Fine nozzles can be used and reduce spray drift : when used at low boom height and smaller nozzle spacing

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Stallinga, H.; Zande, J.C.; Michielsen, J.M.G.P.; Velde, P.

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Fine nozzles can be used and reduce spray drift; when used at low boom height and smaller nozzle spacing

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

Wageningen UR - Agrotechnology and Food Innovations, P. O. Box 17, 6700 AA Wageningen, The Netherlands

Summary

Lowering boom height decreases spray drift. When lowering boom height to 30 cm above crop height nozzle spacing has to be adapted to 25 cm instead of 50 cm to give good coverage and overlap of spray fans (cross distribution). To apply the same spray volumes as with conventional practices, e.g. 200-300 litres ha^{-1}, nozzle sizes have to change also to lower outputs and are therefore finer. In a field experiment it is shown that the reduction of boom height to 30 cm, the use of low output nozzles (200 litres ha^{-1}; DG110015, ID110015) used with and without air assistance reduces spray drift from 50 up to more than 95% compared to a standard application of 300 litres ha^{-1} with XR11004 nozzles.

Key words: spray drift, nozzle type, air assistance, sprayer boom height

Introduction

Legislation is introduced by the Dutch government for reduction of the emission of plant protection products to soil, (surface) water and air. The drift deposition, when spraying, contributes to the contamination of water surface. Therefore spray free and crop free buffer zones are introduced, to minimise the risk (Water Pollution Act, Plant Protection Act). Especially aquatic life is vulnerable to the toxic contents of plant protection products. Field measurements of spray drift from boom sprayers operating over arable crops have shown that drift increases with increase in wind speed, boom height, forward speed, and when a high proportion of the spray is produced in fine drops (<100 µm in diameter). The need to make timely applications of pesticide involves operating with high work rates. This often involves the use of wide booms and low-volume rates involving fine sprays. All of these trends increase the risk of spray drift (Zande et al., 2000). A general reduction in spray drift deposition to water surface next to the sprayed field can be achieved by improvements in spray application techniques. One of the techniques to lower spray drift is to decrease the sprayer boom height.
A methodology to classify spray nozzles for driftability (Porskamp *et al*., 1999) was developed, based on laboratory measurements (Phase Doppler Anemometry) and spray drift model calculations (IDEFICS; Holterman *et al*., 1997). Porskamp *et al.* (1999) showed that the combination of nozzle type, nozzle size and spray pressure defined the spray drift predominantly. Model calculations showed also a correlation between sprayer boom height and drift, the lower the boom height the lower the drift. The effect of sprayer boom height on spray drift was measured in the field (Jong et al, 2000). A drift reduction of around 50% was found when lowering boom height from 0.70 m to 0.50 m as well as lowering from 0.50 m to 0.30 m above crop canopy. Lowering further down will give even more drift reduction, up to 90%, as is shown with band sprayers (Zande et al., 2000) but also causes stripes in the application. When lowering boom height to 0.30 m above crop canopy cross distribution can therefore give a

problem, and nozzle distance on the boom is advised to be adapted to 0.25 m spacing instead of the usual 0.50 m. Doubling the number of nozzles on the boom requires nozzles with half the flow rate of the normal used nozzles when applying the same spray volume. Applying normally 300 litres ha^{-1} with F110/1.6/3.0 nozzles now will then be changed to F110/0.8/3.0 nozzles, or smaller, also producing a finer spray. This again increases spray drift risk and requires the choice of low drift nozzles. Model calculations showed that the effect of low boom heights overruled the negative effect of fine spray qualities. Field measurements were suggested to validate this perspective outcome. No data are available from field measurements on the combined effects on spray drift of lowering the sprayer boom from 0.50 m to 0.30 m; decrease nozzle spacing distance from 0.50 m to 0.25 m and the use of lower flow rate nozzle types. Therefore in field experiments spray drift was quantified. In combination with the nozzle-types a comparison was made with and without the aid of air assistance on the field sprayer. This paper describes the results of the field experiments.

Materials and Methods

Drift measurements

Drift measurement were carried out according to the ISO-draft standard (ISOCD 22866;2003) adapted for the situation in the Netherlands (ground deposits, ditch, surface water next to the sprayed field) following the Dutch protocol (CIW, 2003). Drift was measured on ground surface on the downwind edge of an experimental field with a potato crop (cv Agria). Average canopy height of the potato crop was 0.6-0.8m. The swath-width of potatoes sprayed was 24 m. The length of the sprayed track was at least 50 m. The distance of the last downwind nozzle to the edge of the field (the last crop leaves) was determined at approximately 0.7m. During the growing season ten repetitions of the measurements were done on more dates to obtain an average crop season (crop height) result.

