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Edge of field variation of spray drift deposition

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Summary

Spray drift experiments were performed to quantify the variation of spray drift deposition alongside the treated field. A comparison is made between the standard setup of a spray drift measurement measuring spray drift deposition in the middle downwind of the edge of the sprayed field. Ground collectors are used in the area 0.50–15 m from the last nozzle and a continuous line of ground collectors at 2 m and 5 m from the last nozzle alongside the total length of the crop-edge of the field. A potato field of 102 m length and 75 m width edges was therefore sprayed. During spray application wind speed and direction was recorded. The spray liquid used was tap water with fluorescent dye added (Brilliant Sulfo Flavine) and a non-ionic surfactant (Agral Gold). In the laboratory, the BSF was extracted from the collectors with demineralised water and analysed by fluorimetry (Perkin Elmer LS 45). Spray deposits were expressed as $\mu L\ cm^{-2}$ and as percentage of the applied spray volume. During spraying the sprayer boom movement was measured in the horizontal plane and vertical plane. Spray drift deposition pattern alongside the field edge was compared to the standard spray drift setup and the sprayer boom movement.

Key words: Spray drift, variability, spray technique, reference, risk assessment, exposure

Introduction

In the authorisation procedures of Plant Protection Products (PPP) the exposure of surface water is determined by the spray drift deposition for a surface water distance based on a single spray drift curve (Ctgb, 2017; FOCUS, 2001; Zande *et al*., 2012; Rautmann *et al*., 2001). This one value spray drift deposition is in the authorisation procedure of PPP distributed over a 100 m length field ditch, assuming the spray drift deposition is evenly distributed along the field edge. Due to variation in sprayer boom movement, variation in forward speed and therefore spray pressure (and spray dose of the PPP) and variation in wind speed and direction during application a large variation of the spray drift deposition may occur over the length of the ditch. First indication (Zande *et al*., 2006) showed that coefficients of variation of spray drift deposition at 2 m from the edge of the field could be around 40–75% depending on type of spray technique and nozzle type. Also starting and stopping effects of the sprayer at the headlands caused variation in actual spray drift exposure. To come to a more realistic exposure of surface water at the field edge, it was suggested to take these kind of variability parameters up in future spray drift modelling at the landscape scale (Holterman & Zande, 2008). As limited information is available additional spray drift measurements were performed to quantify the edge of field variation of spray drift deposition in more detail spraying a potato field in the Netherlands. Although experiments were done with a boom sprayer equipped with two nozzle types (standard flat fan and 50% drift reducing nozzle) and with and without air assistance (Hardi Twin Force) only the results of a standard sprayer setup are presented in this paper.

Materials & Methods

Spray techniques

In 2007–2008 spray drift was measured spraying a potato field (Oostwaardhoeve, Slootdorp NL). The potato field (72 m (three swaths) wide, 102 m long) was surrounded by a crop-free area of 25 m, which was used to measure spray drift deposition (Fig. 1). Spray drift was measured downwind of the sprayed swath alongside either the long end of the field (Fig. 1 A-B, C-D) or the headland (Fig. 1 B-C, D-A) depending on the wind direction, as well as halfway of the field swath sprayed, with a standard spray drift measurement setup. Start and stop effect in the corners of the field on spray drift were also measured (Fig. 1).

The spray technique used was a 24 m working-width Hardi Commander (Twin Force) used as a conventional boom sprayer equipped with standard flat fan nozzles (TeeJet XR11004, nozzle spacing 50 cm and spray boom height 50 cm) operated at 3 bar spray pressure and 6.0 km h^{-1} forward speed, thereby applying a spray volume of 310 L ha^{-1}. During application, the potato crop height was 40–70 cm.

