. The results of this study indicate that nozzle type TeeJet AI 80 03 VS at a liquid pressure of 2 bar qualifies for classification as DRD90 for lowered boom spray applications.

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

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Report WPR-1332

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Contents

Summary	5
1 Introduction	7
2 Methods	8
2.1 Liquid distribution measurements	8
2.2 Drop size measurements	9
2.3 Spray drift computations	9
2.4 Classification into drift reduction classes	10
3 Measurements	11
3.1 Liquid flow rate	11
3.2 Spray liquid distribution on a patternator	11
3.3 Drop size distribution	11
3.4 Spray drift deposition and nozzle classification	12
4 Conclusion	13
References	14
Annex 1 PDPA drop size measurements	15
Annex 2 Measurements of droplet sizes	16



Summary

In this study, the nozzle type TeeJet AI 80 03 VS is investigated to classify its drift reduction potential for downward spray applications. The uniformity of the spray distribution below a sprayer boom was tested on a patternator for the appropriate nozzle height (lowered boom: 0.30 m). The resulting coefficient of variation (CV) was less than 10% at 2 bar liquid pressure. Measurements of droplet sizes and velocities were carried out using a PDPA drop sizing system. The results of these measurements were used in the IDEFICS spray drift model, as required for a classification of DRD75 or higher. Spray drift deposits on a standardized ditch were computed, from which the drift reductions compared to the reference situation were derived. The results of this study indicate that nozzle type TeeJet AI 80 03 VS at a liquid pressure of 2 bar qualifies for classification as DRD90 for lowered boom spray applications.

1 Introduction

The Decision on Activities in the Environment (IPLO, 2024; since 1 January 2024 replacing the former 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, 2024a). Drift-reduced nozzles can vary considerably in actual drift reduction. The 'Technische Commissie Techniekbeoordeling' (Technical Committee for Assessment of Techniques; TCT, 2024a) classifies nozzle-pressure combinations into drift reduction classes (DRD50, DRD75, DRD90, DRD95) for use in the various drift-reducing techniques (DRT; TCT, 2024b) 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.

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 the nozzle type TeeJet AI 80 03 at 2 bar, intended for a lowered boom application.

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 DRD 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. 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 the TeeJet AI 80 03 VS nozzle type, 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. For a DRD75 classification or higher, spray drift simulations were carried out to determine drift reduction capabilities of the nozzle-pressure combination. 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. Table 1 shows that the nozzles were tested for a DRD90 qualification, in combination with a lowered boom application.

Table 1 Nozzle type and pressure in this study.

No.	Nozzle type	Liquid pressure [bar]	Intended DRD class	Nozzle height above crop [m]	Nozzle distance along sprayer boom [m]
1	AI 80 03 VS	2	90	0.30	0.25



Figure 1 The TeeJet AI 80 03 VS nozzle.

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 combination 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 to the Measurement Protocol CV should be less than 10%.

At a nozzle spacing of 0.25 m, there was room for 10 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 if the tested combination would yield a CV lower than 10%, further investigation in spray drift simulations is carried out.

2.2 Drop size measurements

The flow rates of 10 nozzles 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. 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 determined, 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

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 0.25 m for the candidate nozzles, 0.5 m for the reference nozzles;
- 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).

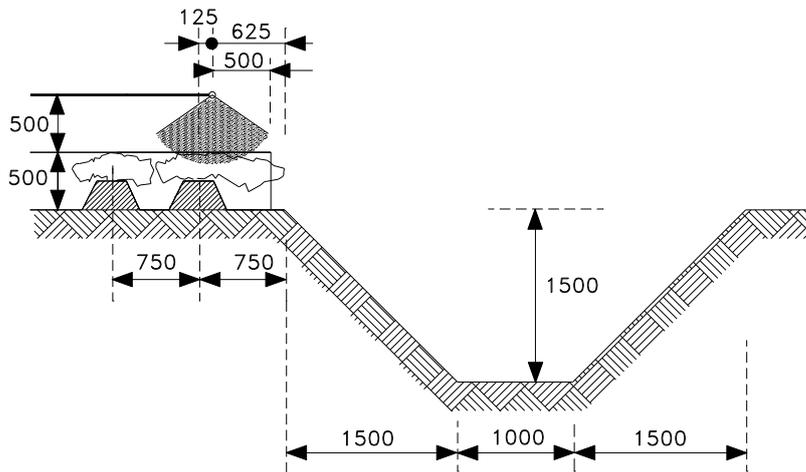


Figure 2 Overview of the field situation for model calculations for a potato crop (dimensions in mm). In model calculations with lowered sprayer boom, nozzle heights of 300 mm were applied (after Huijsmans et al., 1997).

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; MiniI&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 AI 80 03 VS nozzles at 3 bar liquid pressure.

Nozzle type	Nozzle index and flow rate [ml/min]										Median [ml/min]	Selected nozzles
	1	2	3	4	5	6	7	8	9	10		
AI 80 03 VS	1195.0	1195.0	1200.0	1192.5	1187.5	1192.5	1190.0	1197.5	1190.0	1187.5	1192.5	2 4 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 nozzles were tested at the specified liquid pressure, as given in Table 3, the coefficient of variation (CV) was below 10%.

