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Effect of differences in international reference technique and evaluation zone on the classification of spray drift reducing techniques

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Summary

A series of spray drift experiments were conducted to classify a specific spray technique for the Netherlands, the United Kingdom and France. The candidate spray technique was equipped with three different nozzle types; a standard flat fan, a 50% and a 90% drift reducing nozzle type. In order to classify the sprayer for the spray drift reduction classification system in the Netherlands and the UK the reference spray technique used was a boom sprayer operating at 50 cm boom height, 50 cm nozzle spacing at 6.5 km h^{-1} forward speed and equipped with TeeJet XR11004 flat fan nozzles operated at 3 bar spray pressure. For the French system, the reference spray technique was a boom sprayer operating at 70 cm boom height, at 8 km h^{-1} forward speed and equipped with TeeJet XR11002 flat fan nozzles operated at 2.5 bar spray pressure. The classification against different reference spray techniques and evaluation zones (2–3 m; 2–6 m; 5 m) is presented for three candidate spray techniques based on comparative spray drift experiments under similar crop and weather conditions. Similarities and differences between the classifications following the different systems are highlighted. Results show a basis for the exchangeability of the classification of spray drift reducing techniques between the different classification systems based on field data and the potential for further harmonisation of certification procedures between countries.

Key words: Spray drift, nozzle type, spray technique, drift reducing technology, DRT, reference, classification

Introduction

Reducing the emission of Plant Protection Products (PPP) is of high importance for many countries in Europe. In the Netherlands, with its dense network of waterways, many regulations are in use to minimise spray drift and to implement spray drift reducing measures in general regulations on sustainable agriculture; Towards sustainable crop protection (EZ, 2013), the Activity Decree Environment (I&M, 2012) and in the authorisation procedure for PPP (CTGB, 2016). The implementation of the Sustainable crop protection programme (EZ, 2013) means that at least 75% drift reducing techniques (DRT) are to be used when applying PPP on all fields, even when no surface water is bordering the field. Apart from exposure of surface water, spray drift is also important in the authorisation procedure for the evaluation of non-target plants, non-target arthropods, bystanders and residents. Each of these protection targets, however, have their specific zones of protection so evaluation distances of spray drift ground deposition differ for each zone (CTGB, 2016). For the Netherlands, the evaluation of spray drift reducing techniques for protecting surface water gave rise to the classification system of drift reducing techniques relative to a defined standard spray technique, following ISO22369. The position of the surface water to the sprayed field is defined by the dimensions of a standard ditch at 2–3 m distance from the last nozzle of the sprayer (Huijsmans *et al*., 1997). In this way spray techniques are classified in the DRT classes 50%, 75%, 90% and 95% based on field experiments spraying a cropped field and measuring spray drift downwind on a bare soil surface (following ISO22866 and CIW, 2003).

In other EU member states, similar procedures are setup (Huijsmans & van de Zande, 2011) following the implementation of the Sustainable Use Directive (EC/2009/128). In the UK, regulation is setup as the Local Environmental Risk Assessment Procedure (LERAP) in which spray drift reducing techniques are to be used based on the size and location of the surface water to the treated field, buffer zone width and the dose of PPP applied (Gilbert, 2000). Spray drift reducing techniques can be classified in the LERAP-low drift star rating scheme in the spray drift reduction classes 25% (one star), 50% (two star) and 75% (three star) compared to a defined reference spray technique, evaluated at 2–6 m distance from the treated area. In France spray drift reducing technologies are allowed to be used to minimise the buffer zone alongside waterways. The buffer zone is dependent on the toxicity of the PPP and the dose used and to the size of the surface water. Classification of spray drift reducing techniques is done in only one class specifying that spray drift deposition should be at least 2/3 lower than of a defined reference spray technique at 5 m distance from the treated area.

