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Spray drift of drift reducing nozzle types spraying a bare soil surface with a boom sprayer

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Summary

In the Netherlands spray drift reduction measures are obligatory when spraying alongside waterways. Drift Reducing Technology (DRT) is certified through standardised spray drift measurements in the field and by means of the classification of drift reducing nozzle types in the laboratory. Approved DRT and classified nozzles in the drift reduction classes 50%, 75%, 90% and 95% are officially published on a website. Since the introduction of the nozzle classification system in 1999, little measurements have been done with higher levels of drift reducing nozzles, and not at all with the recently developed nozzle types. Moreover the initial spray drift measurements in the field to calibrate the spray drift model IDEFICS were performed spraying a potato crop. Therefore a series of measurements was set up to validate the outcome of the spray drift model with field results of some 'old and new' nozzle types spraying a bare soil surface with a boom sprayer. Results are presented for spray drift deposition next to the sprayed swath on bare soil surface and for airborne spray drift measured at 5 m and 10 m distance from the last nozzle up to 6 m height. A comparison is made with the outcome of the classification of the different nozzle types based on spray drift model calculations and the field measurements on bare soil surface. A comparison is also made with the results from the same nozzle types running over a standard drift test bench (ISO22369-3) which were measured under similar conditions in the field.

Key words: Spray drift, Drift Reducing Technology, airborne drift, drift reduction, nozzle classification

Introduction

In the Netherlands spray drift reduction measures are obligatory when spraying alongside waterways. Drift Reducing Technology (DRT) is certified through standardised spray drift measurements in the field (ISO22866; CIW, 2003) and by means of the classification of drift reducing nozzle types (VW & LNV, 2001; Porskamp *et al*., 1999). Approved DRT and classified nozzles in the drift reduction classes 50%, 75%, 90% and 95% are published on the website (TCT, 2013). Nozzle classification in drift reduction classes is done based on spray drift calculations using the IDEFICS model (Holterman *et al*., 1997) under standard field conditions and drop size and drop speed measurements in the laboratory of the specific nozzle. Since the introduction of the classification system in 1999 little measurements have been done with higher levels of drift reducing nozzles, and not at all with the recently developed nozzle types. Moreover the initial spray drift measurements in the field to calibrate the model were only performed spraying a potato crop (Zande *et al*., 2000). Therefore a series of measurements was setup to validate the outcome of the model with field results of some 'old and new' nozzle types spraying a bare soil surface with a boom sprayer. Results are presented for spray drift deposition next to the sprayed swath on bare soil surface and for airborne spray drift measured at 5 m and 10 m distance from the last nozzle up to 6 m height. A comparison is made with the outcome of the classification of the different nozzle types based on model calculations) and the field measurements on bare soil surface to show the similarity (or difference).

A comparison is also made with the results from the same nozzle types running over a standard drift test bench (ISO22369-3; Balsari *et al*., 2007) which were measured under similar conditions in the field.

Materials and Methods

In November 2012 field measurements of spray drift were done to quantify the effect of different drift reducing nozzle types. Measurements were performed spraying a bare soil surface using a 27 m working width John Deere 840i sprayer (Fig. 1). Boom height during measurements was 50 cm above soil surface, nozzle spacing was 50 cm, sprayer speed was 6 km h^{-1} and spray pressure was for some nozzles 3 bar and some 1 bar. Nozzles were selected from earlier measurement (Zande *et al*., 2000, 2012) and from the low drift nozzle list (TCT, 2013) from the classes 75%, 90% and 95% drift reduction. As reference nozzle a Teejet XR11004 nozzle was used sprayed at 3 bar spray pressure. The nozzle types selected were: TeeJet DG11004 pre-orifice flat fan nozzle (50% drift reducing, 3 bar), Agrotop XLTD11004 venturi flat fan nozzle (90% drift reducing, 3 bar), Lechler IDN12003 venturi flat fan nozzle (75% drift reducing, 3 bar), TeeJet AIXR11004 venturi flat fan nozzle (90% drift reducing, 1 bar) and Agrotop Airmix 11004 venturi flat fan nozzle (95% drift reducing, 1 bar). Wind direction during the measurements was ±30^{o} cross to the driving direction of the sprayer. Spray drift measurements were done following ISO22866. Collectors (Technofil TF-290; 0.10 m × 0.50 m) were placed on soil surface at 0.5 m till 6 m distance from the last nozzle and at 10 m, 15 m, 20 m and 25 m (Technofil TF-290; 0.10 m × 1.0 m). At 5 m and 10 m distance from the last nozzle airborne spray drift was measured up till 6 m height using at every metre, ball shaped collectors (Siebauer Abtrifftkollektoren). Spray liquid was tap water with a fluorescent tracer added (Brilliant Sulfo Flavine, BSF, 3 g L^{-1}) and an additive to mimic agrochemical tank mix (Agral Gold, 0.0075%).

