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Nozzle classification for drift reduction in orchard spraying

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Summary

Due to the high values of spray drift compared to arable field applications the reduction of the emission of plant protection products in fruit growing is still of major importance. Therefore highest priority was given to the development of a nozzle classification system for drift reduction in orchard spraying. In the period 2006–2010 a project was carried out to identify typical threshold nozzles for drift reduction classes 50%, 75%, 90% and 95% drift reduction based on the volume fraction of droplets smaller than 100 micron (V_{100}) in the spray fan. With these identified nozzles, spray drift measurements were performed, spraying an apple orchard to verify the expected drift reduction in the field. Measurements were performed in the dormant situation and in the full leaf stage of the tree canopy. Also spray drift measurements were done taking into account one-sided spraying of the outside tree row. This paper describes how laboratory measurements of the V_{100} can be used to classify spray nozzles for drift reduction in orchard spraying The results of the spray drift field measurements with the drift reduction class threshold nozzles will be used in a certification procedure of drift reducing nozzles for orchard spraying in the Netherlands.

Key words: Spray nozzle classification, fruit crop spraying, spray drift, spray drift reduction, low drift nozzle

Introduction

Due to the high values of spray drift compared to arable field applications the reduction of the emission of plant protection products in fruit growing is still of major importance. However, research on emission reducing measures is costly. To prioritize research subjects and to use financial funds as economically as possible an Advisory Committee gave unanimously highest priority to the development of a nozzle classification system for drift reduction in orchard spraying.
Decisive arguments were:

- In earlier research it was shown that the combination of reduced air assistance, one-sided (inward) spraying of the outside tree row and a coarse spray quality nozzle reduced drift extensively (Wenneker *et al*., 2005);
- Low drift nozzles can be used on every (already in use) orchard sprayer;
- Low drift nozzles do not require high investment costs from the grower;
- Introduction of low drift nozzles for orchard spraying into practice can be fast;

- Links up with the used system of nozzle classification for drift reduction for field sprayers (Porskamp *et al*., 1999) , and international initiatives on nozzle classification;
- Links up with the drift reduction class systematic used in the authorization procedure of crop protection products (Pesticide Act) and the Water Pollution Act.

In the period 2006–2010 a project was carried out to identify typical threshold nozzles for drift reduction classes 50%, 75%, 90% and 95% drift reduction based on the volume fraction of drops smaller than 100 micron (V_{100}) in the spray fan (van de Zande *et al*., 2008). With these identified nozzles, spray drift measurements were performed, spraying an apple orchard to verify the expected drift reduction in the field. Measurements were performed in the dormant situation (Michielsen *et al*., 2009) and in the full leaf stage of the tree canopy (Stallinga *et al*., 2011). Also spray drift measurements were done taking into account one-sided spraying of the outside tree row. This paper describes how laboratory measurements of the V_{100} can be used to classify spray nozzles for drift reduction and the results of the spray drift field measurements with the drift reduction class threshold nozzles can be used in a certification procedure of drift reducing nozzles in orchard spraying in the Netherlands.

Materials and Methods

The identification of drift reduction class threshold nozzles is done based on drop-size measurements of a series of 30 nozzles which potentially can be used in orchard spraying. Spray quality was quantified using a Phase Doppler Particle Analyser (PDPA, Aerometrics). All measurements were performed on three nozzles – selected from a set of 10 – whose flow rates were closest to the median for each batch. Spray liquid was tap water of 20ºC. Measurements were performed in a conditioned room at 20ºC and 70% RH. Nozzle height above the measuring volume of the laser was 0.50 m. During measurements the nozzle was moved in a 3D-traverse system. Nine tracks were made at distance intervals of 0.04 m, sampling the complete fan and traversing speed was 0.04 m s^{-1} (van de Zande *et al*., 2008). The nozzles were ranked based on their V_{100} – and the reduction in amount of drops smaller than 100 micron (V_{100}) relative to the reference nozzle Albuz ATR Lilac at 7 bar spray pressure (Fig. 1). The suggested threshold nozzles for the drift reduction classes 50%, 75%, 90% and 95% based on the laboratory measurements of the V_{100} in the spray fan (van de Zande *et al*., 2008) are respectively; TeeJet DG8002, Albuz AVI 80015, Lechler ID9001 and Albuz TVI80025 all at 7 bar spray pressure, except for the Lechler ID 9001 which is used at 5 bar pressure (Fig. 2).

