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Title:

Ranking of low-drift nozzles and air-assistance for spray drift

Authors:

Zande, J.C. van de (*); Michielsen, J.M.G.P.; Stallinga, H.; Jong, A. de

Institute of Agricultural and Environmental Engineering (IMAG), P.O.Box 43, 6700AA Wageningen, The Netherlands. Tel: ++31.317.476315 Fax:++31.317.425670 email: j.c.vandezande@imag.wag-ur.nl

Summary:

In two years of field experiments spray drift was quantified for a series of low-drift nozzle types applying a spray volume of 300 l/ha (1998) or 150 l/ha (1999). Drift deposition was evaluated of the nozzle types: standard flat fan (XR11004/XR11002), pre-orifice flat fan (DG11004/DG11002), anvil flatfan (TT11004/TT11002) and two types of venturi nozzles (ID12004/ID12002 and XLTD11004/XLTD 11002). All nozzles were used conventionally and in combination with air assistance. Spray drift measurements were carried out by adding the fluorescent dye Brilliant Sulfo Flavine (BSF) to the spray agent. Spray drift deposition was measured by placing collectors up to 15m downwind of a 18m width sprayed swath of potatoes
Compared with a XR11004 nozzle, as a reference situation for most spraying applications, a ranking for drift reduction can be presented when soil deposit is evaluated at 2-3 m distance from the last nozzle. Results show that the terminology low drift nozzle needs further specification.

Introduction

The spraying of agrochemicals for crop protection should result in a more direct application to the crop, providing a better spray coverage and the prevention of drift to the soil and the air adjacent to the sprayed field. Spray quality and driftability are two important nozzle parameters in this context (Southcombe *et al*., 1997). IMAG developed a methodology to classify spray nozzles for driftability (Porskamp *et al*., 1999), based on laboratory measurements (Phase Doppler Anemometry) and a 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. This classification holds only for conventional use of nozzles. Extension of the classification of driftability of nozzle types in combination with air-assistance on field sprayers was therefor incorporated by means of data from field measurements of spray drift. Experiments were therefor setup to quantify the effect on spray drift of nozzle-types spraying at two spray volumes in combination with air assistance. Also to find out if air assistance gave a similar drift reduction when using different low-drift nozzle-types.Therefor in two years of field experiments spray drift was quantified for a series of low-drift nozzle types all applying a spray volume of 300 l/ha (1998) or 150 l/ha (1999). 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.

Material and methods

Drift measurement were carried out according to the ISO-draft standard (ISOCD 12057; ISO/TC23/SC6N283 dated 01-08-1997) adapted for the situation in the Netherlands (ground deposits, ditch, surface water next to the sprayed field). Drift was measured on the downwind edge of an experimental field with a potato crop. The swath-width of potatoes sprayed was 18m. The length of the sprayed track was at least 50m. The distance of the last downwind nozzle to the edge of the field (the last crop leaves) was determined.

Spray drift measurements were carried out by adding the fluorescent dye Brilliant Sulfo Flavine (BSF; 2.5 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 with dimensions of 0.50x0.08m and 1.00x0.08m. The collectors were washed and the BSF concentration in the extracted fluid was measured by fluorimetry (Perkin Elmer fluorimeter).

Used spraying techniques

The nozzle types as indicated in Table 1 were used to spray either 300 l/ha (1998) or 150 l/ha (1999). All nozzles were used in a conventional way and with the use of air assistance, with identical travelling speed, sprayer boom height (0,5 m above crop canopy) and liquid pressure (3 bar). In case of air assistance (Hardi Twin), nozzles were kept vertical and air velocity was set to the maximum capacity of the fan.

In 1998 two sprayers were used, a hitched one (Sprayer I) and a trailed one (Sprayer II). In 1999 only the hitched one was used (Sprayer I). Sprayer boom construction was the same for both sprayer types. The working width of the sprayers was 18m with a nozzle spacing of 0.5m on the sprayer boom.The last nozzle was on average at a distance of 0,6m from the outer edge of the potato crop canopy.

Repetitions of the measurements were done on more dates during the growing season, to obtain an average crop season (crop height) result.