Fig. 1. Field measurement of spray drift spraying a bare soil surface.

At the end of the sprayed track a test bench was setup to measure the Drift Potential Value (Fig. 2). Driving direction over the test bench was into the wind direction. The test bench was positioned in the centre of half the boom width (left) parallel to the wind direction.

The same nozzles as used in the field measurements of spray drift were used to quantify DPV on the test bench. Nozzles used in both experiments are specified in Table 1. Collectors used were filter

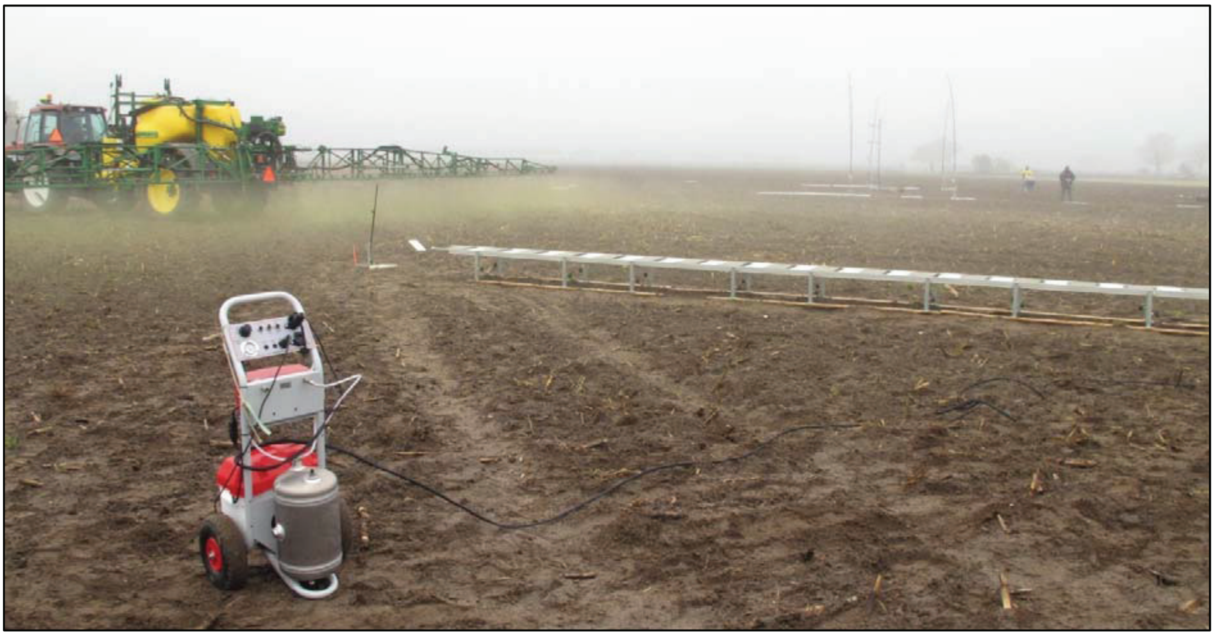

Fig. 2. Spray drift test bench measurement of Drift Potential Value.

material (Technofil TF290), stuck to the positions on pvc plates with velcro tape, and measuring 0.50 × 0.10 m and 1.00 m × 0.10 m for the field lay-out and of 0.25m × 0.10 m for the test bench.