Spray drift measurements were carried out adding the fluorescent dye Brilliant Sulfo Flavine (BSF; 3.0 g/L) and a surfactant (Agral; 0.1%) added to the spray agent. Ground deposit was measured on horizontal collection surfaces placed at ground level in a double row downwind of the sprayed swath. The collectors were placed at distances 0-0.5, 1-1.5, 1.5-2, 2-3, 3-4, 4-5, 5-6, 7,5-8,5, 10-11, 15-16 m from the last downwind nozzle. Collectors used were synthetic cloths (Technofil TF-290) with dimensions of 0.50x0.10 m and 1.00x0.10 m.

Airborne spray drift was measured at a distance of 5.5 m from the last downwind nozzle of the field sprayer. The collection of airborne spray was done on two separate lines with attached collectors at 0, 1, 2, 3, and 4 m height. Collectors used were spherical synthetic cleaning pads (Siebauer nr.00140; diameter 0.08 m). The collectors were washed and the BSF concentration in the extracted fluid was measured by fluorimetry (Perkin Elmer LS30).

Sprayer boom height

To distinguish the initial set boom heights during spray drift experiments these were checked with a system consisting of a laser distance indicator and an ultrasonic sound height indicator (Jong *et al.*, 2000). The ultrasonic sensor was connected at the end of the sprayer boom, to measure boom height over the open strip where the drift collectors were placed. The system checked every 0.1 second the distance and height of the boom tip in the field. The height and the distance, together with the time were recorded online. The data of a 20 m strip where the drift collectors were placed were used for further analyses of the sprayer boom movement under field circumstances.

Used spray techniques

Specifications of the two trailed sprayers used in the experiments are as summarised in Table 1. The conventional sprayer applied 300 litres ha^{-1} using Medium or Coarse spray quality (Southcombe *et al.*, 1997) nozzle types. The low-boom sprayer was equipped with two types of low drift

Table 1. *Settings of the field sprayers during spray drift field experiments*

spray technique	Conventional field sprayer		Low-boom field sprayer	
machine	Hardi TwinForce		Rau AirPlus	
working width [m]	24		24	
nozzle spacing [m]	0.50		0.25	
nozzle type	XR 11004	DG11004	DG80015	ID90015
end nozzle	none	IS8004	IS8002	IS8002
spray pressure [bar]	3		3	
nozzle orientation	vertical		backwards 35^{o}	
spray quality	Medium	Coarse	Fine	Coarse
nozzle flow rate [l/min]	1.61	1.68	0.59	0.58
driving speed [km/u]	6		7	
spray volume [litres ha^{-1}]	325	345	199	198
air assistance	maximum at 240 bar		maximum 10	
air speed at outlet [m/s]	30		25	

nozzles producing 200 litres ha^{-1}. All nozzles were used in a conventional way and with the use of air assistance, with identical travelling speed, and liquid pressure (3 bar). In case of air assistance on the conventional sprayer (Hardi TwinForce), nozzles were kept vertical. On the low boom sprayer (Rau AirPlus) air direction was kept vertical and nozzles were angled 35^{o} backward, optimised for use with the air assistance system. In both cases air velocity was set to the maximum capacity of the fan. Both sprayers were trailed ones having a working width of 24 m.

Reference spraying system

Measurements of spray drift were compared to a reference situation, a XR11004 @ 3 bar pressure nozzle situation. Sprayer boom height was set at 0.5 m above the top of the crop canopy. Driving speed was 6 km/h resulting in an applied volume rate of 300 litres ha^{-1}.

Meteorological conditions

Meteorological conditions during the spray drift measurements were recorded. Wind speed and temperature were recorded at 5 s interval at 0.5 and 2.0 m height, using cup anemometers and Pt100 sensors, respectively. Relative humidity was measured at 0.5 m height and wind direction at 2.0 m height. Average recorded meteorological circumstances during the measurements are summarised in Table 2. All measurements were within the wind direction range of 90^{o} +/- 30^{o} to the spray track.

