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Spray drift and spray distribution of end nozzles

By H STALLINGA, J C VAN DE ZANDE, J M G P MICHIELSEN and P VAN VELDE

Wageningen UR Plant Research International,
PO Box 616, 6700 AP, Wageningen, The Netherlands
Corresponding Author Email: hein.stallinga@wur.nl

Summary

In 2011–2012 single nozzle field experiments were carried out to determine the effect of different end-nozzles on minimising 'over-the-edge spraying' and spray drift. Experiments were performed with single nozzle spraying on an outdoor spray track perpendicular to the wind direction. End nozzle types were selected both of the 02 and the 04 sizes and compared with the BCPC threshold nozzle Fine/Medium and a standard flat fan nozzle TeeJet XR11004. Ground deposits were measured from 1 m upwind to 10 m downwind with respect to the nozzle. Differences in spray drift reduction were measured for the different nozzle types. It was obvious that the higher level of drift reduction of end-nozzles coincided also with lower amounts of drop sizes smaller than 100 um in the spray fan. This suggests that also for end-nozzles a drift reduction classification in classes 50%, 75%, 90% and 95% drift reduction can be made.

Key words: Spray drift, end nozzle, spray track, nozzle classification, spray drift reduction, spray quality

Introduction

To prevent spray drift coming into the waterways drift reducing nozzles (50%) and end nozzles are obligatory to be used in The Netherlands spraying alongside surface water. The reason for the use of end nozzles is twofold: minimising 'over-the-edge-spraying' and reducing spray drift by coarseness of the spray quality in combination with the nozzles selected on the spray boom.

In 2009 and 2013 studies were performed with the spray drift model IDEFICS (Holterman *et al*., 1997) to evaluate the drift reducing effects of end nozzles. Holterman *et al.* (2009) found that a single end nozzle can give drift reductions up to 70% compared to a standard flat fan nozzle (Teejet XR11004) in the last nozzle body. They also found that at 2−3 m distance from the last nozzle, when spraying with low-drift nozzles, the use of end nozzles has only minor effect because there is almost no spray drift. The largest effects of end nozzles were found at 0.5–1.0 m off the crop edge. This was also found by Zande *et al.* (2013) who determined that preventing overspray effect of the end nozzle lies, depending on the nozzle type, between 0.90 m and 2.50 m from the nozzle. To verify these studies single nozzle spray drift measurements were performed on an outdoor spray track.

Materials & Methods

An experimental single-nozzle spray carriage was used to pull a single nozzle at constant speed (7.2 km h^{-1}) over a 24 m rail, perpendicular to mean wind direction. The nozzle was placed

0.50 m above a field of cut grass (0.1 m high). The field was chosen for its obstruction-free situation in various directions, to account for a well-developed logarithmic wind profile in the experiments. Ground deposits were measured using synthetic cloths (0.10 × 1.00 m^2) positioned in two parallel rows (2 m apart), from 1 m upwind to 10 m downwind with respect to the nozzle. Airborne drift was sampled at 5 m and 10 m downwind of the nozzle. Airborne spray drift is not subject of this paper. A schematic overview of the experimental layout is shown in Fig. 1.