Table 1. *Used nozzles, applied spray volume (l/ha) and typical parameters to specify spray quality as measured with PDPA-system (from Zande* et al.*, 2012)*

Nozzle type	Manufac-turer	Spray pressure [bar]	Nozzle Flow rate [L min^{-1}]	D_{10} (μm)	VMD (μm)	D_{90} (μm)	V100 (% < 100 μm)	Spray volume [L ha^{-1}]
XR 11004	TeeJet	3,0	1,61	140	274	434	3,41	330
DG 11004	TeeJet	3,0	1,64	168	322	507	1,90	335
XLTD 11004	Agrotop	3,0	1,67	251	485	794	0,47	340
IDN 12003	Lechler	3,0	1,20	296	573	913	0,24	245
AIXR 11004	TeeJet	1,0	0,92	348	646	967	0,13	190
Airmix 11005	Agrotop	1,0	1,16	332	648	982	0,17	240

After spraying the collectors were collected and stored for analysis in the laboratory. In the laboratory collectors were diluted with demineralised water (1000 mL for 1.0 m and 0.5 m collectors and 100ml for 0.25 m collectors).

Weather conditions during the drift measurements were recorded. For the field measurements a weather pole was set up in between the two measuring places and a metpak ultrasonic weather station next to the test bench. Average wind speed during the measurements was 2.9 m s^{-1}, temperature was 9^{o}C and wind direction was for the field measurements 20^o perpendicular to the driving direction. Number of repetitions was eight for the field measurements and three for the test bench.

Results

Spray drift field measurements

Results for the spray drift field measurements is presented in Fig. 3 as spray drift deposition (% of sprayed volume) downwind of the sprayed swath (27 m wide). Spray drift deposition decreases with increasing distance from the sprayed swath.

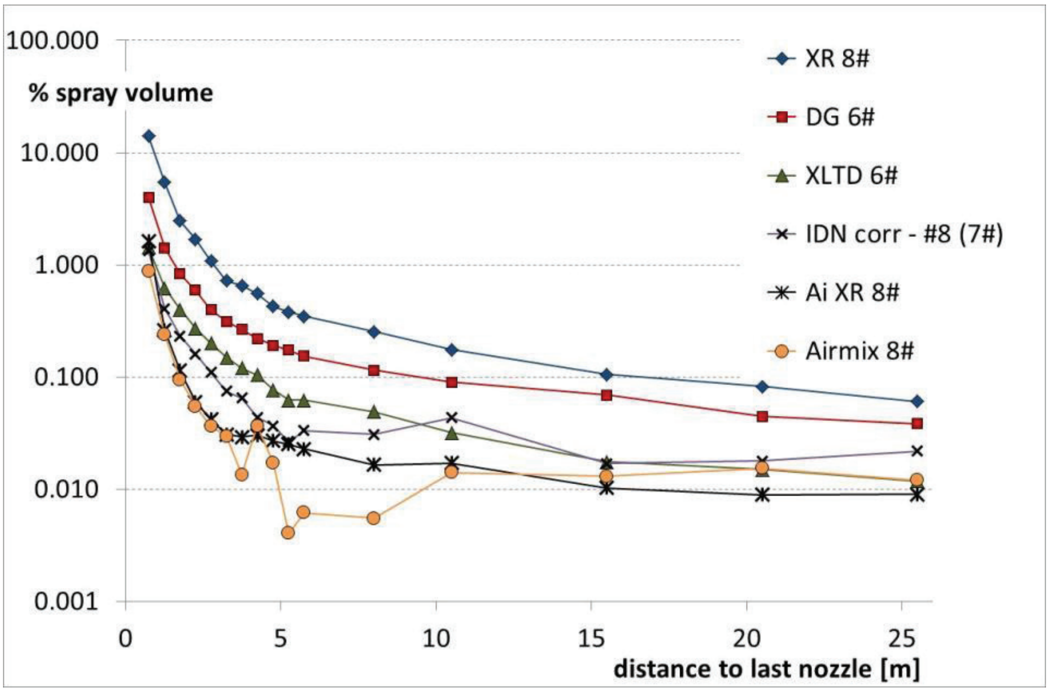

Fig. 3. Average spray drift deposition (% of sprayed volume) downwind of a 27 m sprayed swath of bare soil surface using different nozzle types at a boom height of 50 cm above ground surface and a driving speed of 6 km h^{-1}.

The spray drift deposition is presented at evaluation zones of 2–3 m distance from the last nozzle, which is used in The Netherlands for drift reduction classification as in general that is the area where the surface water is with most arable crops. Following ISO22369-2 (2006) also spray drift deposition is presented for the evaluation zones 1–5 m, 5–10 m, and 10–15 m from the last nozzle to be able to make a better comparison with the results from the test bench and show how spray drift deposition and reduction changes with distance from the treated area (Table 2).