Table 2. *Average weather conditions during spray drift field experiments*

sprayer	temperature [^{o}C]		RH [%]	wind angle	windspeed [m/s]	
	0.5 m	2.0 m		^{o} to square	0.5 m	2.0 m
Hardi TwinForce	23.0	22.1	55	14	2.1	2.8
Rau AirPlus	22.3	21.6	58	11	2.0	2.6

Presentation of results

Spray deposits were calculated and presented as percentage deposit of the applied volume rate per unit surface-area on the different distances of the collectors. As a comparison to the reference situation spray drift reduction was calculated for the zones 1-5 m, 1.5-6 m and 2.5-3.5 m, 3-4 m from the last nozzle being the zones where in the Netherlands most often a ditch with surface water is located. Differences were analysed with a standard statistical package (GENSTAT, analysis of variance; Payne et al., 1993 or IRREML ; Keen & Engel, 1998) at a 95% confidence interval.

Results

Sprayer boom height

During spray drift measurements boom height was recorded, the results are presented in table 3. The Hardi sprayer recorded 85% of time a deviance of initial boom height of less than 10 cm, the Rau in 62% of time.

Table 3: *Measured sprayer boom height during spray drift measurements*

			Nozzle height [cm]				Stdev [cm]		
Sprayer	nozzle	Air assistance	initial	During drift measurement	Min	Max	average	min	max
Hardi	XR 110.04	-	50	46	21	55	3	4	13
		+	50	44	27	56	9	4	26
	DG 110.04	-	50	54	44	59	4	3	13
		+	50	49	35	58	4	5	14
Rau	DG 80.015	-	30	22	2	38	8	2	10
		+	30	26	14	46	9	4	26
	ID 90.015	-	30	22	6	41	15	3	33
		+	30	28	15	40	12	6	27

Standard deviation of the average boom height is for the Rau sprayer higher than for the Hardi sprayer. This indicates that the Rau was less stable than the Hardi. In the field, on sight, impression of boom stability for both sprayers was good.

Spray drift deposition

For the conventional spraying average spray drift deposition at different distances next to the field is presented in figure1. A steep decrease in spray drift in the first 2 m distance is clear for the Rau and Hardi DG11004 nozzle. This is predominantly because of the use of an end-nozzle. Lower levels of spray drift from 2m onwards are because of nozzle type, air assistance and boom height. It is shown that from 8m upwards the lower-boom sprayer with the DG80015 nozzle has similar drift as the reference sprayer. The drift deposition of the lower-boom sprayer in combination with the ID90015 nozzle is lower than of the DG11004 nozzle on the conventional sprayer.

Calculated average spray drift deposition on zones coinciding with distances where ditches (1-5 m, 1.5-6 m) and surface water (2.5-3.5 m, 3-4 m) are situated depending on the crop-free buffer zone of respectively 1.0 m or 1.5 m are presented in table 4.