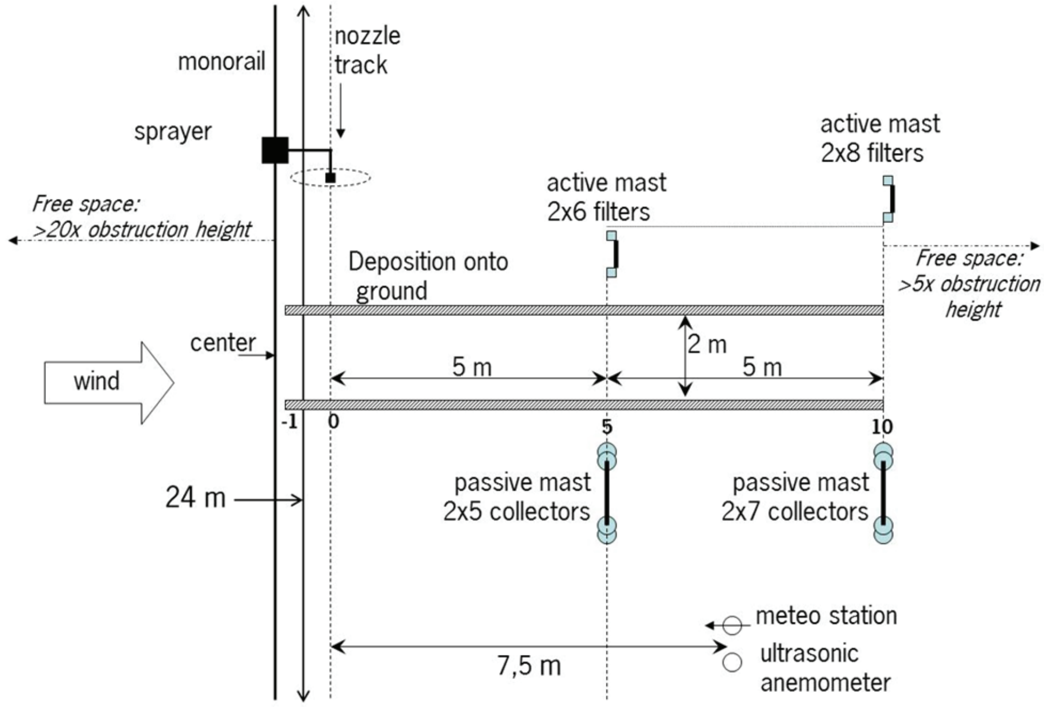

Fig. 1. Schematic overview of the experimental layout.

Eight types of end-nozzles were selected both of the 02 and the 04 sizes and compared with the BCPC threshold nozzle Fine/Medium (Southcombe *et al*., 1997; Lurmark 31-03-F110; 300 kPa; 1.2 L min^{-1}) and a standard flat fan nozzle (TeeJet XR11004; 300 kPa; 1.6 L min^{-1}). The characteristics of the used nozzles are presented in Table 1. In order to be classified as a low drift nozzle in The Netherlands the volume fraction drops smaller than 100 µm (V100 in %) has to be less than half of the V100 of the BCPC F/M (*VW&LNV, 2001*) which in this case is less than 2.23%. Table 1 shows that for all measured nozzles, except the Teejet UB8504, the V100 is less than half of the BCPC F/M and therefor all end nozzles can be classified as a low drift nozzle. A total of 55 experiments were carried out obtaining 3 replications of each end-nozzle. All end-nozzles couldn't be measured on the same day. For comparisons between all experimental days either the BCPC Fine/Medium or the TeeJet XR11004 was measured. Ground deposits were measured using synthetic cloths (0.10 × 0.50 m^2) positioned in two parallel rows (2 m apart), from 1 m upwind to 10 m downwind with respect to the nozzle. The carriage was allowed to run 10 passages before drift and deposition samples were collected. The weather conditions during applications were measured at 5 s time intervals: wind velocity was measured at heights 0.5, 2, 3 and 4 m using cup anemometers, air temperature at heights 0.5 and 4.0 m using Pt100 sensors, and relative humidity and temperature at 1.2 m height using a 'Rotronic' device; wind direction was measured at 4.3 m height. The average wind speed at 0.5 m, 2 m, 3 m and 4 m during the measurements were respectively 2.2(1.6–2.8), 2.8 (2.0–3.7), 3.2 (2.2–4.2) and 3.3 (2.3–4.4) m s^{-1}. The average wind direction was 18º perpendicular to the spray track and therefor driving direction. The average temperature was 16.1ºC and the relative humidity was 66%. The spray liquid was tap water with added fluorescent dye (Brilliant Sulfo Flavine; BSF 3 g L^{-1}) and a non-ionic surfactant (Agral

Gold; 7.5 mL L^{-1}). In the laboratory the BSF was extracted from the collectors with demineralised water. Extracts were analysed by fluorimetry (Perkin Elmer LS 45; wavelengths: excitation 450 nm, emission 500 nm). Spray deposits were expressed as percentage of the applied dose.