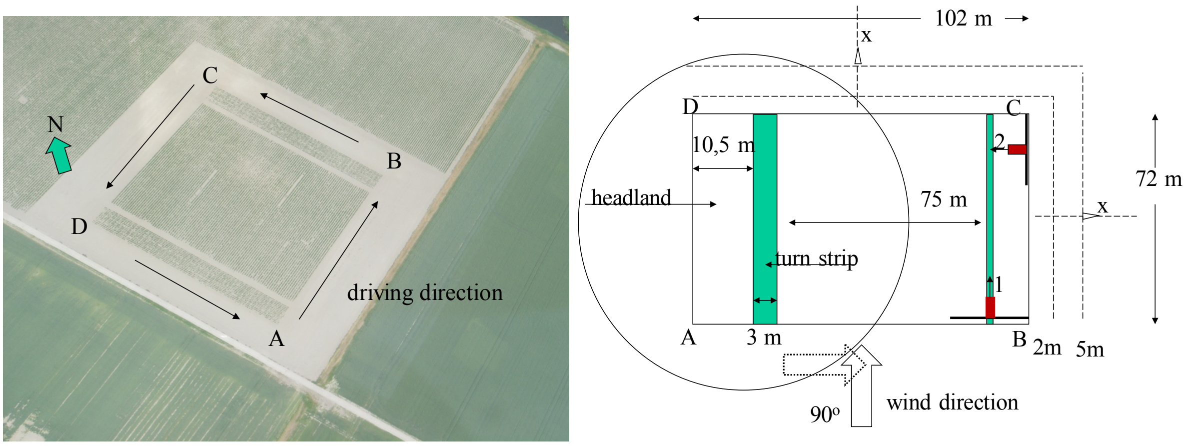

Fig. 1. Aerial view of field layout (2008) with dimensions, driving directions (swath 1 headland, swath 2 long edge) and spray drift measuring array setup (2 m, 5 m, x = standard) alongside downwind long edge of field and at headland.

Spray drift measurements

The spray drift measurements were performed in 2007 (11 July, 2, 28 August) and 2008 (23, 29 July, 9, 10 September) spraying a potato field. During the spray application, a single swath of 24 m was sprayed over 102 m or 72 m length, resp. long end and headland. Spray drift measurements were done spraying tap water to which a fluorescent tracer Brilliant Sulfo Flavine (BSF, Chroma CI 56205, 3–4 g L^{-1}) and a non-ionic surfactant (Agral, 1 mL L^{-1}) was added.

Spray drift collector layout

Around the planted potato crop was an approximately 25 m wide bare soil surface area. In the downwind strip of land two continuous measurement arrays were laid out at 2 m and 5 m from the last crop row. Collectors (Technofil TF 290; 10 cm × 50 cm) were positioned next to each other. At the middle of the edge of the field a standard drift setup was positioned. The standard spray drift field setup consisted of a double line of ground collectors was laid out at 2 m spacing between the lines. Spray drift collectors (Technofil TF 290; 10 cm × 100 cm, 10 cm × 50 cm) were laid out normal to the crop rows and travel direction of the sprayer to quantify spray drift fallout at ground level at positions:

- At 0.5–6 m in a continuous line of collectors of 0.5 m length;
- At 7.5–8.5 m, 10–11 m, 15–16 m collectors of 1 m length.

Distances were measured from the last nozzle position in the sprayed field.

Airborne spray drift was measured at 5.5 m distance from the last nozzle up to 6 m height with 2 lines of ball shaped collectors (Siebauer Abtrifftkollektoren art. nr. 00140)spaced at 1m intervals. The applied field spray volume was checked with collectors (Technofil TF 290; 10 cm × 100 cm) positioned on top of leaf canopy surface.

Fig. 2. Spray drift collector strips along field edge at 2 m and 5 m distance (top), with spray boom movement measuring device (top right); start of spraying swath at upwind headland field edge (bottom left) and sprayer passing the standard spray drift halfway the downwind edge of the field (bottom right).

Spray drift deposition analysis

After spraying the collectors were put in plastic bags, coded, collected and stowed for further analysis of the collected amount of BSF. Every measuring day samples of the tank spray solution were collected from a spraying nozzle to determine the solution concentration. In the laboratory, the collectors were washed with demineralised water and the BSF concentration was analysed with a fluorimeter (Perkin Elmer LS 45). For determination of the background fluorescent signal of the collectors' blank collectors were analysed too. From the reading of the fluorimeter, the calibration line, the collector surface area, the spray concentration, the background (collector + dilution liquid) and the volume of dilution liquid the amount of spray deposit per unit area was calculated, and expressed in µL cm^{-2}. From this spray drift deposition figure the percentage of spray drift on a collector was calculated relating the spray drift deposition to the amount applied in the field on the same unit of area. Spray drift evaluation presented in this paper is focussed on the 2 and 5 m distance for the standard drift setup, 20 m around the position of this standard setup (40–60 m) and the full length of the sprayed field of 100 m of collectors.