Table 2. *Average spray drift deposition (% of sprayed volume) at different evaluation zones from the last nozzle for different nozzle types downwind of a 27 m sprayed swath of bare soil surface sprayed at a boom height of 50 cm above ground surface and a driving speed of 6 km h^{-1}*

		Evaluation zone [m from last nozzle]							
dop	n ##	2–3 m		1–5 m		5–10 m		10–15 m	
XR	8	1.39	a	1.63	a	0.27	a	0.14	a
DG	6	0.50	b	0.53	b	0.13	b	0.08	b
XLTD	6	0.24	c	0.24	c	0.05	c	0.02	c,d
IDN	7	0.13	c,d	0.14	c	0.04	c,d	0.04	c
AIXR	8	0.05	e	0.07	d	0.03	d	0.02	d
Airmix	8	0.05	e	0.06	d	0.02	e	0.02	d

a) different letters mean significant differences at 95% confidence level.

Spray drift reduction on the presented evaluation zones is calculated relative to the spray drift deposition of the reference XR11004 nozzle in Table 3.

At the NL evaluation zone (2–3 m from last nozzle) the nozzles will be classified (ISO22369-1, 2006) in the classes 50% for the DG11004, 75% for the XLTD11004, 90% for the IDN12003 and 95% for the AIXR11004 and Airmix11005 both at 1 bar spray pressure. This ranking is similar for the 1–5 m evaluation zone but changes for the 5–10 m and 1–15 m zones

(DG in 50% class, XLTD, IDN and AIXR in 75% class and Airmix in 90% class) and to all classified as 75% for the 10–15 m zone except the DG11004 which is lower than 50% class.

Table 3. *Spray drift reduction (%) on different evaluation zones from the last nozzle for different nozzle types downwind of a 27 m sprayed swath of bare soil surface sprayed at a boom height of 50 cm above ground surface and a driving speed of 6 km h^{-1}*

		Evaluation zone [m from last nozzle]				
dop	n ##	2–3 m	1–5 m	5–10 m	10–15 m	1–15 m
XR	8	0	0	0	0	0
DG	6	64%	68%	51%	43%	54%
XLTD	6	83%	85%	83%	83%	83%
IDN	7	90%	91%	86%	75%	84%
AIXR	8	96%	95%	87%	85%	89%
Airmix	8	97%	96%	93%	87%	92%

Airborne spray drift

Airborne spray drift was measured up to 6 m height at 5 m and 10 m distance downwind from the last nozzle (Fig. 4 and Table 4). Airborne spray drift reduced averaged over 6 m measuring height from the XR to the DG, XLTD, IDN, AIXR and Airmix nozzle type, both at 5 m and at 10 m distance from the last nozzle.

Airborne spray drift is highest at 1 m height for the XR, DG and XLTD nozzle type and less clear for the other nozzle types. Airborne spray drift for the XR11004 nozzle (3 bar) is 1.51% at 1 m height and 0.61% over 6 m height at 5 m and reduced to 0.81% at 1 m height and 0.40% over 6 m height at 10 m distance. Airborne drift is lowest for the Airmix 11005 nozzle (1 bar) with highest values at 2 m height of 0.09% at 5 m distance and 0.03% at 10 m distance, and average over height values of 0.03% and 0.02% at respectively 5 m and 10 m from the last nozzle. Airborne drift reduction relative to the XR11004 was at 5 m distance 59% for the DG, 80% for the XLTD, 91% for the IDN, 94% for the AIXR and 95% for the Airmix nozzle types.

Table 4. *Airborne spray drift (average of 6 m height, % of sprayed volume) of different spray nozzles spraying a bare soil surface at 5 m and 10 m distance from the last nozzle and drift reduction relative to XR nozzle*

Nozzle	Airborne drift 5 m	Airborne drift 10 m	Drift reduction 5 m	Drift reduction 10 m
XR	0.61	0.40	reference	reference
DG	0.25	0.18	59%	54%
XLTD	0.12	0.08	80%	80%
IDN	0.06	0.04	91%	90%
AIXR	0.03	0.03	94%	93%
Airmix	0.03	0.02	95%	96%

Spray drift modelling (Zande *et al*., 2012) resulted in spray drift reduction values relative to theXR11004 nozzle of 51% for the DG, 88% for the XLTD, 94% for the IDN, 96% for the AIXR and 96% for the Airmix.