Table 1. *Overview of used reference and end nozzles and their spray parameters (3 bar spray pressure and 7.2 km h^{-1} forward speed)*

Manufacturer	Nozzle type	Size	Flow rate (L min)	Spray volume (L ha)	D_{V50} [µm]	V_{100} [%]
TeeJet	XR 110.04	04	1.58	263		4.01
Lurmark	31-03-F110	03	1.24	207	247	4.46
Agrotop	Airmix AM OC	02	0.82	137	459	0.59
TeeJet	AI UB	02	0.78	130	563	0.23
Albuz	AVIOC	02	0.79	132	552	0.33
Hardi	B-Jet	02	0.60	100	480	0.50
Lechler	IDKS	02	0.58	97	417	0.72
Lechler	IS	02	0.60	100	493	0.46
Agrotop	Turbodrop TD OC	02	0.80	133	779	0.08
Agrotop	Airmix AM OC	04	1.61	268	387	1.06
TeeJet	AI UB	04	1.60	267	513	0.35
Albuz	AVIOC	04	1.60	267	465	0.63
Hardi	B-Jet	04	1.35	225	590	0.37
Lechler	IDKS	04	1.19	198	420	0.80
Lechler	IS	04	1.34	223	585	0.33
Agrotop	Turbodrop TD OC	04	1.62	270	556	0.34
TeeJet	UB 8504	04	1.59	265	289	3.09

Results

Spray drift

In Fig. 2 the average spray drift is presented for the 02 size end nozzles in comparison with the BCPC F/M and the XR11004. In Fig. 3 this is done for the 04 size end nozzles. Both figures show the two effects of drift reduction of end nozzles; prevention of over spray and reduction in downwind spray deposition because of spray quality. Between 0.5–1.0 m from the nozzle there is a sharp decline in the drift deposition curve indicating that there is a clear cut-off in the spray distribution which is the end nozzle effect based on its one-sided reduction in top angle. On further distances the drift reducing potential of end-nozzles can be observed depending on nozzle type. Both figures also show that there are differences in spray deposition between the different end nozzles at 0.5–1.0 m and also at further distances. The XR11004 and BCPC F/M give the highest spray drift deposition and the lowest spray drift is found with the use of the TDOC02 and the AIUB02. This coincides with the lower amounts of dropsizes smaller than 100 µm which are 0.08% and 0.23% for the TDOC02 and the AIUB02 respectively in comparison to for instance the 4.46% of the BCPC F/M.

For the 04 series of end nozzle types lowest spray drift deposition is found for the IS04 and the AIUB04. Although not a drift reducing end nozzle following the Dutch V100 threshold the UB8504 results in a 70% drift reduction.

The spray drift reduction of an end nozzle can be determined for an 'over-spray' part at 0.5–1.0 m and a spray quality effect at distances further than 2 m downwind from the nozzle. In Table 2 the effects are presented for the different end nozzle types compared to the BCPC threshold nozzle at 0.5–1.0 m (over-spray) and 2.0–3.0 m (drift reduction because of spray quality).