Spray drift reduction classification can be undertaken through field studies or through other methods, such as wind tunnel measurements, or spray characterisation, combined with model predictions. Field studies are usually used only for complete spraying systems where smaller scale measurements are not possible. The aim of this research was to compare the spray drift of a candidate spray system (MagGrow magnetics) implemented at a boom sprayer and three nozzle types with appropriate end nozzles and 40 cm sprayer boom height above crop canopy, measured in the field. Spray drift measurements were made to fulfil the requirements of the spray drift classification systems in The Netherlands (CIW, 2003), the UK and France (MAAF, 2017) and international agreements on spray drift measurements and spray drift reduction classification (ISO22866, 2005; ISO22369, 2006).

In this paper results of the spray drift experiments using the candidate system and reference spray techniques for the Netherlands, the United Kingdom and France are described spraying an onion and a potato crop. Potential spray drift reduction classification is presented for different reference techniques and downwind spray drift deposition evaluation zones.

Materials & Methods

Review of national drift-reduction classification requirements

There are differences between the UK and NL requirements for a field trial for measurement of drift reduction. The reference spray technique for boom sprayers in the Netherlands is a standard flat fan nozzle (TeeJet XR11004) at 3 bar spray pressure, 50 cm nozzle spacing, a spray boom height of 50 cm above crop canopy and a forward speed of 6.5 km h^{-1} and applying 300 L ha^{-1}. The UK reference nozzle is a standard flat fan nozzle (Hypro FF110/1.2/3.0) also operated at 3.0 bar which, although it is a smaller nozzle size, because it is not an ‘extended range’ type nozzle is likely to have similar drift to the NL reference nozzle. The sprayer speed in the UK reference condition is 8 km h^{-1} but since this small difference in forward speed has only a relatively small influence on spray drift, and the test sprayer was to be tested at the same speed, it was proposed that the lower speed would be acceptable. The slower speed and larger nozzle size result in a significantly larger applied volume for the NL than for the UK, but since drift is not dependent on volume *per se*, it was proposed that the higher volume would be acceptable in the UK. The boom height of the reference sprayer is the same for both countries. Other differences relate to the surface conditions, with the UK requiring a 'flat level surface with no appreciable crop cover' as the treated area, whereas the NL protocol required a crop, and the downwind surface being 'short grass' for the UK and 'bare ground' for the NL. It was thought that there would be only small differences between 'grass' and 'bare ground' as long as there was no appreciable warming of the soil surface, and therefore this would be acceptable to the UK, but there was concern that an experiment conducted over one crop could not be extrapolated to another. This would not invalidate the results of the work, but would limit its usefulness. Other small differences (e.g. quantity of non-ionic surfactant, boom width) were identified, but again, because we are measuring relative drift, it was suggested that there was sufficient flexibility in the UK system to accept the NL requirements. In discussions with the UK regulator (Chemicals Regulation Directorate) these proposals were accepted and it was therefore agreed that this NL reference could also be used as a reference spray technique for the United Kingdom.

The French reference spray technique is a conventional boom sprayer equipped with XR11002 flat fan nozzles, 2.5 bar spray pressure, 70 cm boom height, 8 km h^{-1} forward speed and applying a spray volume of 110 L ha^{-1} (Jean-Paul Douzals, personal communication). This is significantly different from both the UK and NL and therefore a separate set of measurements relating to the French reference was required. A further difference in the three schemes is the evaluation distance. The typical evaluation zones are 2–3 m for the Netherlands, 2–6 m for the UK and 5 m for France, with distance measured from the last nozzle. However, this requires only changes to the analysis of the data, not to the experimental protocol.

