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Single nozzle spray drift measurements of drift reducing nozzles at two forward speeds

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Summary

In 2011–2012 single nozzle field experiments were carried out to determine the effect of different flat fan spray nozzles of the spray drift reduction classes 50, 75, 90 and 95% on spray drift at two different forward speeds (7.2 km h^{-1} and 14.4 km h^{-1}). Experiments were performed with a single nozzle spraying on an outdoor spray track perpendicular to the wind direction. Nozzle types were 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. At 5 and 10 m distances, airborne spray drift was measured with passive and active collectors. Differences in spray drift reduction were measured for the different nozzle types. Results showed that with a higher nozzle forward speed the spray drift deposition increased for both the ground deposition and the airborne spray drift. Higher nozzle forward speeds may lead to nozzles to be classified in a lower spray drift reduction class.

Key words: Spray drift, drift-reducing nozzle, spray track, nozzle classification, forward speed

Introduction

Results from field measurements (Zande *et al*., 2005) with boom sprayers fitted with standard flat fan nozzles (TeeJet XR11004 at 3 bar spray pressure) showed that an increase in forward speed from 6 km h^{-1} to 12 km h^{-1} gave an increase in spray drift deposition measured at 2½–3½ m from the last nozzle of 46%. When using a pre-orifice nozzle (TeeJet DG11004 at 3 bar) in combination with an end-nozzle (Lechler IS8004) an increase in spray drift of 364% was found. Single nozzle spray drift validation measurements for the IDEFICS spray drift model showed that an increase in forward speed from 0.5 m s^{-1} to 1.5 m s^{-1} increased spray drift on average by 20% (Holterman *et al*., 1997).

From a number of selected standard flat fan, pre-orifice, Venturi type, twin fan, and high speed flat fan nozzles, certified in the drift reduction classes 50, 75, 90 and 95% (TCT, 2015), drop sizes were measured and spray drift was calculated (Zande *et al*., 2012) with the IDEFICS spray drift model (Holterman *et al*.,1997). Spray drift was calculated for driving speeds of 6, 8, 10, 12 and 18 km h^{-1}. Results of the spray drift model calculations showed that on average spray drift increased by 20% for the different increases in forward speeds. As these model results do not coincide with earlier field measurements of spray drift and increased forward speed, experiments were set up to validate the effects of the different nozzle types with forward speeds of 2 m s^{-1} and 4 m s^{-1} (resp.

7.2 and 14.4 km h^{-1}). Single nozzle measurements were performed evaluating spray drift deposition on ground surface and airborne spray drift at 5 and 10 m distance from the nozzle. Airborne spray drift was quantified on passive collectors and with an active air suction system at different heights. Results of those single nozzle outdoor spray drift measurements are presented in this paper.

Materials & Methods

An experimental single-nozzle spray carriage was used to pull a single nozzle at constant speed (2 m s^{-1} and 4 m s^{-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 give a well-developed logarithmic wind profile in the experiments. Ground deposits were measured using synthetic cloths (0.10 m × 0.50 m; Technofil TF-290) positioned in two parallel rows (2 m apart), from 1 m upwind to 10 m downwind with respect to the nozzle. Airborne spray drift was sampled at 5 m and 10 m downwind of the nozzle. A schematic overview of the experimental layout is shown in Fig. 1.