Table 1. Nozzles (3 bar spray pressure) used in the drift measurements spraying 300 l/ha (1998) and 150 l/ha (1999)

nozzle type	code	Manufacturer	nozzle size and BCPC spray quality			
			1998		1999	
flat fan standard	ST	Teejet	XR 11004	Medium	XR 11004	Medium
flat fan	XR	Teejet	-		XR 11002	Fine
anvil flat fan	TT	Teejet	TT 11004	Coarse	TT 11002	Medium
pre-orifice flat fan	DG	Teejet	DG 11004	Coarse	DG 11002	Medium
venturi	ID	Lechler	ID 12004	Very Coarse	ID 12002	Very Coarse
venturi	XLTD	Agrotop	XLTD04-110	Very Coarse	XLTD02-110	Very Coarse

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 0.5m above the top of the crop canopy. Driving speed was 6 km/h resulting in an applied volume rate of 300 l/ha (ST in Table 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 2.0m height, using cup anemometers and Pt100 sensors, respectively. Relative humidity was measured at 0.5m 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 the wind direction range of 90^o +/- 30^o to the spray track.

Table.2. Average weather conditions during spray drift measurements in 1998 and 1999

	temperature [^{0}C] at 2m height	Relative Humidity [%]	winddirection[1]) [degrees]	windspeed [m/s] at 2m height
1998	19.0	74	15	4.0
1999	18,4	72	19	2.2

[1]) ^{o} square to driving direction

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 zone 2-3 m from the last nozzle being the zone 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

Spray volume 300 l/ha

Spray drift deposition

The results of the spray drift measurements for the 300 l/ha spray volume are presented in Figure 1, averaged for the 10 repetitions. Sprayer I and Sprayer II resulted in a different level of spray drift deposition, therefore the nozzle types are compared with the Standard nozzle on the same sprayer. The statistical analysis of spray drift deposition on 2-3m distance from the last nozzle is presented in Table 3.

Table 3. Average spray drift deposition (% of sprayed volume) for 04 nozzle types spraying 300 l/ha, on 2-3m distance from the last nozzle

sprayer	air assistance	ST	DG	TT	ID	XLTD
I	-	6.68 [a]	1.60 [c]	2.89 [b]		
	+	1.22 [a]	0.73 [b]	0.64 [b]		
II	-	2.64 [a]			0.33 [b]	0.31 [b]
	+	0.51 [a]			0.09 [b]	0.09 [b]

statistical significant differences ($\alpha<0.05$) are indicated with different letters in the same row

The difference in spray drift deposition between the conventional and the air assisted spraying is for each nozzle type significantly different ($\alpha<0.05$). The values for both Sprayer I and II for the Standard nozzle type (resp. 6.68% and 2.64%) are significantly different, also for the air-assisted spraying (1.22% and 0.51% resp.). Spray drift deposition of the low drift nozzles is significantly different from the standard nozzle, both conventionally sprayed and with the use of air assistance.

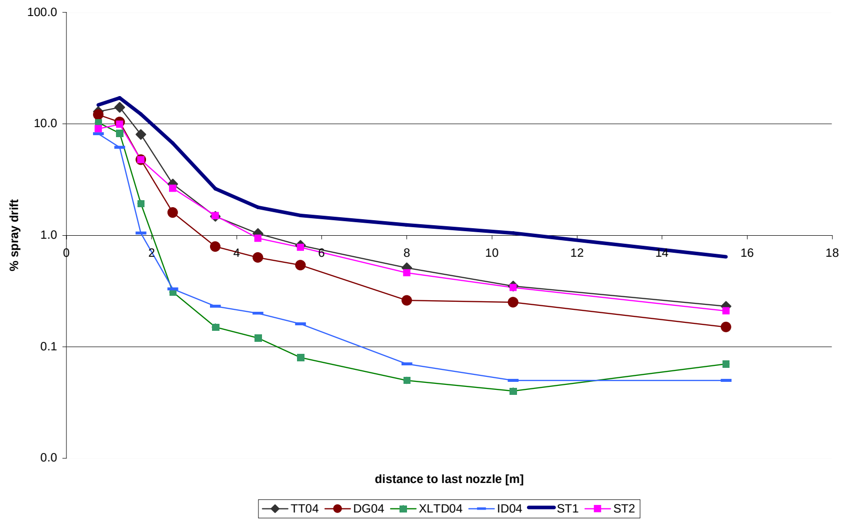
Spray drift reduction

The effect of both nozzle type and nozzle type in combination with air assistance on spray drift reduction on 2-3m distance from the last nozzle are calculated, compared to the standard nozzle-type, and are presented in Table 4.