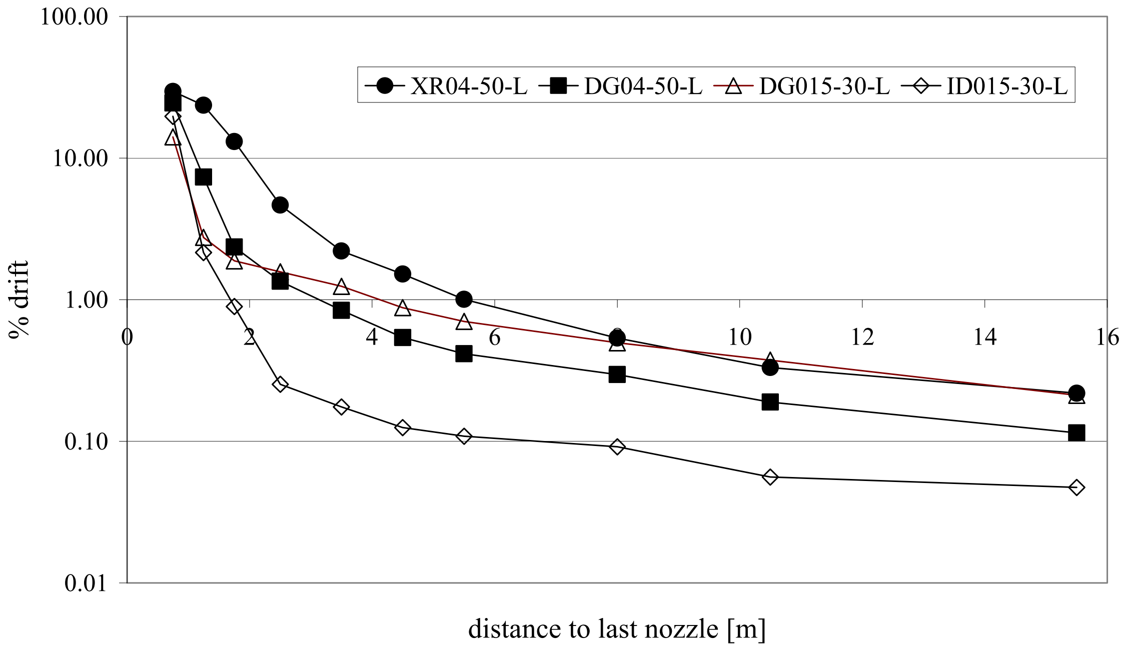

Figure 1. *Spray drift deposition (% of volume application rate) next to a sprayed potato field with a standard sprayer (Hardi 300 litres* ha^{-1}*; 0.50 m nozzle spacing) using standard flat fan XR11004 and pre-orifice flat fan nozzles (DG11004) and a low-boom sprayer (Rau 200 litres* ha^{-1}*; 0.25 m nozzle spacing) with pre-orifice flat fan nozzles (DG110015) and venturi-flat fan nozzles (ID90015)*

Table 4: *Averaged spray drift deposition (% of volume application rate) on different zones next to the field (m distance from the last nozzle) spraying potatoes with a standard sprayer (Hardi; 0.50 m nozzle spacing) and a low-boom sprayer (Rau; 0.25 m nozzle spacing) with different nozzle types, conventional or with air assistance*

Sprayer	nozzle	air	spb. height [cm]	Spray drift deposition 2½-3½ m	1-5 m	3-4 m	1½-6 m
Hardi	XR11004	-	50	3,14^{A}	6,69^{A}	2,21^{A}	3,55^{A}
		+	50	0,14^{CDE}	1,64^{B}	0,08^{EF}	0,49^{C}
	DG11004+IS8004	-	50	1,06^{B}	1,90^{B}	0,84^{B}	0,96^{B}
		+	50	0,06^{E}	0,25^{D}	0,05^{E}	0,08^{D}
Rau	DG80015+IS8002	-	30	1,39^{B}	1,50^{B}	1,24^{BC}	1,19^{B}
		+	30	0,18^{CD}	0,46^{CD}	0,14^{F}	0,21^{EF}
	ID90015+IS8002	-	30	0,20^{C}	0,52^{C}	0,17^{D}	0,25^{CE}
		+	30	0,08^{DE}	0,21^{D}	0,07^{EF}	0,11^{DF}

*) different letters in the same column are significantly different ($\alpha<0,05$)

All low-boom (Rau) combinations of nozzle-type and air assistance have a significant lower level of spray drift deposition on these ditch and surface water zones compared to the reference situation (XR11004). Except for the DG80015 nozzle sprayed conventional, all low-boom combinations (Rau) result also in significant lower drift levels than the DG11004 nozzle on the standard sprayer.

Airborne spray drift

Airborne drift measured at 5.5 m distance from the last nozzle is averaged over height (0-4 m) and presented in table 5. All combinations of low-boom spraying and air assistance give, except for the DG80015 nozzle, a significant lower airborne drift than the reference sprayer (XR11004). Although the DG11004 nozzle on the standard sprayer has a lower level of airborne drift, this difference is not significantly different with the level of the reference situation (XR11004). Except for the DG80015 nozzle sprayed conventional, all low-boom combinations (Rau) result in a significant lower level of airborne drift than the DG11004 nozzle on the standard sprayer also.

Table 5: *Airborne spray drift (% of volume application rate averaged over 0-4 m height) measured at 5.5 m distance from the last nozzle spraying a potato field with a standard (Hardi) and a low-boom (Rau) sprayer with different combinations of nozzle types and air assistance*

Sprayer	nozzle	air	spb. height [cm]	0-4 m*)
Hardi	XR11004	-	50	$2{,}33^{A}$
		+	50	$0{,}25^{BCD}$
	DG11004+IS8004	-	50	$1{,}46^{A}$
		+	50	$0{,}18^{D}$
Rau	DG80015+IS8002	-	30	$2{,}08^{A}$
		+	30	$0{,}53^{B}$
	ID90015+IS8002	-	30	$0{,}35^{BC}$
		+	30	$0{,}21^{CD}$

*) different letters mean significant difference (α<0,05)

Spray drift reduction

Spray drift deposition at different distances next to the field can be expressed as spray drift reduction compared to the reference situation, the standard sprayer using XR11004 flat fan nozzles at 3 bar pressure. In table 6 the drift reduction is calculated for the zones where the ditch and surface water can be situated when a 1m or 1,5 m crop-free buffer zone is used. When the