Spray techniques

In 2016, in a series of field experiments, spray drift was assessed of a boom sprayer equipped with the MagGrow magnetic system (Dublin, Ireland), the candidate spray technique and two reference spray techniques. The candidate spray technique was used at a boom height of 40 cm above crop canopy and with three different nozzle types: a standard flat fan nozzle, a 50% drift reducing nozzle (DRN50) (classified in NL at pressures up to 6 bar and a boom height of 0.5 m) and a 90% drift reducing nozzle (DRN90) (classified in NL at pressures up to 3 bar and a boom height of 0.5 m), with appropriate end nozzles in the last nozzle body:

- System 1: Standard flat fan - Hypro 11003 + end nozzle TeeJet UB8503;
- System 2: TeeJet AI 110 03 (50% DRN) + AIUB8503 end nozzle;
- System 3: Lechler ID-120-03 (90% DRN) + IS 80-03 end nozzle.

The spray pressure of the candidate spray technique was set to 3 bar (at the nozzle outlet), applying a nominal 230 L ha^{-1} at a forward speed of 6.5 km h^{-1}. Spray applications were performed using a John Deere trailed boom sprayer (John Deere, Horst The Netherlands) for the reference spray techniques and a trailed Dubex boom sprayer (Stadskanaal, The Netherlands) with the MagGrow magnetic system implemented. Both sprayers had a 27 m boom width.

Spray drift measurements

The spray drift measurements were performed on 30 September, 7, 12 and 17 October 2016 spraying an onion and a potato field at the WageningenUR Unifarm experimental fields (Wageningen, the Netherlands). In total 10 repetitions of each technique were sprayed. The applications in onions (four measurements) were made on 30 September and 17 October. On 7 and 12 October, the applications were made to a potato crop (six measurements). During the spray application, a single swath of 27 m was sprayed over 70–80 m length, spraying tap water to which a fluorescent tracer Brilliant Sulfo Flavine (BSF, Chroma 1F 561, CI 56205, 2–4 g L^{-1}) and a non-ionic surfactant (Agral Gold, 0,075 mL L^{-1}) was added.

Description of crop

The onion crop was planted in beds 1.50 m wide with 1.20 m planted bed surface. On the bed surface five rows of onions are sown (row spacing 20 cm). Under the centre of the sprayer is one planted bed and on both sides eight beds under the spray boom; in total 1+16 beds under a working width of 27 m. The onion crop was a standing crop (crop height 50 cm) with partially flattened areas. Only the upstanding crop area, at the eastern downwind side (40 m width × 80 m length) was used, with a westerly wind. For an easterly wind direction (7 October, 12 October) a potato field on the eastern side of the bare soil spray drift measurement area was used. Row spacing was 75 cm and plant density was about 45 000 plants ha^{-1}. The potato crop was already far desiccated but an area where an upstanding crop with green leaf tissue (BBCH 93) was available (70 m long and 50 m wide) and was therefore used for the spray drift experiments. Average crop canopy height of the potato field was 40 cm

Position of last nozzle

For the onion crop, the last downwind nozzle was positioned just above the last row of onions on the bed/edge of the bed on which the onions were sown. In the potato field the last nozzle was positioned about 10–12 cm downwind of the last crop row (centre potato ridge). From these last nozzle positions the distances for the ground collectors and the position of the airborne spray drift pole were determined

Forward speed

To check the forward speed of the sprayers in the field the time was recorded for a 20 m travelled distance length. In case of the 8 km h^{-1} forward speed of the French reference spray technique we took the logged GPS forward speed from the tractor as large variations in clocked time were found. To determine applied spray volume, collectors (1 m length) were positioned in the sprayed area at leaf canopy height on both side of the sprayer underneath the spray boom.

Weather conditions

During the spray drift experiments the average temperature at 0.5 m height was 12.8°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 3.0 m s^{-1}.

Spray drift collector layout

Downwind of the crops was an approximately 50 m wide bare soil surface area. In this strip of land two measurement areas were laid out. At each measuring area two lines of ground collectors were laid out at 1 m spacing between them. 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 0.5–10 m in a continuous line collectors of 0.5 m length;
- At 15–16 m, 20–21m and 25–26 m collectors of 1 m length.