Test bench

Average results (three repetitions) of the spray deposition (% of sprayed volume) deposited on the test bench is presented in Fig. 5.

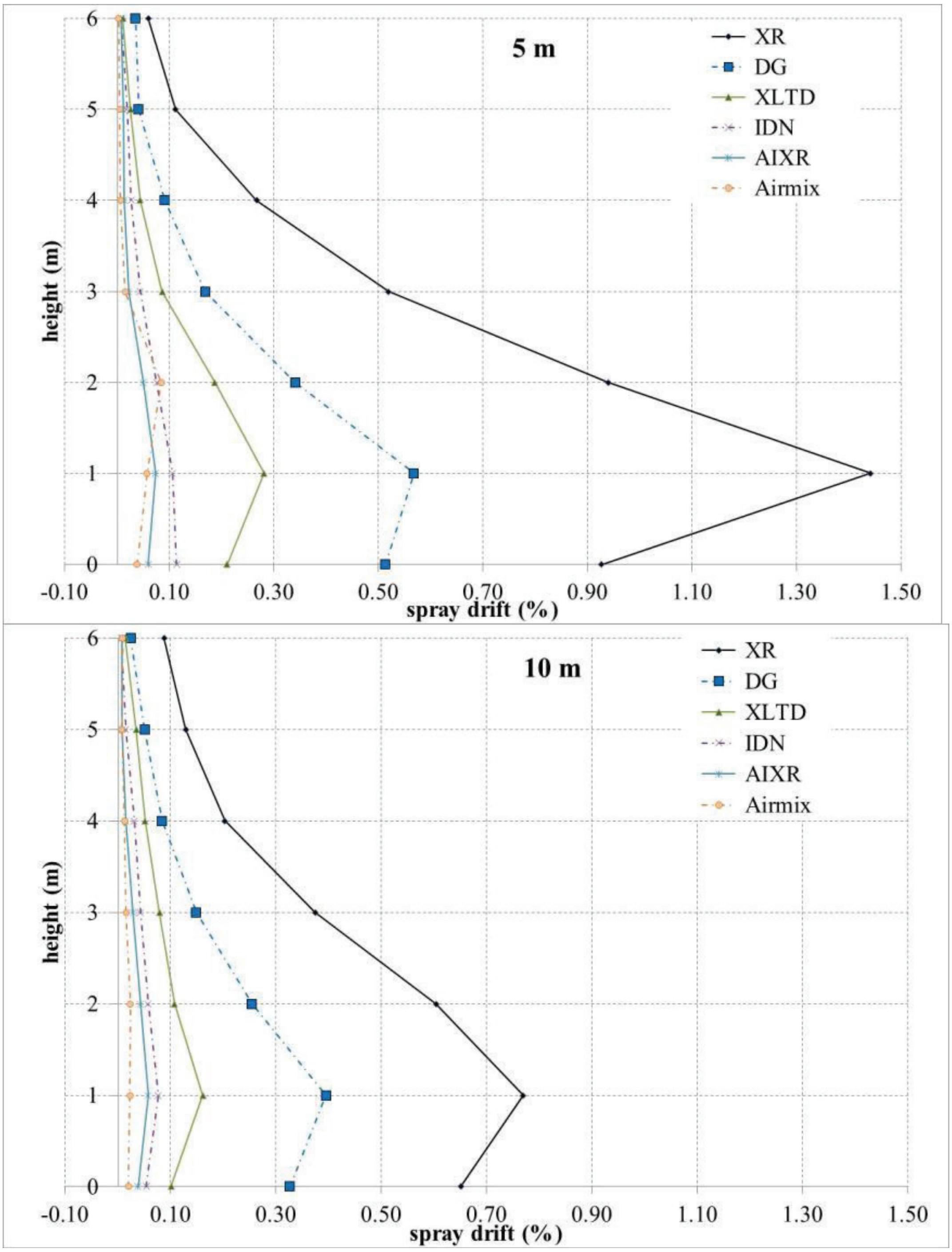

Fig. 4. Airborne spray drift (% of sprayed volume) up to 6 m height measured at 5 m (top) and 10 m (bottom) from the last nozzle for different nozzle types at 6 km h^{-1} forward speed spraying a bare soil surface.