These identified threshold nozzles were used on a Munckhof cross-flow fan sprayer to assess spray drift spraying an apple orchard (cultivar Elstar, small spindle trees, 3 m row spacing, 1.2 m tree spacing, eight rows treated; 24 m wide) in the dormant (before 1 May) and the full leaf (after 1 May) stage. Both two-sided spraying as one-sided spraying of the outside tree row was performed. The effect of air assistance was measured using the low and a high gear-box setting of the air assistance of the Munckhof cross-flow fan sprayer. Average air speed at the outlet of the air ducts were 18 m s^{-1} and 21 m s^{-1} for respectively the low and the high air setting of the Munckhof cross-flow fan sprayer. The spray drift measurements were made by spraying the fluorescent tracer Brilliant Sulpho Flavine (BSF) in the leeward outside 20 m of an apple orchard. The measurements of spray drift deposit were made on a short cut grass strip next to the orchard to a distance of up to 25 m from the last tree row. The collectors used were filter material cloths (Technofil TF-280) of 0.50 m × 0.10 m in a continues line up to 15 m and of 1.00 m × 0.10 m at points 20 m and 25 m. At 7.5 m distance a 10 m high measuring pole was placed with double lines of ball shaped collectors (Siebauer 00140) at 1 m interval up to 10 m height. The drift measurements were repeated 10 times. The results of these experiments were used to determine the drift reduction at 4.5–5.5 m, 6–7 m, 7.5–8.5 m, and 10.5–11.5 m distance from the last tree row. These evaluation distances coincide with the surface water area in the Netherlands taking into account 3 m, 4.5 m, 6 m, and 9 m crop-free buffer zones (distance between last tree row and top of the ditch bank) as mentioned in Dutch regulation. Drift reduction is calculated as 1 – the fraction spray deposit of the drift reduction threshold nozzle and spray deposit of the Albuz ATR Lilac (7 bar) at the same distance from the last tree row. The potential use of the threshold nozzles to discriminate in the drift reduction classes 50%, 75%, 90% and 95% drift reduction is indicated for these evaluation zones for both two-sided and one-sided spraying of the outside tree row.