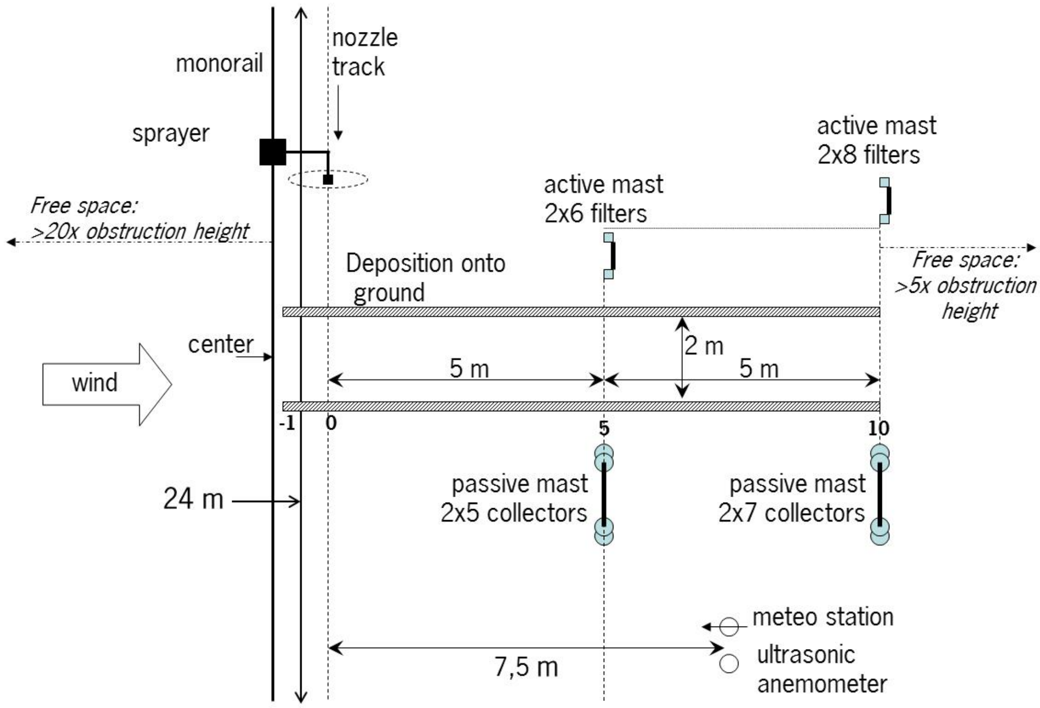

Fig. 1. Schematic overview of the experimental layout.

Thirteen types of drift reducing nozzles (DRN) were selected 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}), a 50% DRN (TeeJet DG11004; 300 kPa), a 75% DRN (Lechler ID12002; 300 kPa), and a 90% DRN (Agrotop XLTD11004; 300 kPa). The characteristics of the nozzles used and their drift reduction classification (TCT, 2015) are presented in Table 1. A total of 55 experiments were carried out obtaining three replications of each drift reducing nozzle type and one of the reference nozzles. Not all nozzles could be measured on the same day. For comparisons between all experimental days either the BCPC Fine/Medium or the TeeJet XR11004 was measured. Total number of measurements of the BCPC F/M and the TeeJet XR11004 were therefore resp. 14 and 16. The carriage was allowed to run 10 passages before spray drift deposition samples were collected. The weather conditions during applications were measured at 5 s time intervals: wind velocity was measured at heights 0.5, 2.0, 3.0 and 4.0 m using cup anemometers, air temperature at heights 0.5 and 4.0 m using

Pt100 sensors, and at 1.2 m height temperature and relative humidity (Rotronic); wind direction was measured at 4.3 m height. The average wind speed at 0.5 m, 2.0 m, 3.0 m and 4.0 m during the measurements were respectively 2.2(1.6–2.8) m s^{-1}, 2.8 (2.0–3.7) m s^{-1}, 3.2 (2.2–4.2) m s^{-1} and 3.3 (2.3–4.4) m s^{-1}. The average wind direction was 18° perpendicular to the spray track and therefore driving direction. The average temperature was 16.1°C and the relative humidity was 66%. The spray liquid was tap water with a fluorescent dye (Brilliant Sulfo Flavine; BSF 3 g L^{-1}) and a non-ionic surfactant (Agral Gold; 0.075 mL L^{-1}) added. In the laboratory the BSF was extracted from the collectors with deionised 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 spray drift reducing nozzles and their spray parameters (spray volume at 2 m s^{-1} forward speed)*

Manufacturer	Nozzle type	Pressure (bar)	Class	Flow rate (L min^{-1})	Spray volume (L ha^{-1})	Dv_{50}	V100[%]
TeeJet	TTI04	1	95	0.92	153	645	0.16
Agrotop	Airmix11005	1	95	1.16	193	648	0.17
Agrotop	TD_hispeed_04	2	90	1.31	218	573	0.28
Hardi	MD-D-110-04	1	90	0.91	152	659	0.12
TeeJet	AIXR11004	3	90	1.58	263	646	0.13
Agrotop	XLTD110-04	3	90	1.62	270	485	0.47
Agrotop	TD_hispeed_02	3	75	0.80	133	574	0.22
Albuz	AVI Twin 110-03	3	75	1.18	197	552	0.48
Lechler	IDN12003	3	75	1.20	200	573	0.24
Lechler	ID12002	3	75	0.80	133	456	0.54
Hardi	MD_D110-03	3	50	1.19	198	452	0.50
Agrotop	Airmix11003	3	50	1.19	198	357	1.29
TeeJet	DG11004	3	50	1.61	268	322	1.90
TeeJet	XR110-06	2	50	1.96	327	320	2.11
TeeJet	XR11004	3	0	1.58	263	274	3.41
TeeJet	ISO F/M	3	0	1.20	200	262	3.45
Lurmark	BCPC F/M	3	0	1.20	200	248	4.09