Table 3 Coefficient of variation (CV) of spray distribution on a patternator for the TeeJet 80 03 VS nozzle, at the indicated liquid pressure, nozzle distance and nozzle height.

Nozzle type	Pressure [bar]	Nozzle height [m]	Nozzle distance [m]	CV [%]
AI 80 03 VS	2	0.30	0.25	9.2

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 the nozzles were measured three times, the results represent the average of 9 measurements. The results of the reference nozzle is an average of 6 measurements, which represents an average over the days at which the different TeeJet AI 80 03 VS nozzles were measured. 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. 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	113.9	217.6	359.6	6.51	3.83	110	35900
AI 80 03 VS	2	324.6	651.2	996.4	0.23	3.08	82	15100

3.4 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 AI nozzles in this study. 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 combination is within the class of 90% drift reducing nozzles (DRD90).

Table 5 Computed drift deposits and drift reductions at the location of the standardized ditch (1.625 – 2.625 m from the crop edge¹), for TeeJet AI 80 03 VS nozzles 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	2.245	0.028	0				
AI 80 03 VS	2	0.25	0.5	0.191	0.001	91.5			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 the nozzle type TeeJet AI 80 03 VS at 2 bar liquid pressure was examined. The nozzle-pressure combination was tested for a drift reduction of 90% (DRD90). 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%. For a DRD90 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 combination in this study appear to qualify for classification as DRD90 for a lowered boom spray application:

- Teejet AI 80 03 VS at 2 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.

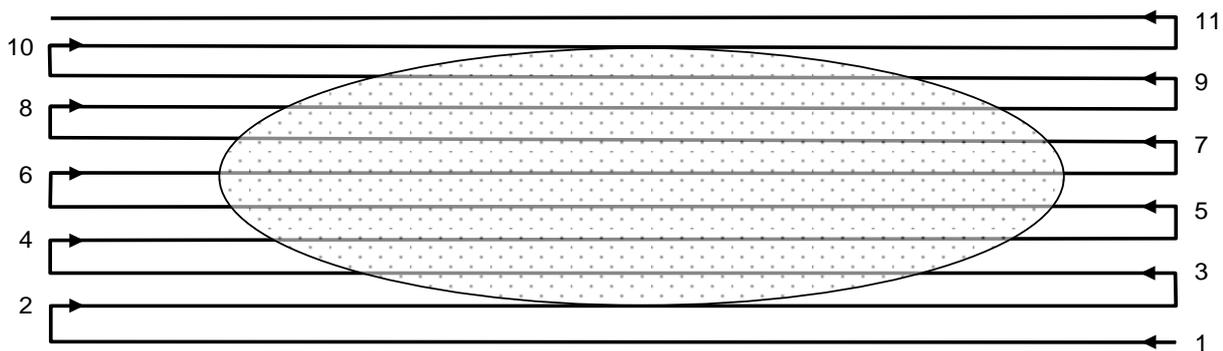


Figure A.1 Pattern of paths along which the tested nozzle was moved to obtain the drop size distribution averaged over the cross-sectional area of the spray cone in a horizontal plane 0.30 m below the nozzle. Length of the paths and distance between parallel paths were adjusted to fit the cross-section 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 AI 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 an overview is given of drop size measurements for the TeeJet AI 80 03 VS nozzles at 2 bar 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 AI 80 03 VS nozzles were tested.

Run	Date	D _{v10} [μm]	D _{v50} [μm]	D _{v90} [μm]	V ₁₀₀ [%]	V _{avg} [m/s]	Droplet count
1	14-3-2024	113.5	218.4	369.6	6.60	4.01	35800
2		113.8	216.7	348.2	6.45	3.97	35600
3		116.5	217.7	365.1	6.06	3.92	33700
4	28-3-2024	113.0	216.9	354.2	6.69	3.76	36200
5		113.7	219.6	367.1	6.49	3.64	36500
6		112.7	216.4	353.6	6.75	3.69	37500
average		113.9	217.6	359.6	6.51	3.83	35900

Table A.2 Overview of the drop size characteristics for nozzle type TeeJet AI 80 03 VS 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	14-3-2024	324.9	653.9	1001.8	0.24	2.96	15000
2	4		320.2	634.3	995.5	0.24	3.07	15100
3	6		321.9	651.2	996.6	0.25	3.05	16200
4	6		322.7	649.6	996.2	0.24	3.09	15400
5	4	28-3-2024	322.7	646.6	975.4	0.25	3.09	15500
6	2		333.4	660.2	1008.5	0.18	3.14	13300
7	2		328.9	668.0	1031.1	0.21	3.08	14400
8	4		325.1	659.6	980.1	0.25	3.11	15300
9	6		321.1	637.5	982.7	0.25	3.12	15600
average			324.6	651.2	996.4	0.23	3.08	15100



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