The airborne spray drift was measured at 5.5 m distance from the last nozzle. At a pole of 6 m height two lines with ball shaped collectors (Siebauer Abtrifftkollektoren) were positioned every 1 m in height.

Spray drift deposition analysis

After spraying the collectors were put in plastic bags, coded and collected for further analysis of the collected amount of BSF. Samples were taken of the tank concentration of each sprayed tank mix from a spraying nozzle. In the laboratory, the collectors were put in jars to which demineralised water was added (1000 mL for ground collectors and 50 mL for airborne collectors). The jar was shaken for 15 mins and the solution was poured into tubes (10 mL) to be analysed with a fluorimeter (Perkin Elmer LS 55; λ_{ex}=450 nm; λ_{em}=500 nm) on BSF concentration. The concentration of BSF in the tank samples was also determined fluorimetrically. For determination of the background, blank collectors were also analysed. The recovery of the collectors for the BSF was analysed in a separate experiment and was more than 99%. The limit of detection was 0.010% of applied spray volume

(0.00023 µL cm^{-2} at 230 L ha^{-1}). The effect of sun degradation on the breakdown of the BSF on the collectors was determined in a separate experiment, showing that more than 95% of BSF was still recovered after 30 mins. As collection time of the collectors in the field was on average within 10–15 mins; no correction for sun degradation was made. The measured concentration of BSF from the washed collectors was calculated as quantity of spray volume per unit area and then expressed as a percentage of the applied volume based on measured forward speed and nozzle flow rates.

To compare the spray drift deposition of the different techniques the spray drift deposition is calculated at typical evaluation zones. Also 1–5 m, 5–10 m and 10–15 m were evaluated as identified by ISO22369-2. Airborne spray drift is compared for the average amount collected over 0–6 m height.

The differences in spray drift deposition values at the evaluation zones for the different application techniques is statistically analysed using Genstat (Genstat Release 9.2, Payne *et al*., 2006) at a probability level of 95%. For the statistical analyses the Genstat procedure IRREML (Keen & Engel, 1998) was used. To discriminate between very low levels of spray drift deposition a pairwise comparison was performed to minimise the variance effect of higher spray drift deposition results in the comparison.

To classify the reduction in spray drift deposition (ISO22369-1) of the candidate spray technique compared to the different reference situations the spray drift reduction was calculated at the different evaluation zones.

Results

Spray drift deposition

Fig. 1 shows that the French reference spray technique has the highest downwind spray drift deposition followed by the NL-UK reference spray technique. The spray drift deposition of System 1 is similar to the NL-UK reference spray technique. Lowest spray deposition is seen with the Systems 2 and 3. Spray drift deposition of System 3 is the lowest of the experiment.