Results

Spray drift deposition

In Fig. 2 the average spray drift is presented for the reference and the different drift-reducing nozzles with a forward speed of 2 m s^{-1} and 4 m s^{-1}. The drift reducing potential of the different drift-reducing nozzles can be observed. The XR11004 and BCPC F/M gave the highest spray drift deposition and for both forward speeds while the lowest spray drift deposition was found with the TTI11004 nozzle at 1 bar spray pressure and the spray fan directed in the forward direction.

For most of the nozzle types measured the spray drift deposition increased with increasing forward speed from 2 m s^{-1} to 4 m s^{-1} (Table 2). Only for the nozzle types XLTD11004, TTI11004 (3 bar) and IDN12003 spray deposition decreased at the higher forward speed. For the reference nozzles BCPC F/M and the XR11004 the increase in spray deposition with the increased forward speed was resp. 17% and 32% at 1.0–5.0 m distance and 35% and 56% at 5.0–10.0 m from the nozzle.

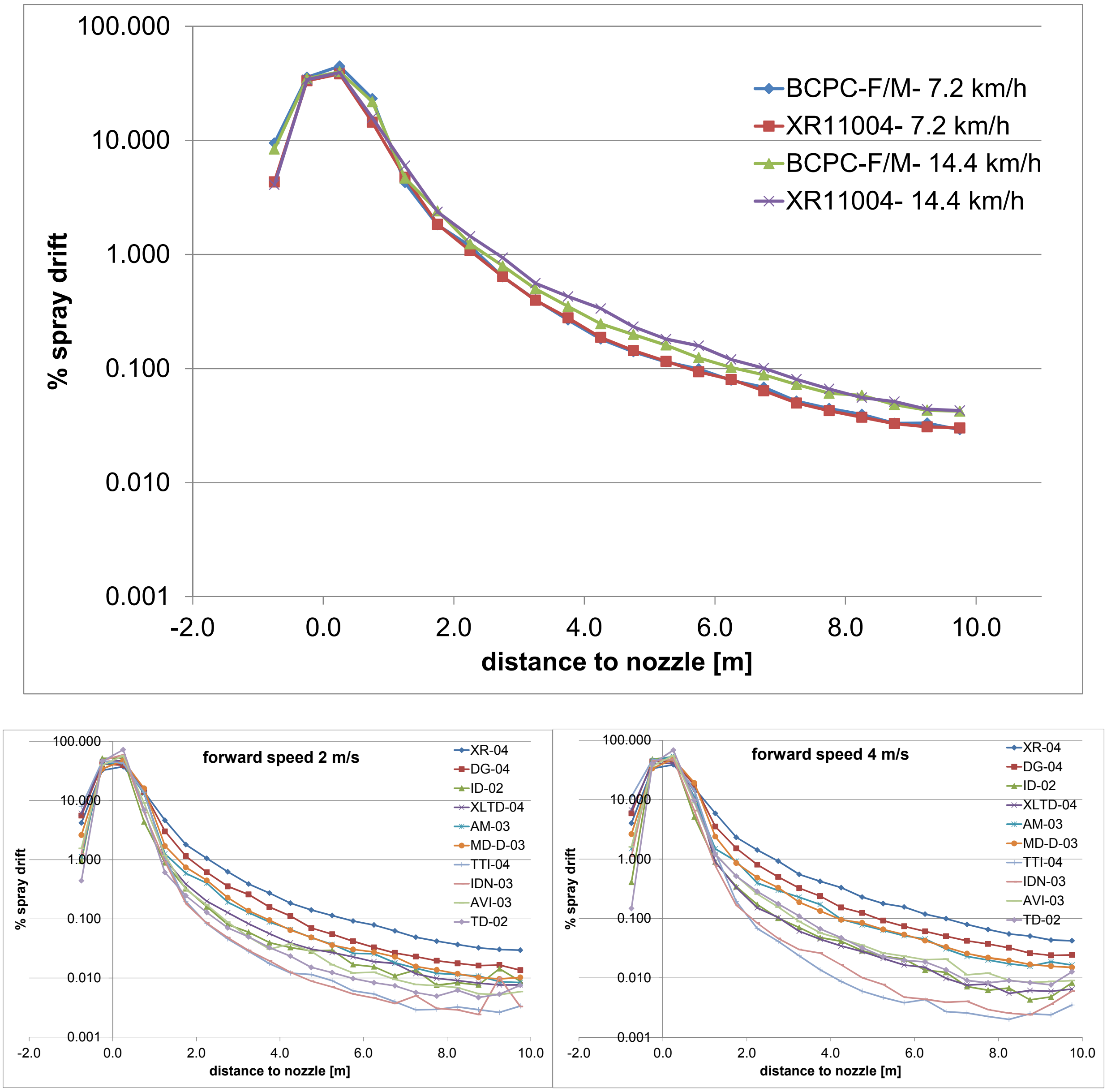

Fig. 2. Average spray drift (% of applied dose) of single nozzle spraying with two different speeds for the reference nozzles XR11004 and BCPC F/M (top) and the different drift reducing nozzles at 2 m s^{-1} (bottom left) and at 4 m s^{-1} (bottom right) forward speed (0.0 = nozzle position).

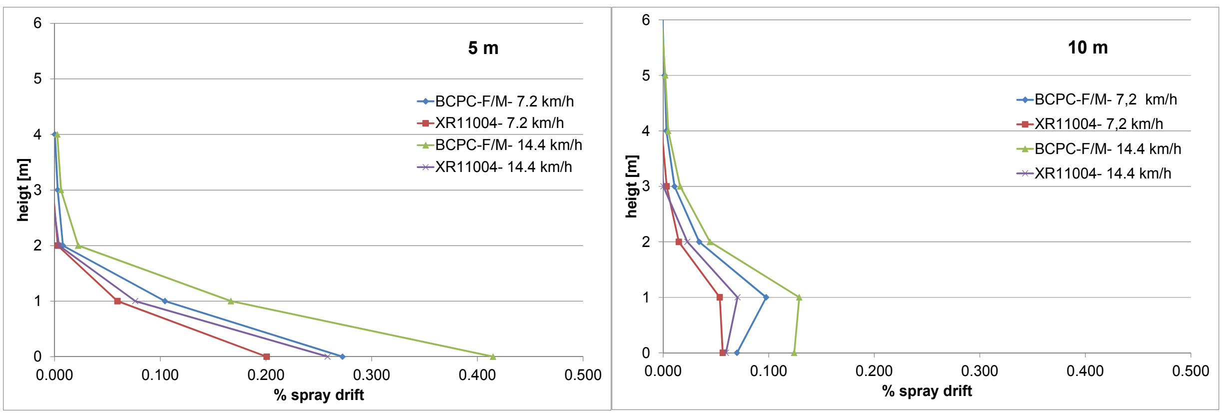

Fig. 3. Average airborne spray drift (% of applied dose) at different heights for single nozzle spraying at two forward speeds with the reference nozzles XR11004 and BCPC F/M (0.0 = nozzle position) at 5 m (left) and 10 m (right) distance from the nozzle.

Increases in spray drift deposition at 2–3 m distance from the nozzle are up to a level of 134% (Table 2) for the TD Hispeed 11002 nozzle, which is also highest at 1–5 m distance. At 5–10 m distance from the nozzle highest increase in spray drift deposition because of increased forward speed is 106% for the TD Hispeed 11004.