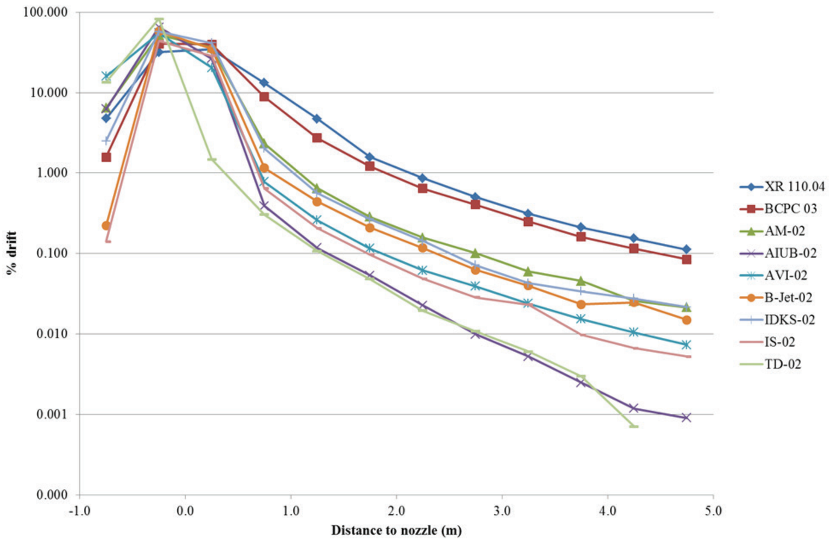

Fig. 2. Average spray drift (% of applied dose) of single nozzle spraying with different 02 end nozzle types and the reference nozzles XR11004 en BCPC F/M (0.0 = nozzle position).

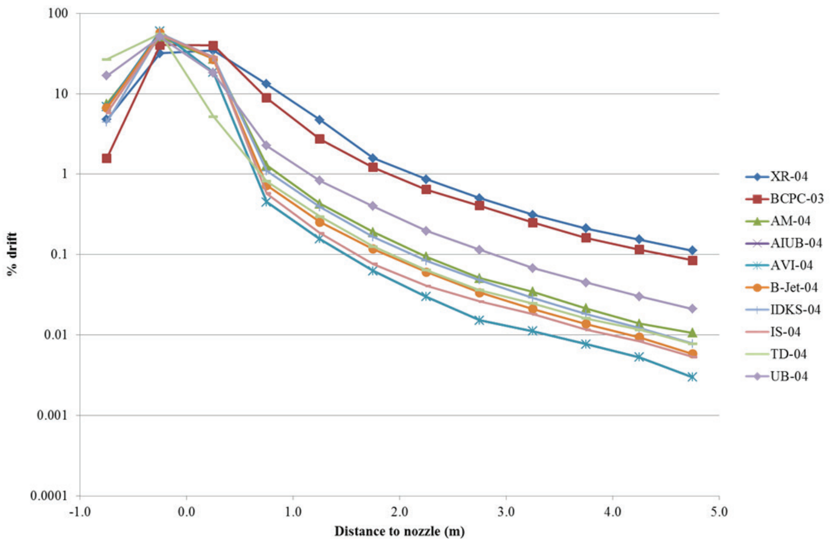

Fig. 3. Average spray drift (% of applied dose) of single nozzle spraying with different 04 end nozzle types and the reference nozzles XR11004 and BCPC F/M (0.0 = nozzle position).

At 0.5–1.0 m from the nozzle spray drift reductions between 74–97% are found (resp. AMOC-02 and TDOC-02). At 2.0–3.0 m drift reductions range between 70–97% (resp. UB-04 and TDOC-02). This indicates that both at 0.5–1.0 m and 2.0–3.0 m end nozzles can be classified in different reduction classes.

At 2.0–3.0 m the end nozzles can be classified in the following drift reduction classes:

50%: UB04;
75%: AM-02, B-Jet-02, IDKS-02, AM-04, AVI-04, IDKS-04;
90%:AVI-02, IS-02, B-Jet-04, IS-04, TD-04;
95%: AIUB-02, TD-02, AIUB-04.

The drift reducing effect of an end nozzle placed on a spray boom

From the single nozzle drift patterns full spray boom simulations can be calculated to evaluate the use of an end-nozzle in the last nozzle body on a spray boom equipped with standard flat fan nozzles or drift reducing nozzles of the 50%, 75% or 90% drift reduction class. Figures 4 and 5 show the effect of end nozzle types on the drift reduction of a spray boom equipped with respectively the 50% drift reducing nozzle DG11004 and the 75% drift reducing nozzle ID12002. The downwind spray drift deposition was compared with a spray boom equipped with XR11004standard flat fan nozzles.