Sprayer boom movement

During spraying the boom position in the field was measured with a system (Jong *et al*., 2000) consisting of a laser distance indicator (Sick DME200) and an ultrasonic sound (AE, P42-A4N-2D-1C1-130) height sensor. The ultrasonic sensor was positioned at the end of the sprayer boom, to measure boom height over the open strip. The data from the ultrasonic sensor was sent wireless (ADAM 4550) to the computer connected to the laser-measuring device. The system checked the distance and height of the boom tip in the field every 0.1 s (10Hz). The height and the distance, together with the time were synchronised and recorded online. In the field two markers were positioned ± 10 m from the centre of the standard spray drift setup.

Weather conditions

During the spray drift experiments the average temperature at 2.0 m height was 19 °C, the average wind direction normal to the driving direction was -6° (predominantly from behind the sprayer) and the average wind speed at 2 m height was 3.5 m s^{-1}.

Results

Sprayer boom movement

Examples of vertical and horizontal boom movement are presented for the 2007 measurements spraying one of the long edges (A to B, Fig. 1) of the potato field (Fig. 3). Similar boom movement patterns occur driving through the same track during the growing season repeatedly and amplitude both in the horizontal and the vertical plane also increases.

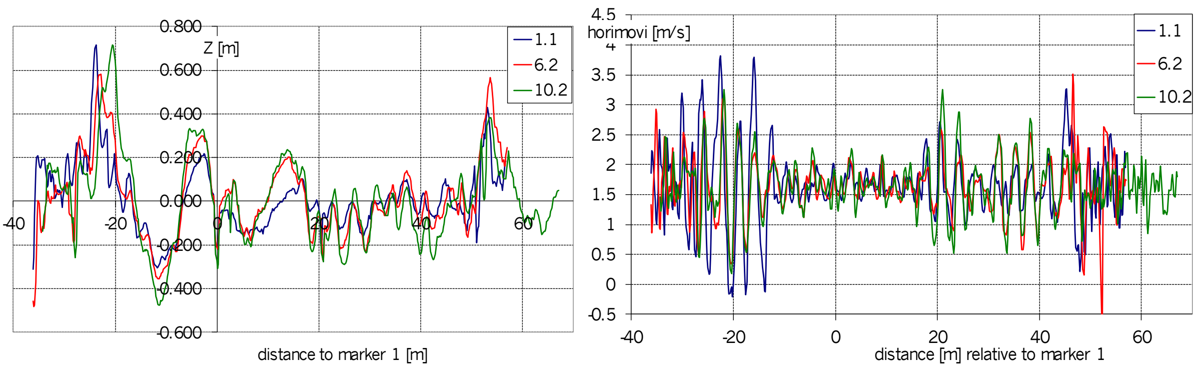

Fig. 3. Sprayer boom height (left; (m) relative to set boom height of 0.5 m above crop canopy) and horizontal boom speed (right; (m s^{-1}) average sprayer forward speed 1.65 m s^{-1}) for a 24 m working width trailed boom sprayer equipped with standard flatfan nozzles spraying the long edge of a potato field expressed relative to the marker of the standard spray drift setup.

Vertical and horizontal boom movement can be presented in parameters as Standard Deviation (SD) of recorded sprayer boom speed relative to the average forward speed and recorded boom height relative to the set boom height above crop canopy and therefor ground level. To evaluate the data the percentage of time the boom was within the 10% limit of the set boom height and the average measured forward speed is presented (Table 1). It is shown that for the vertical boom movement time within ± 10 cm of set boom height is in the range of 13–100%. Horizontal boom movement shows to be, for 24–92% of the time, within the range of ± 10% of average measured forward speed. Starting and stopping spraying at the headland and passing the turning strips at the headland clearly induces more sprayer boom movement than spraying the length of the track of the field as higher peaks in boom height and boom forward speed can be seen (Fig. 3).

Spray drift deposition

Spray drift deposition at 2 m and 5 m distance alongside the long edge of the sprayed potato field shows large variations (Fig. 4; Table 2). At 2 m distance average spray drift deposition is similar

Table 1. *Vertical and horizontal boom movement parameters for a 24 m boom width trailed sprayer spraying the long edge of a potato field*