Table 2. *Calculated increase (%) in spray drift deposition at different zones of the different nozzles when increasing forward speed from 2 m s^{-1} to 4 m s^{-1}; ranked at increase at 2–3 m distance from the nozzle*

Nozzle	Type	Reduction class	2–3 m	3–4 m	1–5 m	5–10 m
XLTD11004	Venturi	90	-21,4	-23,2	-14,5	-27,4
TTI11004- 3 bar	Hispeed	50	-15,4	-19,2	10,5	-27,9
IDN12003	Venturi	75	-2,4	15,1	-12,7	4,1
XR11006	Flat fan	50	4,3	7,2	1,9	14,0
BCPC-F/M	**Standard**	**Reference**	**12,0**	**27,7**	**17,2**	**35,0**
ID12002	Venturi	75	12,6	18,8	4,9	-20,8
AM11003	Venturi	50	16,5	85,7	32,9	74,1
TD Hispeed11004	Hispeed	90	17,4	57,2	34,3	105,6
MD-D-03	Twin flat fan	50	21,3	38,2	32,0	64,6
MD-D-04	Twin flat fan	90	29,2	65,7	12,7	33,3
AM11005	Venturi	95	35,2	73,4	40,6	85,0
DG11004	Pre orifice	50	35,4	34,9	25,9	75,9
XR11004	**Standard**	**Reference**	**38,6**	**46,5**	**31,9**	**56,1**
AVITwin11003	Twin flat fan	75	58,3	80,8	24,6	65,2
AIXR11004	Venturi	90	68,6	68,9	39,9	69,1
LD11004	Pre orifice	50	95,3	129,1	83,9	68,9
TTI11004-1bar	Hispeed	95	98,9	76,7	73,9	77,9
TD Hispeed11002	Hispeed	75	134,0	116,2	108,8	80,5

At 5 m and 10 m distance from the nozzle (Table 3) airborne spray drift increased for most nozzle types when increasing forward speed from 2 m s^{-1} to 4 m s^{-1}. Only for the measured nozzle types ID12002 at both distances and IDN12003 at 5 m distance airborne spray drift decreased with increasing forward speed. The increase in airborne spray drift for the XR11004 nozzle is at 5 m and 10 m distance resp. 29% and 19% and for the BCPC F/M threshold nozzle resp. 57% and 48%. This means that the mean absolute airborne spray drift measured over resp. 4 m height and 6 m height at those distances increased from 0.052% to 0.066% at 5 m and 0.017% to 0.020% at 10 m for the XR11004 and from 0.078% to 0.123% at 5 m and from 0.031% to 0.046% at 10 m for the BCPC F/M nozzle. The highest increase in airborne spray drift both at 5 m and 10 m distance occurred for the AM11005 with a value of more than 500%. This means for the AM11005 nozzle the measured mean airborne spray drift deposition over resp. 4 m and 6 m height increased from 0.002% to 0.011% at 5 m (4 m height) and from 0.001% to 0.004% at 10 m distance (6 m height), so still remains very low in absolute values.

No general conclusions can be drawn on nozzle types and effect of forward speed on airborne spray drift. Some of the presented results may also be biased because of wind speed and wind angle during the measurements but in general the pairwise comparison of the two forward speeds resulted in wind speed values close together (0.6 m s^{-1}) whereas between nozzle types (2.4 m s^{-1}) differences are larger.

Table 3. *Calculated increase (%) in airborne spray drift deposition (passive collectors) at 5 m (4 m height) and 10 m (6 m height) distance of the different nozzles when increasing forward speed from 2 m s⁻¹ to 4 m s⁻¹; ranked at increase at 5 m distance from the nozzle; and average wind speed and wind angle during measurements (2–4 m s⁻¹)*

Nozzle	Type	Reduction class	Wind speed ($m\ s^{-1}$)	Wind direction (°)	5 m	10 m
ID12002	Venturi	75	2.7–3.0	17–13	-35,0	-11,2
IDN12003	Venturi	75	2.9–2.5	17–22	-16,0	114,7
XLTD11004	Venturi	90	3.7–3.4	13–16	2,3	70,2
TTI11004- 3 bar	Hispeed	50	2.8–2.7	14–20	9,7	168,3
MD-D-04	Twin flat fan	90	2.4–2.4	27–32	14,6	61,2
AIXR11004	Venturi	90	2.8–3.0	18–25	16,7	364,3
XR11006	Standaard	50	4.0–4.6	14–11	17,0	29,4
XR11004	**Standard**	**Reference**	**3.7–3.4**	**14–17**	**28,8**	**19,4**
TD Hispeed11002	Hispeed	75	2.9–3.1	16–15	29,1	150,4
BCPC-F/M	**Standard**	**Reference**	**3.2–3.0**	**15–17**	**57,0**	**47,5**
AVITwin11003	Twin flat fan	75	2.5–2.8	20-17	58,0	138,1
TD Hispeed11004	Hispeed	90	3.9-3.7	11-20	68,1	121,6
LD11004	Pre orifice	50	3.8-3.9	13-15	114,2	155,2
TTI11004-1bar	Hispeed	95	3.2-3.0	17-14	117,9	40,3
MD-D-03	Twin flat fan	50	3.8-4.0	17-16	223,6	85,3
DG11004	Pre orifice	50	2.2-2.8	18-14	226,2	95,2
AM11003	Venturi	50	2.4-3.0	21-20	245,8	158,6
AM11005	Venturi	95	2.8-3.0	21-17	508,7	577,1