Table 6 :*Spray drift reduction on different zones next to the field (m distance from the last nozzle) spraying a potato field, compared to the reference situation (XR11004)*

			spb. height	Drift reduction % at zones [m]			
Sprayer	nozzle	air	[cm]	2½-3½	1-5	3-4	1½-6
Hardi	XR 110.04	-	50	*	*	*	*
		+	50	96	75	96	86
	DG 110.04	-	50	66	72	62	73
		+	50	98	96	98	98
Rau	DG 80.015	-	30	56	78	44	67
		+	30	94	93	94	94
	ID 90.015	-	30	94	92	92	93
		+	30	97	97	97	97

ditch (4 m wide) is at 1-5 m from the last nozzle spray drift reduction for the low-boom sprayer is 78% for the DG80015 pre-orifice flat fan nozzle and 92% for the venturi-flat fan (ID90015) nozzle. Combining these nozzle types with air assistance (Rau AirPlus) spray drift reduction is increased to 93% and 97% for both nozzle types respectively.

Compared to the standard sprayer (Hardi) using low drift pre-orifice nozzles (DG11004) the low-boom sprayer (Rau) using venturi flat-fan nozzles (ID90015) gives higher drift reductions (respectively 66-73% and 92-94%) on the mentioned zones. In combination with air assistance both sprayers give similar results in spray drift reduction (respectively 96-98% and 97%) on the different zones.

The effect of air assistance of the two sprayer types is presented in table 7. Reduction in spray drift because of air assistance is expressed relative to the same nozzle on the sprayer at the different zones next to the field. At the zone 1-5 m from the last nozzle the air assistance of the Twin Force results in a drift reduction of 75% and 87% respectively for the standard flat fan nozzle (XR11004) and the pre-orifice flat fan nozzle (DG11004). For the AirPlus air assistance drift reduction on this zone is respectively 69% for the pre-orifice flat fan nozzle (DG80015) and 59% for the venturi flat fan nozzle (ID90015) nozzle type. On all zones the effect of air assistance on the low-boom sprayer (Rau AirPlus) is lower than of the standard sprayer with air-assistance (Hardi Twin Force).

Table 7. *Effect of two types of air assistance on spray drift reduction used with different nozzle types and boom heights at different zones next to a sprayed potato field*.

		spb. height	Spray drift reduction % at [m]			
Sprayer	nozzle	[cm]	2½-3½	1-5	3-4	1½-6
Hardi Twin Force	XR11004	50	96	75	96	86
	DG11004	50	94	87	94	92
Rau AirPlus	DG80015	30	87	69	89	83
	ID90015	30	59	59	62	55

Discussion

Results show that lowered heights of spray booms of field sprayers can give a significant reduction in spray drift despite the double number of nozzles and the lower flow rates. Lower boom heights require however a stable boom. Based on measurements of the boom movement during the drift experiments it is shown that stability varies for the two used sprayers although going through the same track after another. It is suggested that more attention should be paid to boom stability both from the construction perspective as for sprayer settings in the field.

The presented difference in drift reduction for the two air assistance systems does not mean that the one type of air assistance really differs from the other one as the effect of boom height as well as nozzle type is in the comparison. A direct comparison with the same settings under similar conditions is then needed. Lowering boom height had also a decreasing effect on drift reduction because of air assistance on the Hardi Twin Force system as shown by Jong *et al.* (2000) . This resulted in similar spray drift reduction figures at 0.30 m boom height with the standard flat fan nozzle at 2-3m distance from the nozzle (89%).

The shown drift reductions of the low-boom sprayer are an effect originating from the combination of boom height and nozzle type, and cannot be separated from these experiments. From earlier experiments (Zande *et al*., 2000) with a conventional sprayer using comparable nozzle types (DG11002 and ID12002) resulted in lower drift reductions (respectively 29% increase and 79% decrease) than presented in this study. The additional drift reduction effect can therefore be awarded to the lower boom height.

Based on the results on the zones 1-5 and 1.5-6 m from the last nozzle the conclusion was drawn that lower boom heights at 0.30 m above crop canopy can in combination with pre-orifice flat fan (DG80015) nozzle types or venturi flat fan (ID90015) nozzle types sprayed at 3 bar (or lower), at a nozzle spacing of 0.25 m, reduce spray drift more than 50% or even more than 90%

respectively compared to the reference system (300 litres ha^{-1} - XR11004). With the additional use of air assistance (Rau AirPlus) used with an airflow vertically downward and nozzles in a 35° backwards direction these combinations reach drift reduction classes of 90 for the DG80015 nozzle and 95 for the ID90015 nozzle type.

Based on these results these combinations are entered in the certification process for low drift classification of spray techniques (CIW, 2003) in the Netherlands allowed to be used with smaller dimensioned crop-free buffer zones.

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