			Driving direction			Horizontal			Vertical	
Date	Edge	Rep	From	To	km h^{-1}	m s^{-1}	SD	± 10%	SD	± 10 cm
11-7-2007	long	1	A	B	6.0	1.66	0.23	64.8	0.04	86.5
2-8-2007	long	2	A	B	5.9	1.64	0.19	63.6	0.06	54.9
28-8-2007	long	3	A	B	5.8	1.61	0.31	50.3	0.07	42.9
11-7-2007	head	1	B	C	6.1	1.70	0.35	32.3	0.17	12.8
2-8-2007	head	2	B	C	6.2	1.72	0.24	51.6	0.08	47.9
28-8-2007	head	3	D	A	6.2	1.72	0.56	24.1	0.05	40.3
23-7-2008	long	4	A	B	6.1	1.67	0.10	91.8	0.02	100.0
29-7-2008	long	5	C	D	6	1.66	0.18	65.7	0.03	90.4
9-9-2008	long	6	C	D	5.9	1.64	0.26	50.8	0.05	67.6
23-7-2008	head	4	D	A	5.9	1.65	0.32	51.8	0.08	60.4
29-7-2008	head	5	B	C	5.8	1.60	0.19	56.9	0.02	65.7
10-9-2008	head	6	B	C	-				0.37	31.3

Table 2. *Spray drift deposition and its variation in different parameters (% of applied spray volume per unit area) at 2 m distance from the last nozzle for a 24 m working width trailed boom sprayer standard flatfan nozzles spraying the long edge of a potato field for the whole length (100 m) the standard drift setup and 20 m around the standard drift setup (40–60 m) (six repetitions)*

	#	Avg.	SD	Cv	10-perc	Median	90-perc	Min	Max	Span
Length ~100 m	1	3.1	5.4	176	0.53	1.4	6.2	0.08	42.6	3.98
	2	4.3	4.5	105	0.50	2.9	10.6	0.03	24.6	3.53
	3	11.6	6.1	53	5.22	10.0	20.2	2.60	41.0	1.50
	4	6.4	3.7	58	2.37	6.0	11.0	0.03	20.4	1.43
	5	4.5	3.5	78	0.04	3.4	9.5	0.00	15.3	2.80
	6	12.8	8.6	67	2.74	11.4	24.2	0.16	48.3	1.88
	Avg.	**7.1**	5.3	90	1.9	5.8	13.6	0.5	32.0	2.5
40–60 m	1	0.9	0.4	46	0.56	0.8	1.5	0.40	2.4	1.16
	2	4.1	2.7	67	1.33	3.7	5.8	1.06	14.5	1.19
	3	12.0	6.9	58	5.82	9.6	20.9	4.70	29.9	1.57
	4	4.4	1.6	37	2.48	4.2	6.5	2.25	9.2	0.95
	5	3.1	1.4	46	1.67	2.8	5.1	1.45	6.8	1.23
	6	13.1	5.0	38	8.35	12.4	18.2	7.10	32.0	0.80
	Avg.	**6.3**	3.0	49	3.4	5.6	9.6	2.8	15.8	1.2
standard	1	0.8	0.3	33						
	2	5.3	1.0	18						
	3	19.3	6.3	32						
	4	3.8	1.4	36						
	5	2.4	1.6	65						
	6	10.7	4.1	39						
	Avg.	**7.1**	2.4	37						

whether evaluated with a standard drift setup and two collectors at 2 m distance, 20 m around this setup (40–60 m) on 40 collectors or over 100 m length with 200 collectors; being 6.3–7.1%. However, coefficient of variation increases from 18–65% for the standard setup to 37–67% for the 20 m around the standard setup to 53–176% for the full field edge of 100 m and six repetitions. Maximum spray deposition values within the 100 m field edge can be as high as 43% which is 6–7 times higher than measured on average with the standard drift setup and 14 times higher for this specific measurement (#1). The variation in spray drift deposition in the centre of the long edge of the field, where in general the spray drift standard setup is positioned is also lower than for the total length of the field. This is strongly correlated to the shown sprayer boom movements which are in this area also lower (Fig. 3) than when also taking the start and stop effects on the headlands into account. A parameter to specify these variations in spray drift deposition expressing the edge of field variability could, for example, be the measured span ((90-perc-10-perc)/mean) for the centre of the long edge of field and the total field length being on average resp. 1.2 and 2.5.