Discussion

Differences in spray drift reduction were measured for the different drift-reducing nozzle types. It was obvious that the higher level of drift reduction of the drift reducing nozzles coincided also with lower amounts of drop sizes smaller than 100 µm in the spray fan (Table 1). What was observed from the airborne spray drift measurements was a significant difference in active sampling and passive collectors used in mean values of collected airborne spray over 4 m height at 5 m distance (Fig. 4) with the two different forward speeds. This suggests that for the quantification of airborne spray drift more attention is to be paid to the type of airborne collector and how to present these data, especially when they are becoming relevant for legislative purposes (Zande *et al*., 2014).

Spray drift is also very much influenced by environmental circumstances as wind speed during application. The effect of wind speed at 2 m height on spray drift deposition at ground surface is presented in Fig. 5 for the XR11004 nozzle. With a higher forward speed of 4 $m\ s^{-1}$ (14.4 $km\ h^{-1}$) also the effect of wind speed on spray drift is more pronounced, as the spray deposition at 1–5 m distance from the nozzle increased by a factor of 0.32 at 2 $m\ s^{-1}$ forward speed and a factor of 0.46 with a forward speed of 4 $m\ s^{-1}$. This means a doubling of spray drift deposition at the 1–5 m zone when wind speed at 2 m height increases from 2–4 $m\ s^{-1}$; resp. from 0.64% to 1.28% for the 2 $m\ s^{-1}$ forward speed and from 0.92% to 1.84% for the 4 $m\ s^{-1}$ forward speed of the XR11004 standard flat fan nozzle.

Similarly airborne spray drift is also affected by wind speed. The effect of forward speed on airborne spray drift is however more pronounced (Fig. 6) than of spray drift deposition at ground surface (Fig. 5). Airborne spray drift was exponentially related to wind speed at 2 m height whereas spray drift deposition at ground surface is linearly related to increases in wind speed. Results will