Total spray deposition on the test bench is calculated as Drift Potential Value. Rather large differences were found in the summed spray deposition and therefore DPV values between the repetitions. Coefficients of variation ranged from 5% to 75% for the different nozzle types. Differences between DPV values of the different nozzles are therefore not significant although DPV may decrease by more than half (Table 6). Reduction in DPV values compared to the XR11004 nozzle as reference is 49% for the DG nozzle type, 77% for the XLTD, 79% for the IDN, 91% for the AIXR and 93% for the Airmix nozzle type. At the 95% confidence level the DG is lower than the reference XR nozzle type, and the other nozzles are all lower than the DG nozzle but not different form each other. At the 90% confidence level the Airmix nozzle is different from the XLTD nozzle but not from the IDN and AIXR nozzle type. Clearly more repetitions are needed to make these differences statistically significant.

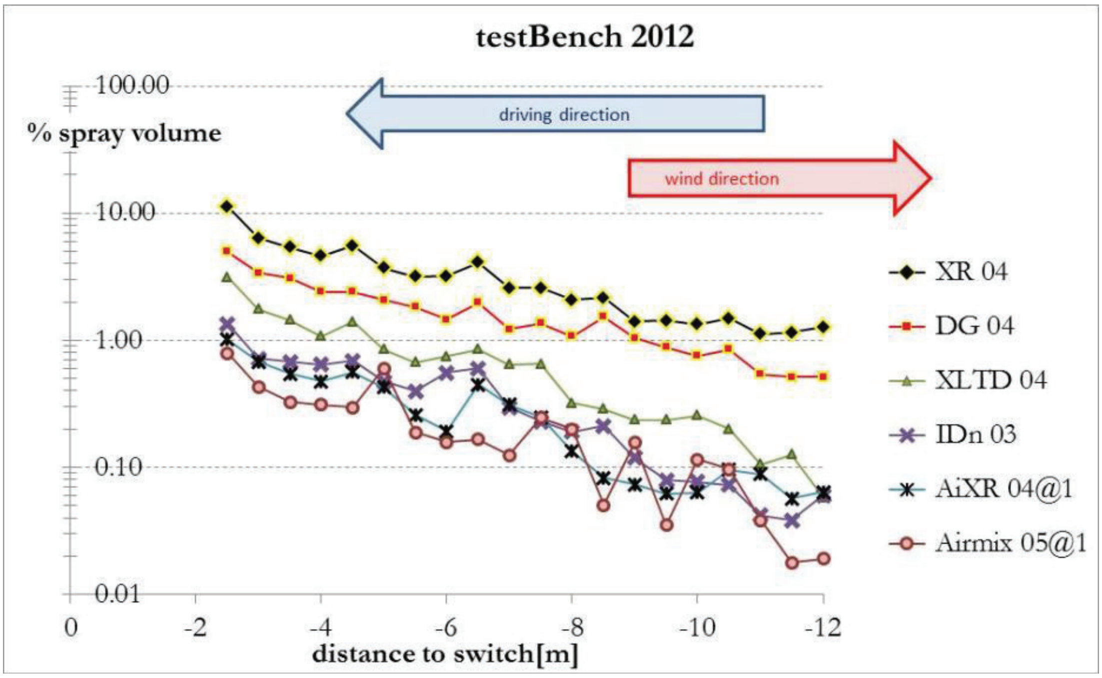

Fig. 5. Spray deposition (% of sprayed volume) for different nozzle types measured after passing of the sprayer on the test bench (three repetitions).

Table 5. *Average DPV values for the different nozzles and statistical differences at 95% level and 90% level*

Nozzle	XR	DG	XLTD	IDN	AIXR	Airmix
Avg DPV	66%	34%	15%	14%	6%	4%
%CV	32%	22%	16%	75%	5%	48%
DPV reduction	Reference	49%	77%	79%	91%	93%
diff-95%	a	b	c	c	c	c
diff-90%	a	b	c	c,d	c,d	d

Discussion

Depending on what zones are looked at in field measurements similar results are obtained for field measurements and the test bench. The ranking of the nozzles is for both test methodologies similar, depending on the evaluation zone. The absolute values do differ for some nozzle types.

Spray drift reduction levels in the field were found up to more than 95% for the Airmix AM111005 (1 bar spray pressure).

Modelling results coincide very well with the results of field measurements at 2–3 m and 1–5 m distance from the last nozzle.

Also airborne spray drift reduction is similar to results for soil deposition at different distances. A drift reduction of 95% for airborne spray drift was found for the Airmix AM 11005 nozzle (1 bar).