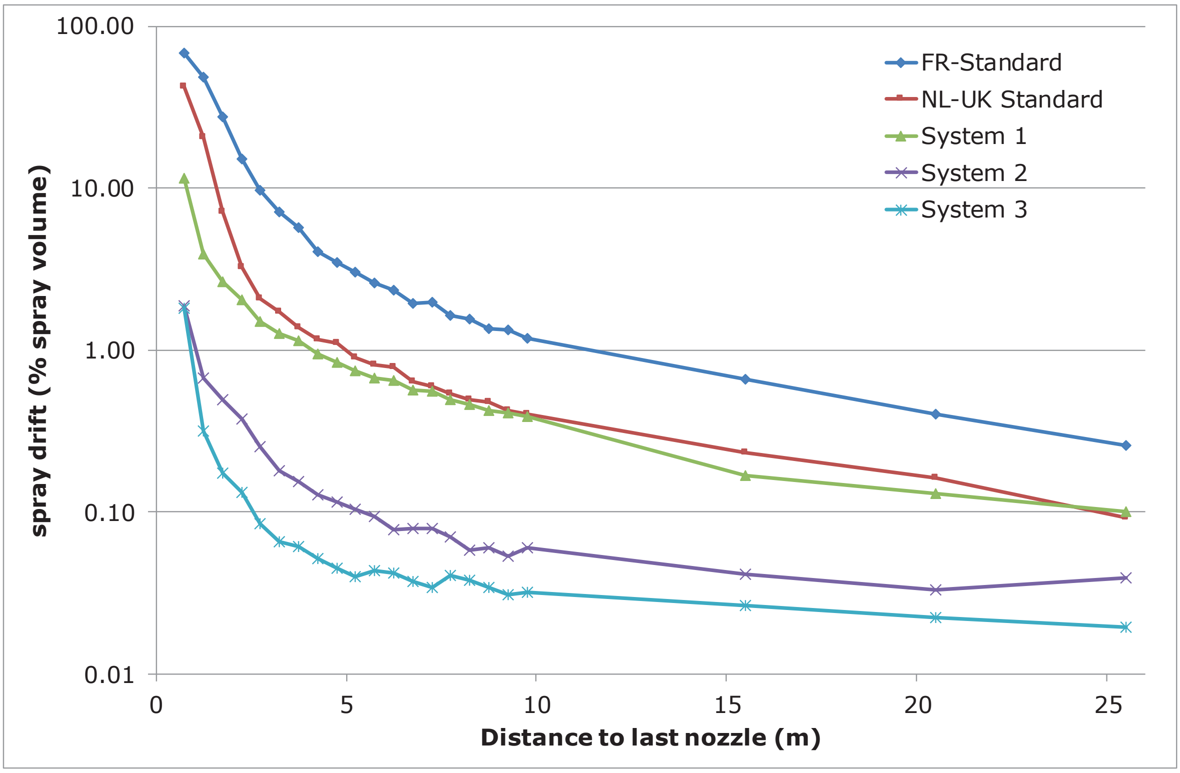

Fig. 1. Average spray drift deposition (% of applied spray volume per unit area) at different distances from the last nozzle spraying potatoes and onions using a reference spray system for the Netherlands and UK (NL-UK standard), a reference spray technique for France (FR standard), and of the candidate spray technique System 1, 2 and 3.

Table 1. *Average spray drift deposition (% of applied spray volume per unit area) at different evaluation zone distances from the last nozzle when spraying potatoes and onions using a reference spray system for the Netherlands and UK (NL-UK standard), a reference spray technique for France (FR standard), and of the candidate spray technique System 1, 2 and 3*

					ISO	
	2–3 m	2–6 m	5 m	1–5 m	5–10 m	10–15 m
FR standard	12.4 a	6.34 a	3.23 a	15.1 a	1.89 a	0.92 a
NL-UK standard	2.64 b	1.54 b	1.00 b	4.77 b	0.60 b	0.32 b
System1	1.77 b	1.15 b	0.79 b	1.79 c	0.54 b	0.28 b
System 2	0.31 c	0.18 c	0.11 c	0.30 c	0.07 c	0.05 c
System 3	0.11 c*	0.07 c*	0.04 c*	0.12 d	0.04 c*	0.03 c

Different letters per column means significant difference between means (a<0.05); * pairwise difference comparison AI and ID nozzle.

Table 1 shows that at all evaluation zones spray drift deposition was highest for the French reference technique followed by the reference from the Netherlands and the UK. No significant difference was found between the NL-UK reference technique and the candidate System 1, except for the 1–5 m zone. The candidate Systems 2 and 3 had the lowest spray drift deposition at the different evaluation zones. In the overall statistical analysis, no differences were found in spray drift deposition at the evaluation zones between the Systems 2 and 3. However, comparing the spray drift deposition data of System 2 and System 3 pairwise separately resulted in significant differences for all evaluation zones except the 10–15 m distance (α<0.05).

Airborne spray drift

Average airborne spray drift at 5.5 m downwind from the last nozzle is for all spray techniques presented in Fig. 2.