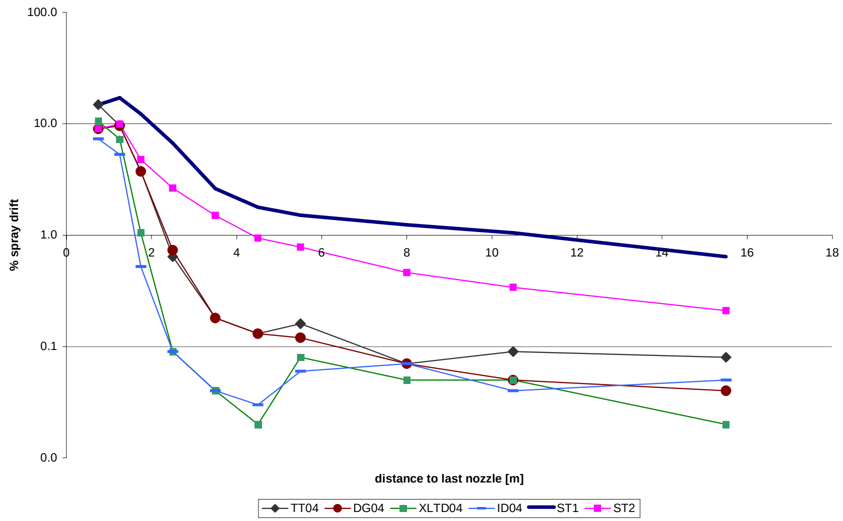
Table 4. Average spray drift reduction because of nozzle type (-) and of nozzle type in combination with air assistance (+) spraying a volume of 300 l/ha on 2-3m distance from the last nozzle

sprayer	air assistance	ST	DG	TT	ID	XLTD
I	-	*	76	57		
	+	82	89	90		
II	-	*			87	88
	+	81			96	96

On average spray drift reduction is more than 50% for the TT nozzle type sprayed conventionally. For the DG nozzle type spray drift reduction is more than 75% and for the ID and XLTD nozzle types more than 85%. With the use of air assistance on the sprayer the drift reduction is increased to more

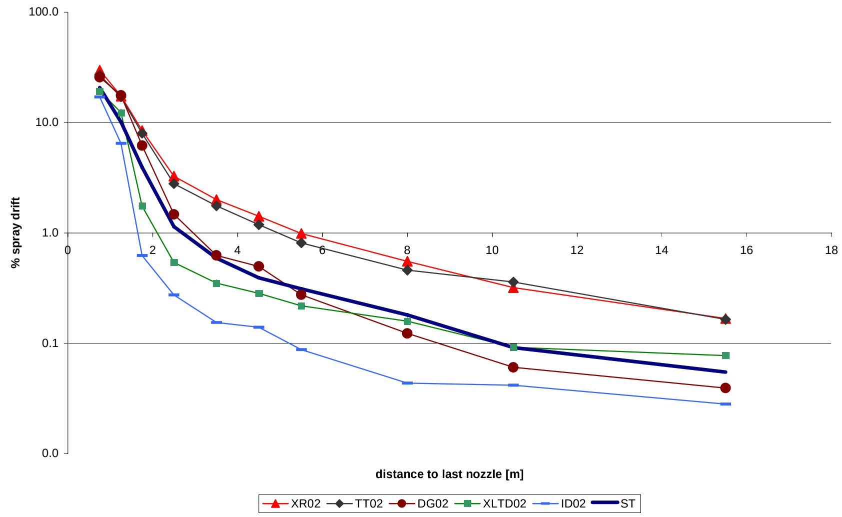


a



b

Figure 1. Spray drift deposition (% of sprayed volume) on different distances next to the field when spraying 300 l/ha (04 nozzle types @ 3 bar) DG, TT and ST1 are mounted on sprayer I; ID, XLTD and ST2 on sprayer II. a. conventional b. with air assistance