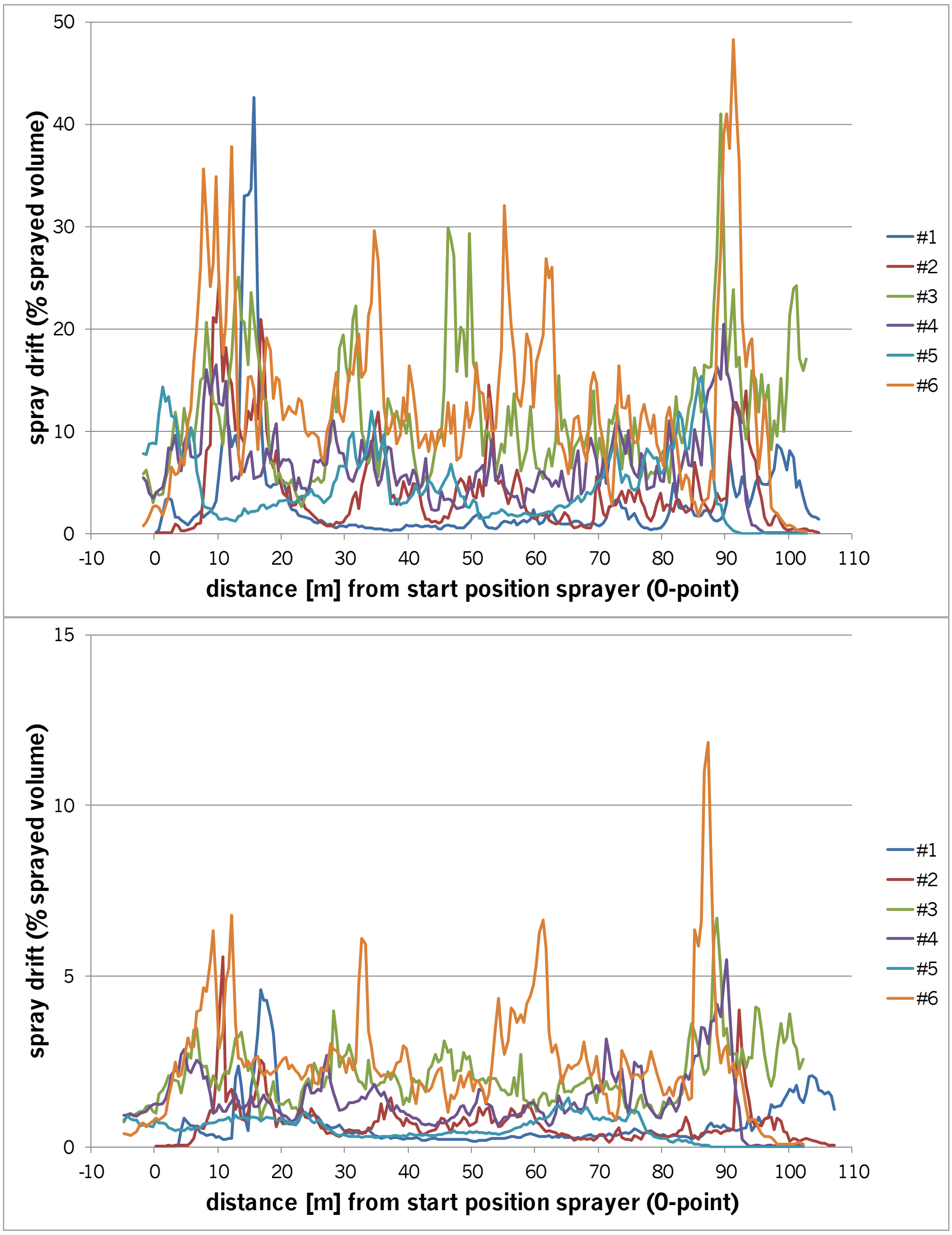

Fig. 4. Variation in spray drift deposition (% of applied spray volume per unit area) at 2 m (top) and 5 m (bottom) distance from the last nozzle for a 24 m working width trailed boom sprayer standard flatfan nozzles spraying the long edge of a potato field 0–100 m (six repetitions).

As spray drift deposition is decreasing with distance from the treated field the spray drift deposition at 5 m distance form the last nozzle is in general lower than at 2 m distance and is 1.1–1.3% and very similar for the different evaluation zones (Table 3). Maximum spray drift deposition decreases also (Fig. 4, Table 3) but still the maximum values of spray drift deposition are found to be 2.8 to 8.2 times higher than the average values for the full field length evaluation zone. For the highest 90-percentile values of spray drift deposition the max/average ratios are 1.6 to 4.5 for the field edge. Coefficient of Variation for the three evaluation zones increases significantly from 5–32% for the standard evaluation setup, 21–43% for the 20 m area around the standard setup and 41–114% for the total length of the 100 m field. The variability in spray deposition at the 5 m distance is a little lower than for the 2 m distance as is shown by the span average being 0.8 ad 2.0 resp. for the centre area around the standard setup and the total field length. At 5 m distance the variability of the total length area is however higher than for the area around the standard setup compared to that of the 2 m distance as the ratio between the both increases from 2.2 to 2.6, about 20% increase.