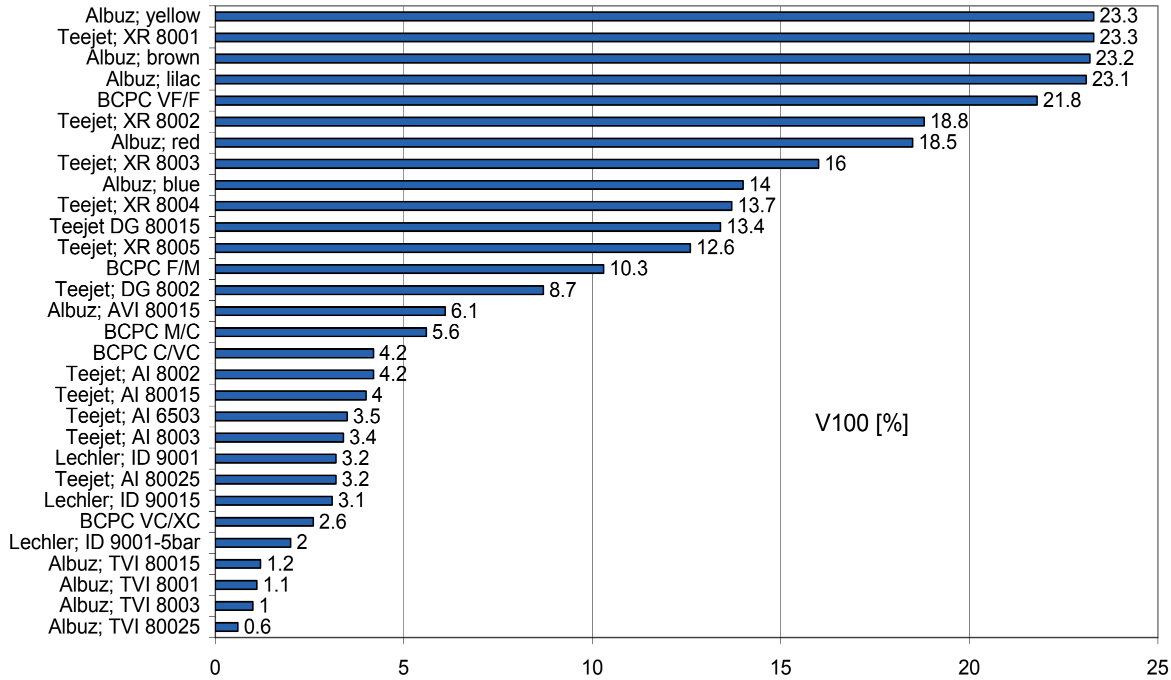

Fig. 1. Evaluated spray nozzles and their volume fraction of drops smaller than 100 micron (V_{100}) to identify the threshold nozzles for the drift reduction classes 50%, 75%, 90% and 95% (van de Zande *et al*., 2008).

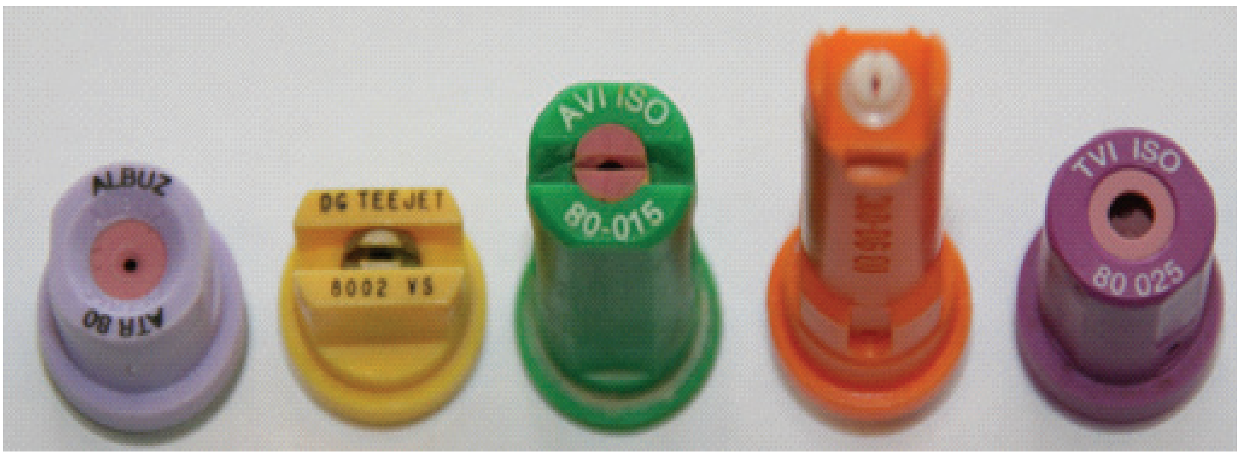

Fig. 2. Reference and threshold nozzles for drift reduction classes 50%, 75%, 90% and 95%.

Results

Dormant situation of orchard

The results of the drift sediment measured in the dormant stage of the apple orchard for the drift reduction class threshold nozzles used on a cross-flow fan sprayer (Munckhof) without the use of air assistance are presented in Fig. 3. The field results were in accordance with the expected drift reduction of the drift reduction class threshold nozzles, which was based on the volume fraction of