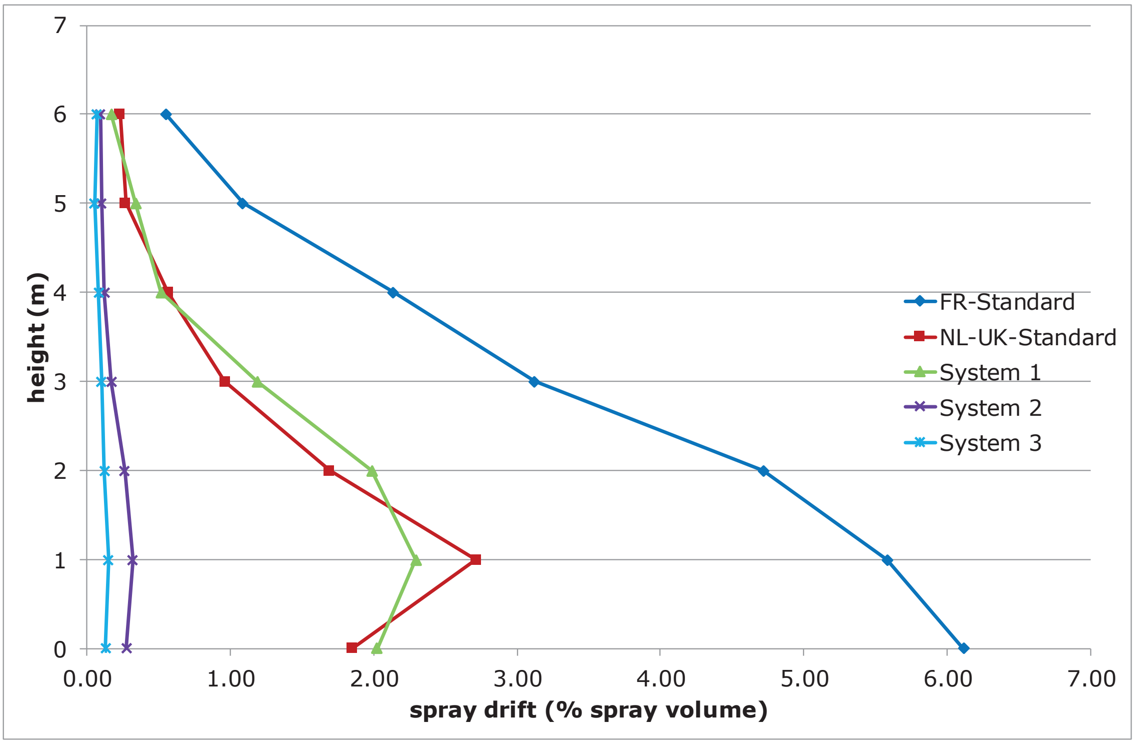

Fig. 2. Average airborne spray drift (% of applied spray volume per unit area) at 5.5 m distance from the last nozzle spraying potatoes and onions using a reference spray system for the Netherlands and UK (NL-UK standard), a reference spray technique for France (FR standard), and of the candidate spray technique Systems 1, 2 and 3.

Airborne spray drift at 5.5 m distance from the last nozzle is highest for the France reference technique (Fig. 2). The Airborne spray drift of the reference technique of the Netherlands and the UK is much lower. The airborne spray drift of the candidate spray technique System 1 is very similar to that of the NL-UK reference technique. The airborne spray drift of the candidate System 2 and System 3 is lower, and lowest for the System 3.

Spray drift reduction

The spray drift reduction of the different spray techniques in Table 2 are presented for comparison with the reference situation in France. The spray drift reduction of the candidate System 1 is 81.9%, for the candidate System 2 the spray drift reduction is 97.2% and for the candidate System 3 the spray drift reduction is 99.0%. Table 2 also shows that the NL-UK reference spray technique can be evaluated as a 75% spray drift reducing technique in France too. The effect of the different evaluation zone distances (2–3 m for the Netherlands and 2–6 m for the UK) on the calculated spray drift reduction relative to the reference spray technique and evaluation zone (at 5 m) as used in France is very limited.