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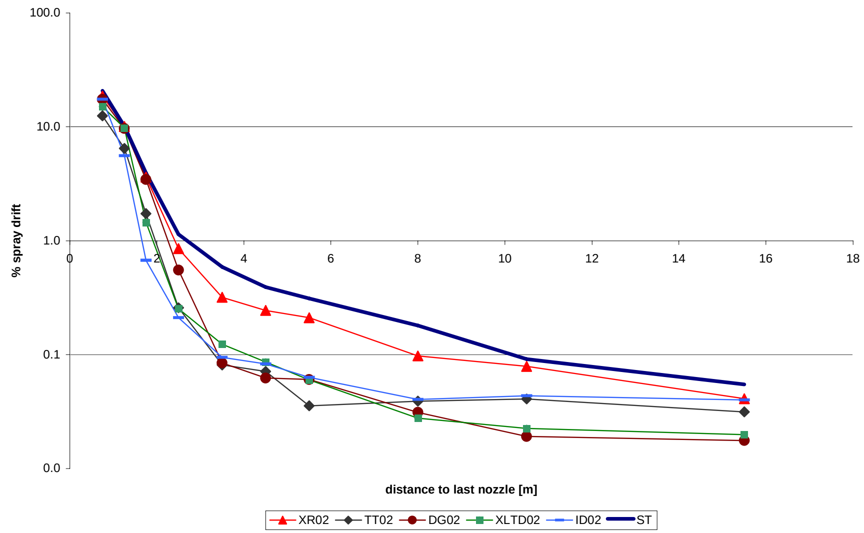

d

Figure 2. Spray drift deposition (% of sprayed volume) on different distances next to the field when spraying 150 l/ha (02 nozzle types @ 3 bar) all nozzle-types are mounted on sprayer I;. c. conventional d. with air assistance

than 80% for all nozzle types, even up to 96% for both types of venturi nozzles (ID and XLTD). Air assistance, irrespective of the nozzle types, reduces spray drift on average with 70%, ranging from 54% to 82%.

Spray volume 150 l/ha

Spray drift deposition

The results of the spray drift measurements in 1999 for the spray volume of 150 l/ha are presented, averaged for the 10 repetitions, in Figure 2. Average spray drift deposition on the distance 2-3m from the last nozzle and the results of the statistical analysis are presented in Table 5 .

Table 5. Average spray drift deposition (% of sprayed volume) for 02 nozzle types spraying 150 l/ha and the standard (04; 300 l/ha), on 2-3m distance from the last nozzle

sprayer	air assistance	ST	XR	DG	TT	ID	XLTD
I	-	1.14[a]	3.26[b]	1.47[ac]	2.79[bc]	0.27[d]	0.54[ad]
	+	0.26[a]	0.85[b]	0.55 [a]	0.26 [a]	0.21[a]	0.25 [a]

statistical significant differences ($\alpha<0.05$) are indicated with different letters in the same row

A significant higher spray deposition does occur when using an XR or TT nozzle of the 02 size instead of the standard (300 l/ha; XR11004). Only the ID venturi nozzle reduces spray drift deposition significantly at 2-3m distance from the last nozzle when spraying 150 l/ha conventionally.

Air assistance reduced spray drift deposition significantly except for both the venturi type nozzles (XLTD and ID.

Spray drift reduction

The effect of both nozzle type and nozzle type in combination with air assistance on spray drift reduction are presented in Table 6.

Table 6. Average spray drift reduction compared to a standard nozzle (ST=300 l/ha; XR11004) of nozzle types (-) and nozzle type in combination with air assistance (+) spraying a volume of 150 l/ha on 2-3m distance from the last nozzle

sprayer	air assistance	ST	XR	DG	TT	ID	XLTD
I	-		-186	-29	-145	76	53
	+	77	25	52	77	82	78

Spray drift reduction differs for the different nozzle types. The XR, DG and TT nozzles increase spray drift compared to the standard 04 nozzle, and the two venturi nozzles reduce spray drift with more than 50% or more than 75% (resp. XLTD and ID nozzle type).

With the use of air assistance on the sprayer the drift reduction can be increased to more than 25% for the XR nozzle type, more than 50% for the DG and even more than 75% for the TT, XLTD and ID nozzle types. The two venturi nozzles (XLTD and ID) reduced spray drift highest when used in combination with air assistance. Air assistance, irrespective of the nozzle type, reduced spray drift on average with 70%, except when used in combination with the ID nozzle type where the effect of air assistance was only 22%. Depending on nozzle type the additional effect on drift reduction of air assistance ranged from 22% (ID) to 91% (TT).