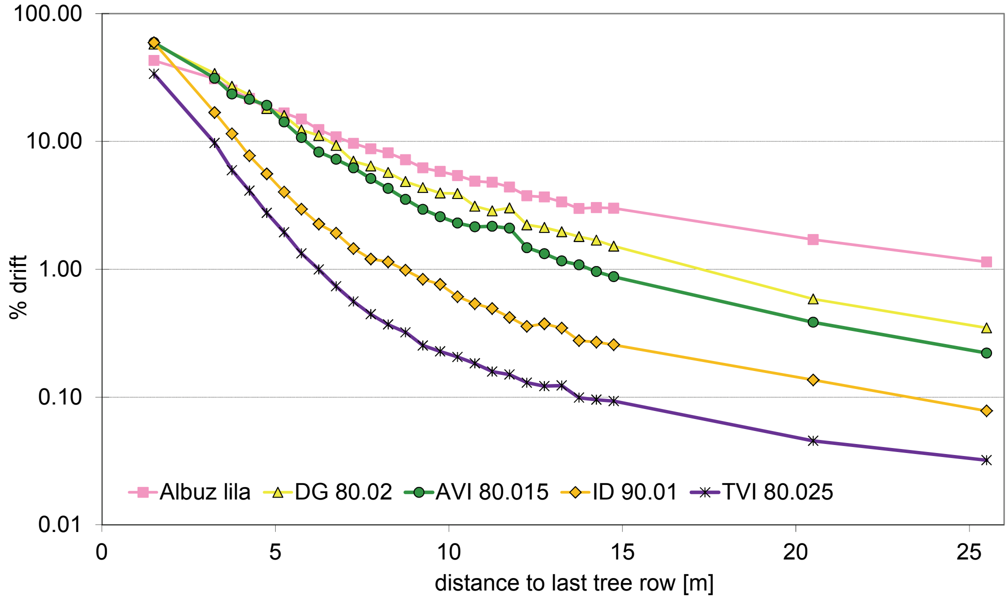

Fig. 3. Spray drift deposition on soil surface next to a dormant apple orchard when spraying with a cross-flow fan sprayer equipped with standard (lilac) and drift reduction class threshold nozzles of the classes 50% (DG), 75% (AVI), 90% (ID) and 95% (TVI) and no air assistance (Munckhof cross-flow fan).

drops smaller than 100 µm. Dependent on the distance of evaluation (e.g. 10 m) a drift reduction of 40%, 60%, 80% and 85% was found for the threshold nozzles in this specific dormant orchard with air setting half air of the cross-flow fan sprayer. (Fig. 4).

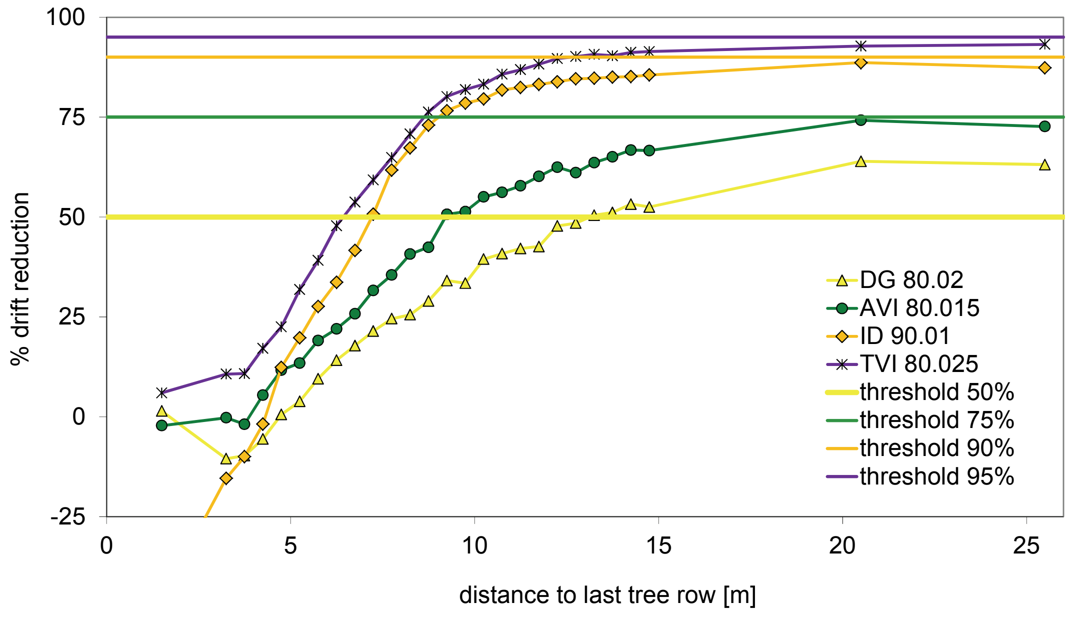

Fig. 4. Spray drift reduction outside the orchard when spraying with different nozzle types and a low setting of air assistance (Munckhof cross-flow fan) in the dormant leaf stage.