Table 2. Spray drift reduction (%) at different evaluation zone distances from the last nozzle when spraying potatoes and onions compared to the reference spray technique for France (FR), for a reference spray system for the Netherlands and the UK (NL-UK), and of the candidate spray technique Systems 1, 2 and 3

					ISO		Airborne
	2–3 m	2–6 m	5 m	1–5 m	5–10 m	10–15 m	0–6 m
FR standard	*	*	*	*	*	*	
NL-UK standard	78.7	69.1	75.6	68.4	68.0	65.3	62.6
System 1	85.7	75.4	81.9	88.1	71.6	69.8	62.2
System 2	97.5	96.6	97.2	98.0	96.1	94.5	93.8
System 3	99.1	98.7	99.0	99.2	98.0	96.8	96.7

The spray drift reduction relative to the NL-UK reference (Table 3) shows spray drift reductions of the candidate systems of 33.1% for System 1, 88.2% for System 2 and 95.9% for System 3 for the 2–3 m evaluation zone and similar, but slightly lower, values for the 2–6 m evaluation zone.

Table 3. *Spray drift reduction (%) at different evaluation zone distances from the last nozzle when spraying potatoes and onions compared to the reference spray technique for the Netherlands and the UK (NL-UK standard), for the candidate spray technique Systems 1, 2 and 3*

					ISO		Airborne
	2–3 m	2–6 m	5 m	1–5 m	5–10 m	10–15 m	0–6 m
NL-UK standard	*	*	*	*	*	*	*
System 1	33.1	25.8	20.2	62.4	11.4	13.0	-1.0
System 2	88.2	88.7	89.1	93.8	87.9	84.1	83.5
System 3	95.9	95.7	95.7	97.6	93.8	90.8	91.1

Evaluating the spray drift reduction at the zones 1–5 m, 5–10 m and 10–15 m from the last nozzle shows that spray drift reduction is at a higher level in the zone 1–5 m than both 5–10 m and 10–15 m; especially for the candidate System 1. A reason for this could be the effect of the use of the end nozzle affecting spray drift deposition in the area close to the edge of the crop included at the 1–2 m area in the 1–5 m evaluation zone.

Discussion

Comparing the evaluation of spray drift reduction relative to the reference technique as used in France (Table 2) and the one used in the Netherlands and the UK (Table 3) it is obvious that the spray drift reductions are for the situation in France at a very much higher level than for the situation in the Netherlands and the UK. Where for France the candidate Systems 1, 2 and 3 are evaluated as having spray drift reductions of respectively 81.9%, 97.2% and 99.0% the spray drift reductions are evaluated as 25.8–33.1%, 88.7–88.2% and 95.7–95.9% for the three candidate Systems in the UK and the Netherlands at their respective evaluation zones.

Results of the spray drift measurements show that the reference technique as used in the Netherlands and the UK will lead to a spray drift reduction of 75.6% when evaluated against the reference technique as defined in France and at 5 m distance from the last nozzle, being the evaluation distance for spray drift reduction in France. Therefore, spray drift reductions evaluated relative to the French reference situation (spray technique and evaluation distance) are higher than evaluated relative to the reference situations for the Netherlands and the UK. The results also show that the calculated drift reduction can be strongly dependent on the evaluation zone, with drift reduction reducing with distance downwind. This is supported by other field data (Butler Ellis *et al*., 2017).

Results show a basis for the exchangeability of the classification of spray drift reducing techniques between the different classification systems, although so far only the UK has agreed (at least in principle) to accept data relating to the NL reference condition, not *vice versa*, and it is clear that neither NL nor UK could accept data relating to only the French reference condition. However, this provides a first step and opens the way to further harmonisation of Drift Reducing Technology classification and certification procedures between countries.

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