Discussion

Results show that not all ‘low-drift’ nozzles show similar results, therefore the terminology low’-drift’ nozzle needs further specification. In order to get a better comparison between years a ranking system can be introduced by expressing spray drift deposition on 2-3m distance from the last nozzle relative to the agreed standard situation.
In Figures 3 and 4 the spray drift deposition on 2-3m for the standard situation (XR11004 @ 3 bar) is set to 1, and the spray drift deposition of the other spray combinations is expressed as a fraction of the standard. This way the effect of both nozzle type and air assistance can be ranked.
Although wind conditions were quite different for both years, average wind speed for the 1998 experiments was 4.0 m/s and for 1999 2.0 m/s, conclusions can be drawn on a relative basis. However a statistical analysis on ranked order should be further developed for this purpose. Furthermore a scaling of drift deposit data towards standard meteorological conditions would be of benefit also. Especially when data on spray drift deposition are used in regulatory calculations e.g. approval of agrochemicals, ecotoxicological risk in surface water, etc.
From both figures 3 and 4 it can be concluded that e.g. the drift reduction by air assistance in combination with the standard nozzle (XR11004 @3bar) was equal for both measuring seasons (around 80%). This effect was also shown for the effect of air assistance on the two different sprayers used in 1998.
Despite the similar weather and crop conditions during experiments, absolute levels of spray drift deposition were quite different for both sprayer types in 1998, using the standard nozzle type. It is suggested that these differences in spray drift deposit levels are caused by sprayer boom height setting. The accurate measurement of boom-height above a crop canopy is troublesome. Moreover there can be a difference in stationary measured and dynamic boom height when driving with a hitched and a trailed sprayer.
Comparing the level of effect on spray drift reduction for the two series of nozzle-types (Figures 3 and 4) it shows that the 02 series of nozzle types used to spray 150 l/ha remains at a higher level than that of the 04 series nozzles used to spray 300 l/ha. These kind of effects were also found by other field experiments (Taylor et al., 1999; Ripke et al., 1998), wind tunnel tests (Taylor et al., 1999) and spray drift modelling (Porskamp et al., 1999).
Spray drift data found in this study are in agreement with other field experiments quantifying the effect of ‘low-drift’nozzles like the TT11002 (Csorba et al., 1995; Debroize & Denoirjean, 2000) the ID12002 (Ripke et al.. 1998), the XLTD (Debroize & Denoirjean, 2000) and the DG11004 (Göbel & Pearson. 1993). However, based on these studies, dealing with a limited number of nozzle comparisons, no good view on the total range of drift reducing effects can be obtained. None of these studies seperate the additional effect of air assistance as in this study. In order to come to a better exchange of data from these kind of field experiments the use of a reference system should be emphasised. A ‘reference spraying system’ is however not only country or regional specific, but can also be crop specific.

Conclusions

From the two years of experiments it becomes clear that within a group of low drift nozzles a ranking towards level of drift reduction is possible. Compared with a XR11004 nozzle, as a reference situation, it shows that a ranking for drift reduction can be presented when evaluated as soil deposit at 2-3 m distance from the last nozzle.