Full leaf situation of orchard

Spraying the orchard in the full leaf situation with the air assistance of the sprayer in the high setting the spray drift reduction is as presented in Fig. 5. It is obvious that little drift reduction can be obtained just outside the orchard. The coarse spray quality drift reducing nozzles do have a higher spray deposit at the first 5 m outside the orchard. Spray drift reduction becomes significant from 10 m distance from the last tree row and further downwind. At 10.5–11.5 m distance from the last tree row spray drift reduction was 64%, 72%, 90% and 91% respectively for the 50%, 75%, 90% and 95% threshold nozzle.

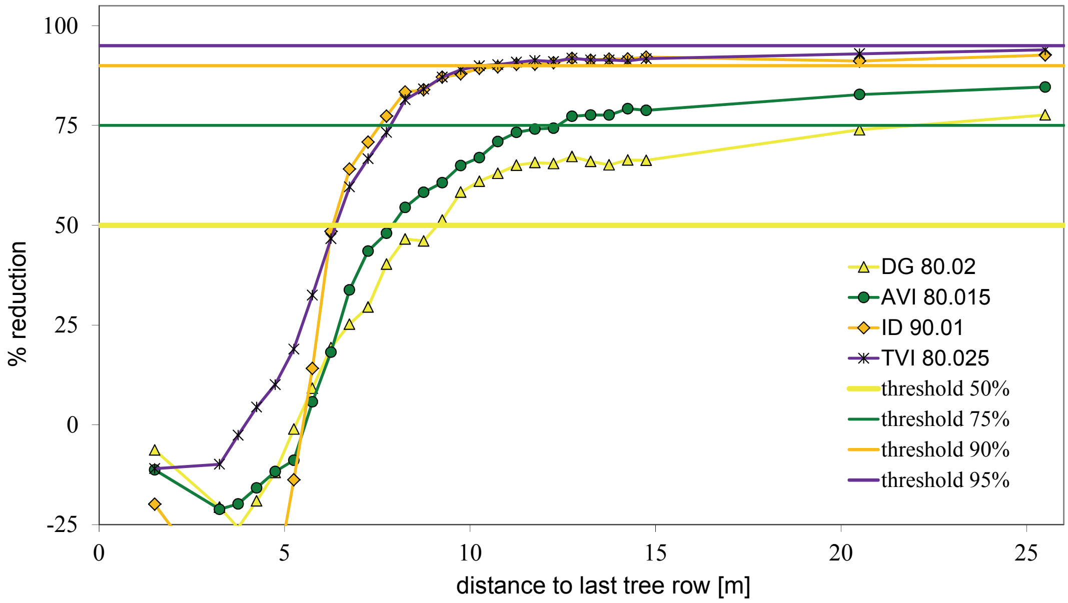

Fig. 5. Spray drift reduction outside the orchard when spraying with different nozzle types and a high setting of air assistance (Munckhof cross-flow fan) in the full leaf stage.

One-sided spraying of outside tree row – full leaf stage

When spraying the outside tree row from the outside of the orchard only (outside path spraying towards orchard and first path not spraying to the outside) the spray drift reduction is as presented in Fig. 6. The high spray deposition in the first 5 m outside the orchard is largely taken away because of one-sided spraying instead of two-sided spraying of the outside tree row. Drift reducing effects of the nozzle types are already obvious at 4.5–5.5 m distance. At 4.5–5.5 m distance from the outside tree row (3 m crop-free buffer zone) the spray drift reduction because of one-sided spraying was for the standard Albuz ATR Lilac nozzle 23%. For the Albuz AVI80015 nozzle it was 77% and for the Albuz TVI80025 it was 91%. At 6–7 m distance from the last tree row (4.5 m crop-free buffer zone) spray drift reduction was 28%, 81% and 95% for respectively the standard, 75% and 95% drift reduction threshold nozzle.