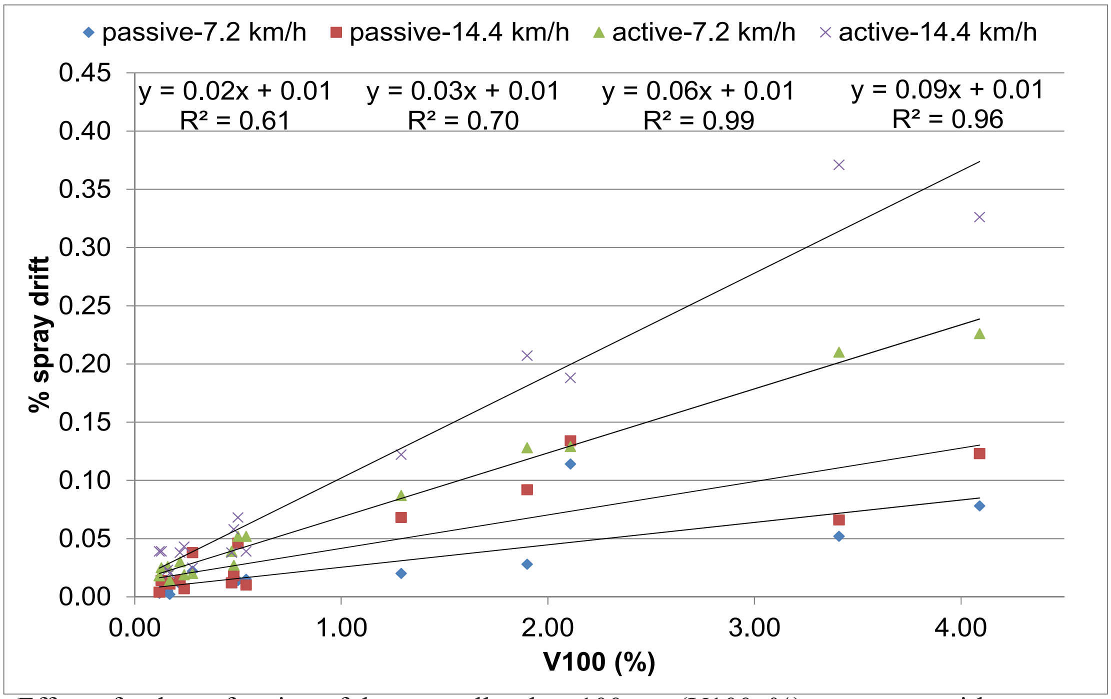

Fig. 4. Effect of volume fraction of drops smaller than 100 µm (V100; %) on average airborne spray drift (% of applied dose) at 5 m distance (4 m height) from the nozzle for single nozzle spraying at two forward speeds with the reference nozzle XR11004 for the active samplers and passive airborne spray drift collectors.

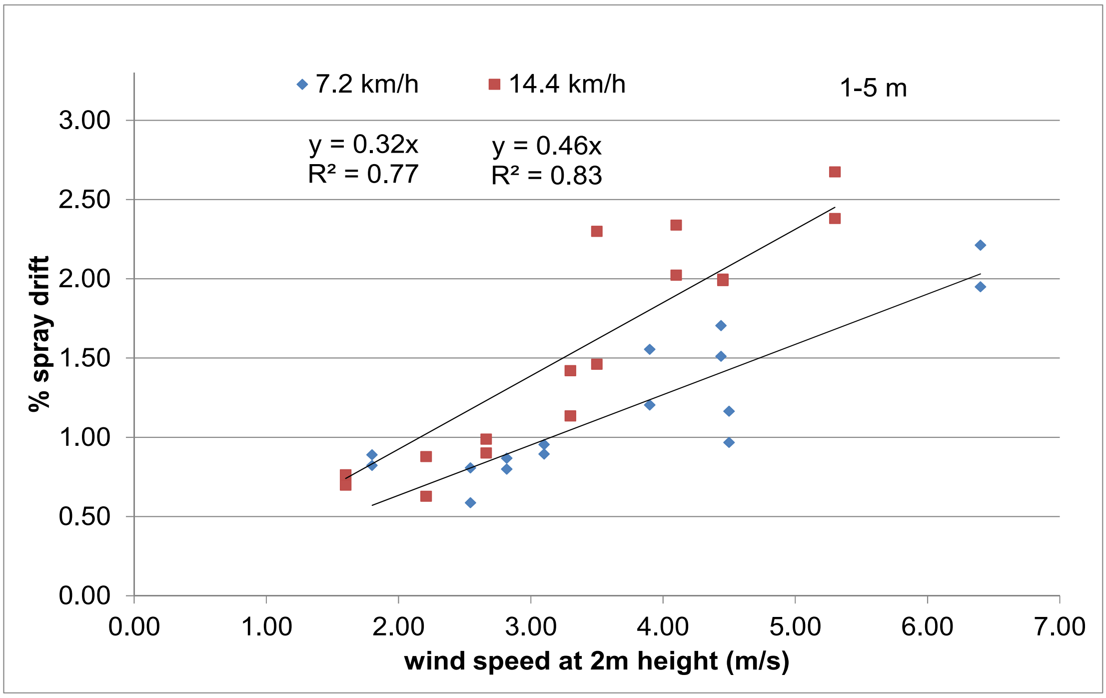

Fig. 5. Effect of wind speed (m s^{-1} at 2 m height) on average spray drift deposition (% of applied dose) at 1–5 m distance from the nozzle for single nozzle spraying at two forward speeds with the reference nozzle XR11004.

be used to further validate the IDEFICS spray drift model (Holterman *et al.*, 1997) as the results of these experiments clearly deviate from the results of the calculations done (Zande *et al.*, 2012). Whereas in this study effects of increased spray drift deposition on ground surface were found of 134% only increases of 20% were found in the modelling in similar circumstances. On the other hand the increase of spray drift deposition of 364% found for the DG11004 nozzle (Zande *et al.*, 2005) was in these single nozzle experiments only 35%.