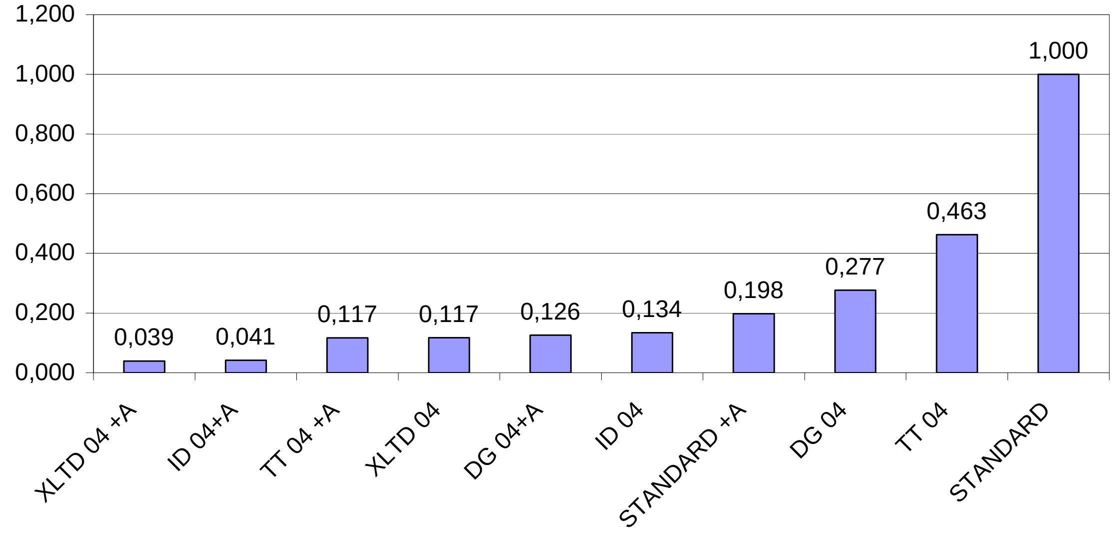

Figure 3. Relative spray drift deposition on 2-3m from the last nozzle for different low-drift nozzles and air assistance (+A) when spraying potatoes with a spray volume of 300 l/ha. Standard nozzle type is XR11004 (=1).

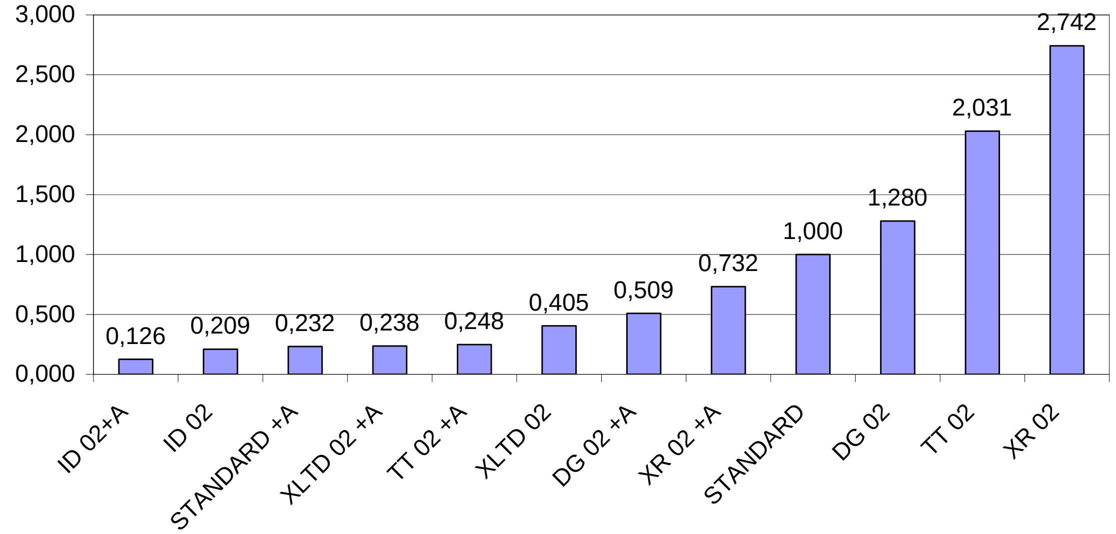

Figure 4. Relative spray drift deposition on 2-3m from the last nozzle for different low-drift nozzles and air assistance (+A) when spraying potatoes with a spray volume of 150 l/ha. Standard nozzle type is XR11004 (=1).

For the 300 l/ha spray volume the ranking for spray drift reduction was: 53% for the TT11004, 73% for the DG11004, 87% for the ID12004 and 88% for the XLTD04.
In combination with air assistance this ranking was: 80% for the XR11004, 87% for the DG11004, 88% for the TT11004, 96% for the ID12004 and 96% for the XLTD04.
For the 150 l/ha nozzles the ranking for spray drift reduction was: 60% for the XLTD02 and 79% for the ID12002. In combination with air assistance this ranking was: 27% for the XR11002, 49% for the DG11002, 75% for the TT11002, 76% for the XLTD02, 87% for the ID12002.
The DG11002, TT11002 and XR11002 nozzles produced resp. 28%, 100% and 170% more spray drift compared to the reference nozzle (XR11004).

The reduction of spray drift by the use of air assistance on the field sprayer seems to be, independent of the nozzle type, around 70% (except for the ID12002 and the XLTD02). The terminology 'low-drift'nozzle needs further specification. Comparison with a standard sprayer-nozzle configuration is of value, also for comparison of the results with other drift experiments.

Acknowledgement

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