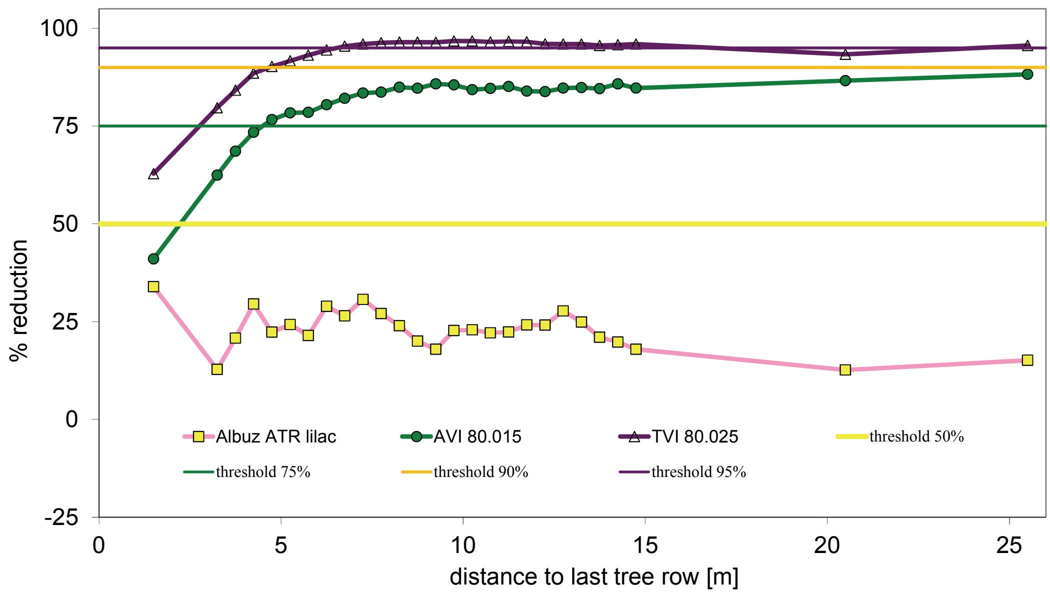

Fig. 6. Spray drift reduction outside the orchard when spraying with different nozzle types and high setting of air assistance (Munckhof cross-flow fan) in the full leaf stage and one-sided spraying of the outside tree row.

Discussion

From the results of Michielsen *et al*. (2009), Stallinga *et al*. (2011) and Wenneker *et al*. (2005), it became clear that the nozzles TeeJet DG 80.02 (7 bar), Albuz AVI 80.015 (7 bar) and Lechler ID 90.01 (5 bar) can be used as threshold nozzles for the drift reduction classes 50%, 75% and 90% when spraying an orchard in the full leaf stage, with a full air setting of the cross-flow fan sprayer, spraying the outside row two-sided and a 9 m crop-free buffer zone. In the full leaf stage of the orchard, spraying the orchard with full air setting of the sprayer, one-sided spraying of the outside tree row and a crop-free buffer zone of 4.5 m the TeeJet DG 80.02, Albuz AVI 80.015, Lechler ID 90.01 (5 bar) and the Albuz TVI 80.025 at 7 bar spray pressure can be used as threshold nozzles for the drift reduction classes 50, 75, 90 and 95 at 6–7 m distance from the last tree row. When spraying the outside tree row one-sided in combination with a 3 m crop-free buffer zone the nozzles TeeJet DG 80.02, Albuz AVI 80.015 and Lechler ID 90.01 (5 bar) can be used as threshold nozzles for the drift reduction classes 50, 75 and 90 at 4.5–5.5 m distance from the last tree row.

Spraying an orchard in the dormant leaf stage of the trees using a low air setting of the sprayer and a crop-free buffer zone of 9 m the nozzles Albuz AVI 80.015 (7 bar), Lechler ID 90.01 (5 bar) and Albuz TVI 80.025 (7 bar) can be used as the threshold nozzles for the drift reduction classes 50%, 75% and 90%. This means that in the dormant situation the threshold nozzles can be used for the identification of a reduction class being one class lower than in the full leaf stage. Air settings of the orchard sprayer and leaf density of the tree canopy influence the level of spray drift but not the relative order of the drift reduction steps of the threshold nozzles.