In general it can be concluded that increasing forward speed has an effect on the drift-reducing abilities of the drift-reducing nozzles. However, based on the results presented no clear distinction

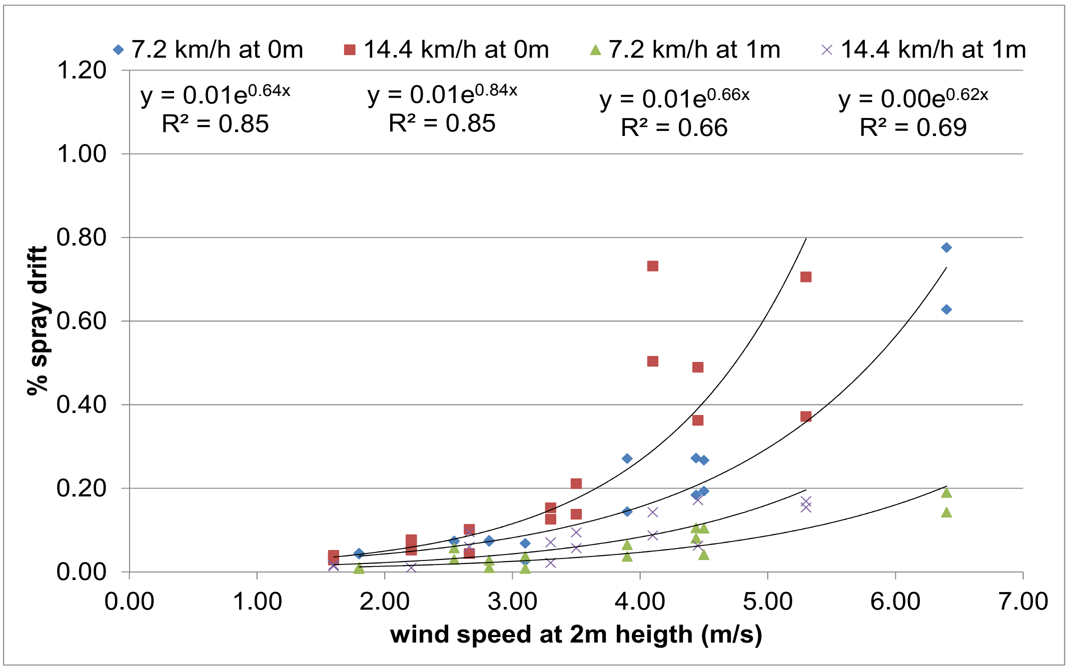

Fig. 6. Effect of wind speed (m s^{-1} at 2 m height) on average airborne spray drift deposition (% of applied dose) at two heights and at 5 m distance from the nozzle for single nozzle spraying at two forward speeds with the reference nozzle XR11004.

can be made for the different groups of types of nozzles. For many nozzles it can be concluded that a classification in drift reduction would be one class lower at a forward speed of 4 2 m s^{-1} than with a forward speed of 2 m s^{-1}.

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References

Holterman H J, Zande J C van de, Porskamp H A J, Huijsmans J F M. 1997. Modelling spray drift from boom sprayers. *Computers and Electronics in Agriculture* **19**:1–22.

Southcombe E S E, Miller P C H, Ganzelmeier H, Zande J C van de, Miralles A, Hewitt A. 1997. The international (BCPC) spray classification system including a drift potential factor. *Proceedings of the Brighton Crop Protection Conference - Weeds, November 1997, Brighton, UK*, pp. 371–380.

TCT. 2015. *List drift-reducing nozzles*. http://www.helpdeskwater.nl/onderwerpen/ emissiebeheer/landbouw-veeteelt/open-teelt/driftarme-doppen/@3575/lijst-driftarme/.

Zande J C van de, Stallinga H, Michielsen J M G P, Velde P van. 2005. Effect of sprayer speed on spray drift. *Annual Review of Agricultural Engineering* **41**:129–142.

Zande J C van de, Groot T T, Holterman H J. 2012. Spray drift and increased sprayer speeds. Model calculations to quantify the effect of sprayer speed, nozzle type, spray boom height and nozzle distance on the spray boom. *Wageningen UR-Plant Research International, WUR-PRI Report* **482**. 68 pp.

Zande J C van de, Butler Ellis M C, Wenneker M, Walklate P J, Kennedy M. 2014. Spray drift and bystander risk from fruit crop spraying. *Aspects of Applied Biology* **122**, *International Advances in Pesticide Application,* pp. 177–186.