Table 2. *Spray drift reduction (%) of the different end-nozzles compared to the BCPC F/M at 0.5–1.0 m (overspray effect) and 2.0–3.0 m downwind from the nozzle(spray quality effect)*

	Drift reduction (%) at	
Nozzle	0.5−1.0 m	2.0−3.0 m
BCPC F/M	*	*
AMOC-02	74	75
AIUB-02	96	97
AVIOC-02	91	90
B-Jet-02	87	83
IDKS-02	77	80
IS-02	93	93
TDOC-02	97	97
AMOC-04	86	86
AIUB-04	95	96
AVIOC-04	89	85
B-Jet-04	92	91
IDKS-04	88	87
IS-04	94	94
TDOC-04	91	90
UB-04	75	70

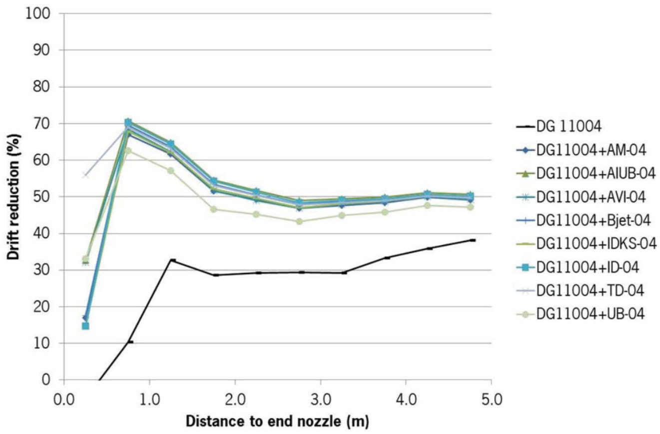

Fig. 4. Simulated spray drift reduction (%) when spraying with DG11004(50% drift reducing) nozzles on a spray boom and different end nozzle types in the last nozzle body.

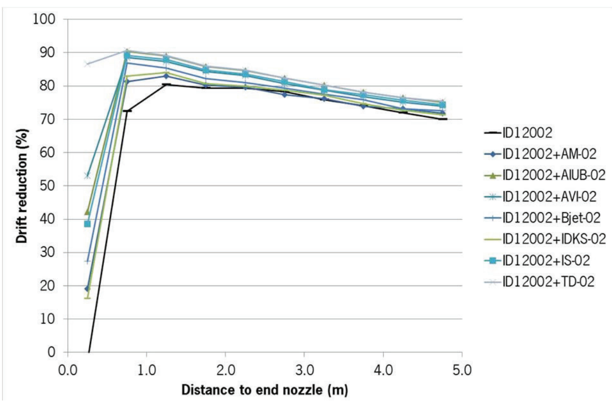

Fig. 5. Simulated spray drift reduction (%) when spraying with ID12002 (75% drift reducing) nozzles on a spray boom and different end nozzle types in the last nozzle body.

Fig. 4 shows that at 2.0–3.0 m the DG11004 (black line) give a drift reduction of approximately 30% compared with the XR11004. The DG11004 with the use of an UB-04 end nozzle gives a drift reduction of 43% which is an extra 13% drift reduction compared with the DG11004 without an end nozzle. Combined with the other end-nozzles the drift reduction is on average 50%, which is 20% extra drift reduction because of the use of the end nozzles. Fig. 5 shows that the effect of an end nozzle on a spray boom with ID12002 nozzles is very limited. At 2.0–3.0 m the maximum extra drift reduction because of the use of an end nozzle was 5% with the TDOC-02.

Discussion

Differences in spray drift reduction were measured for the different end nozzle types. It was obvious that the higher level of drift reduction of end-nozzles coincided also with lower amounts of drop sizes smaller than 100 µm in the spray fan. This suggests that also for end-nozzles a drift reduction classification in classes 50%, 75%, 90% and 95% drift reduction can be made.

It was shown that the contribution on spray deposition and spray drift downwind of the boom still can be lowered by using an end-nozzle. This is especially the case with spray booms using standard flat fan nozzles and 50% drift reducing nozzles and was limited with spray booms equipped with 75% and 90% drift reducing nozzles. Results will be used to further validate the IDEFICS spray drift model.

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