Based on the laboratory measurements of drop size (van de Zande *et al*., 2008) and the results of the spray drift field measurements about 30 nozzles can be classified and are offered for certification as drift reducing nozzle types in the indicated classes 50%, 75%, 90% and 95% drift reduction (Table 1).

Table 1. *Nozzles used in orchard spraying classified in drift reduction classes based on the volume fraction of drops smaller than 100 µm in the spray fan*

Drift reduction class							
50%		75%		90%		95%	
nozzle	press (bar)	nozzle	press (bar)	nozzle	press (bar)	nozzle	press (bar)
BCPC M/C	2	Lechler ID90015	7				
TeeJet DG8002	7	BCPC VC/XC	2	Lechler IDK9001	2	Albuz TVI80025	7
		Lechler ID9001	7	Lechler IDK90015	2		
		Lechler IDK90015	5	Lechler IDK9002	2		
		TeeJet AI80025	7	Albuz TVI8003	7		
		Lechler IDK9002	5	Albuz TVI8001	7		
		TeeJet AI8003	7	Albuz TVI80015	7		
		TeeJet AI6503	7	Lechler ID9001	5		
		TeeJet AI80015	7				
		TeeJet AI8002	7				
		Lechler IDK9001	7				
		BCPC C/VC	2.5				
		Lechler IDK90015	7				
		Lechler IDK9002	7				
		Albuz AVI80015	7				

The drift reducing effect of the threshold nozzles was effective from 8 m with two-sided spraying and from 3 m from the last tree row with one-sided spraying of the last tree row. For the implementation in Dutch regulation it is suggested that in the full leaf situation drift reduction class nozzles up to 90% drift reduction can be used in combination with one-sided spraying of the outside tree row and the obligatory use of 3 m crop-free buffer zones. With 4.5 m and wider crop-free buffer zones also the 95% drift reduction class can be used (Table 2).

Table 2. *Spray drift reduction (% drift reduction to Albuz ATR lilac at same distance) for the nozzle drift reduction classes and high setting of air assistance in the full leaf situation at different distances to the last tree row for different width of crop-free zones to the last tree row*

Crop-free zone [m]	3 m	4.5 m	6 m	9 m	9 m
Surface water distance [m]	4.5–5.5 m	6–7 m	8.5–9.5 m	10.5–11.5 m	10.5–11.5 m
Spray direction last tree row	one-sided	one-sided	one-sided	one-sided	two-sided
Nominal drift reduction class					
50	68.4	72.0	74.7	75.6	64.0
75	77.0	81.0	84.0	85.0	72.0
90	88.1	90.1	92.6	92.9	90.0
95	91.0	95.0	96.0	97.0	91.0

The introduction of the nozzle classification system for nozzles used in orchard spraying will lead to spray drift reductions, when compared to the nowadays standard situation spraying with Albuz ATR Lilac hollow cone nozzles at a spray pressure of 7 bar and a 3 m crop-free zone, of up to more than 95%, 97.5% and 99% with different combinations of crop-free buffer zones (Table 3). These combinations of spray technique and crop-free buffer zone can be introduced as drift reduction classes in the authorisation procedure.

Table 3. *Spray drift reduction (% drift reduction to Albuz ATR lilac and 3 m crop-free zone) in the full leaf situation for the nozzle drift reduction classes and high setting of air assistance at different distances to the last tree row for different width of crop-free zones to the last tree row*

Crop-free zone [m]	3 m	4.5 m	6 m	9 m	9 m
Surface water distance [m]	4.5–5.5 m	6–7 m	8.5–9.5 m	10.5–11.5 m	10.5–11.5 m
Spray direction last tree row	one-sided	one-sided	one-sided	one-sided	two-sided
Nominal drift reduction class					
standard	*	38.9	68.7	79.1	79.1
50	68.4	82.9	92.1	94.9	92.5
75	77.0	88.4	95.0	96.9	94.1
90	88.1	93.9	97.7	98.5	97.9
95	91.0	96.9	98.7	99.4	98.1

Acknowledgements

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