Ranking of the nozzles in drift reduction was similar for field measurements as soil deposition and airborne spray drift reduction as well as for the test bench method and the spray drift modelling. Not all methods resulted however in a classification of the nozzles in the same drift reduction class.

Spray drift deposition on the test bench correlates very well with the spray quality parameters D10, D50(VMD), D90 and V100 the volume fraction smaller than 100 um (Fig. 6). The relation V100 and average spray deposition on the test bench is almost a 1:1 one for the different nozzle types.

Table 6. *Comparison of spray drift reduction values of different nozzle types relative to XR11004 nozzle based on field measurements for evaluation zones 2–3 m, 1–5 m, 1–15 m, airborne drift at 5 m distance from the last nozzle and a drift test bench*

Nozzle	Field 2–3 m	Field 1–5 m	Field 1–15 m	Airborne drift reduction 5 m	Test bench	Drift modelling
XR	Reference	Reference	Reference	Reference	Reference	Reference
DG	64%	68%	54%	59%	49%	51%
XLTD	83%	85%	83%	80%	77%	88%
IDN	90%	91%	84%	91%	79%	94%
AIXR	96%	95%	89%	94%	91%	96%
Airmix	97%	96%	92%	95%	93%	96%

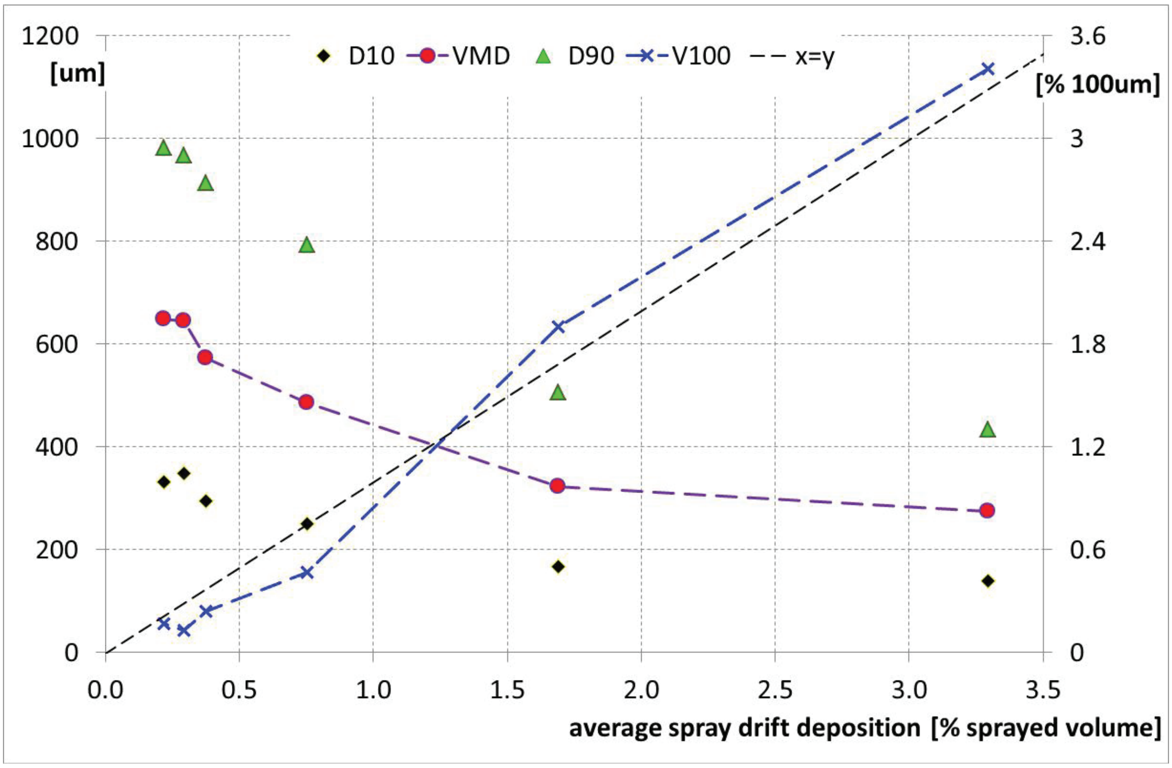

Fig. 6. Relation between spray quality parameters D10, D50(VMD), D90 and V100 and average spray deposition on the test bench for the different nozzle types.

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