Table 3. *Spray drift deposition and its variation in different parameters (% of applied spray volume per unit area) at 5 m distance from the last nozzle for a 24 m working width trailed boom sprayer standard flatfan nozzles spraying the long edge of a potato field for the whole length (100 m) the standard drift setup and 20 m around the standard drift setup (40–60 m) (six repetitions)*

Length	#	Avg.	SD	Cv	10-perc	Median	90-perc	Min	Max	Span
~100 m	1	0.65	0.74	114	0.22	0.37	1.56	0.02	4.6	3.62
	2	0.68	0.65	95	0.18	0.52	1.25	0.02	5.6	2.06
	3	2.06	0.85	41	1.16	1.91	3.12	0.72	6.7	1.03
	4	1.36	0.86	63	0.62	1.20	2.35	0.02	5.5	1.44
	5	0.51	0.33	65	0.00	0.48	0.90	0.00	1.4	1.88
	6	2.47	1.70	69	0.67	2.23	4.61	0.06	11.9	1.77
	Avg.	**1.3**	0.9	75	0.5	1.1	2.3	0.1	5.9	2.0
40–60 m	1	0.24	0.05	21	0.19	0.23	0.30	0.17	0.4	0.48
	2	0.77	0.24	31	0.46	0.73	1.14	0.36	1.2	0.93
	3	2.04	0.48	24	1.39	1.99	2.72	1.17	3.1	0.67
	4	0.96	0.27	28	0.66	0.92	1.29	0.61	1.7	0.68
	5	0.43	0.1	24	0.34	0.41	0.59	0.33	0.8	0.61
	6	2.44	1.05	43	1.52	2.05	4.07	1.00	4.8	1.24
	Avg.	**1.1**	0.4	29	0.8	1.1	1.7	0.6	2.0	0.8
Standard	1	0.33	0.02	5						
	2	0.6	0.13	21						
	3	3.07	0.55	18						
	4	1.05	0.34	32						
	5	0.41	0.04	9						
	6	1.39	0.18	13						
	Avg.	**1.1**	0.2	16						

Evaluating the spray drift deposition along the field edge as a spatial variation the data can be compared to the average measured spray drift deposition at the same distance for the standard spray drift setup and some boundaries around it. The area of collectors receiving average spray drift deposition ±25% of the standard evaluation setup is 23% for the 2 m distance and 29% for the 5 m distance from the last nozzle. The area receiving less than 25% of the average spray drift deposition is 35% at 2 m and 32% at 5 m distance. The area receiving more than 25% higher spray drift deposition than average is 41% for the 2 m distance and 39% for the 5 m distance (Table 4).

Table 4. *Area next to the sprayed field receiving average measured spray drift deposition as with the standard drift setup +/- 25% and the areas with less and higher spray drift deposition values at 2 m and 5 m distance from the last nozzle for a 24 m working width trailed boom sprayer spraying the long edge of a potato field for the whole length (100 m)*

	2 m			5 m		
#	<avg-25%	avg±25%	>avg+25%	<avg-25%	avg±25%	>avg+25%
1	14	20	65	20	37	43
2	65	15	20	40	29	31
3	72	23	4	71	26	3
4	13	20	66	17	45	38
5	21	20	58	27	24	48
6	26	40	35	17	11	72
	35	23	41	32	29	39

Discussion

Large variations in spray drift deposition are recorded when measuring spray drift over the length of the field edge spraying a potato field using a conventional sprayer and standard flat fan nozzles. Although average spray drift deposition is very similar when measured with a standard spray drift setup, over 20 m around this setup and the total field length, spray drift deposition variability is very much higher for the different evaluation zones. Maximum values in spray drift deposition can easily be up to 25-fold higher when measured over the total length of the field compared to the standard setup at the same distance. Expressed as a span, the ratio of the difference between the 90-percentile highest and 10-percentile lowest value and the median spray drift deposition it can be shown that at the centre area of the length of the field variability is lower than for the whole length of the field. This is mainly because of start and stop effects at the headlands which are also shown by more sprayer boom movement in these areas. The area along the field edge receiving average spray drift deposition ±25 % of average is 25–29% resp. for the 2 m and 5 m distance from the last nozzle. Area alongside the field edge receiving more than average + 25% spray drift deposition is around 40% for both distances. Results show that the single value of spray drift deposition used in the authorisation procedure is to be evaluated when adopting the procedure to probabilistic risk assessments and land scale evaluation tools.

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