Influence of Reference Nozzle Choice on Spray Drift Classification

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Summary

The BCPC spray quality classification system utilises the Lurmark 31-03-F110 (F110/1.2/3.0) flat fan nozzle to discriminate the threshold between the classes of Fine and Medium spray. This reference nozzle has also now been used to classify the spray drift potential for other spray nozzle-pressure combinations. This paper discusses whether such a reference nozzle can be described in general terms (F110/1.2/3.0 or ISO 03) or needs more detail by specifying source of manufacturer, type and construction material. Comparisons of performance were made between twelve equivalent rated commercially available nozzles for spray distribution on a patternator, and spray quality and drop speed measurements with a PDPA laser. Drop size and speed data have then been used to calculate spray drift potential for standard conditions with the IDEFICS drift model. Despite identical commercial ratings, large differences can occur for spray distribution and spray quality. Calculated spray drift potential for some nozzle types could even be double that of the currently used BCPC Fine/Medium reference nozzle. It is concluded that for the classification of nozzles towards spray drift reduction classes, a unique, a detailed specification of reference nozzle is needed. Nozzles from different manufacturers of alternative designs and construction materials do affect performance too much to be freely chosen as a reference, despite their consistent specifications for spray pressure, flow rate and top angle (ISO 03 series).

Introduction

Spray from nozzles consists of drops of different sizes. Depending on the size of the orifice, the shape of the nozzle, and the pressure used, the drop size distributions of alternative nozzles may differ. Classification systems have been developed to categorise drop size distributions for agricultural use (Doble *et al*., 1985; ASAE, 1999). These classification systems distinguish drop size ranges using recognisable terms such as Fine, Medium and Coarse spray qualities so that the information can be easily understood by operators. Measurements for these classification systems are predominantly performed with laser based systems (Parkin, 1993). Recently, environmental concerns have raised the need to extend these original spray quality classification systems towards one that predicts spray drift potential (Southcombe *et al*., 1997). Porskamp *et al*. (1999) described a nozzle classification system for driftability based on Phase Doppler Anemometry and a drift model (Holterman *et al*., 1997). A further, more direct method is dependent on comparative measurements in a windtunnel (Walklate *et al*., 2000; Herbst *et al*., 2000). Whichever protocol is chosen, they will all need to be compared with a reference condition in order to justify drift reduction classes for candidate nozzles. The threshold nozzle that differentiates the spray quality classes Fine and Medium of the BCPC classification system (Southcombe *et al*., 1997) has become a *de facto* reference nozzle. However, this nozzle is not widely available and purchasable in large quantities, which is a prerequisite of a suitable reference nozzle. In particular for field experiments of spray drift, large numbers of nozzles should be available. This paper discusses whether a more common available type should replace the BCPC Fine/Medium reference nozzle. The suggestion was raised to freely choose from the market any reference nozzle within the BCPC specification F110/1.2/3.0 or ISO 03 (ISO 10625, 1996). This specifies only flat fan nozzle type, top angle and flow rate. In this research a commercial range of 03 nozzles were assessed for spray distribution on a patternator, spray quality and drop speed with a PDPA laser to understand whether differences in performance within this commercial range do occur and whether the magnitude of such differences is one that has to be considered in the future. Hence, drop size and speed data were then used to calculate spray drift deposition for standard conditions with the IDEFICS drift model (Holterman *et al*., 1997). Finally, the effect of choice of reference nozzle is evaluated for use in a drift reduction classification system.

Materials and Methods

Spray distribution was measured on a patternator - with 25mm grooves – for a commercial range of 03 flat fan nozzles (Table 1) that were set to a nozzle height of 0.30m (10 nozzles of each type). Spray quality and drop speed were quantified (V&W/LNV, 2001) using a Phase Doppler Particle Analyser (PDPA, Aerometrics). All measurements were performed on three nozzles – selected from a set of 10 – whose flow rates were the closest to the median for each batch.

Table 1. The commercial range of selected 03 flat fan nozzles

Manufacturer	Type	Manufacturer	Type
Albuz	ISO API 11003	**Lurmark**	**31-03-F110 (BCPC Fine/Medium)**
Hardi	ISO F-03-110	Lurmark	TR03F110
Lechler	LU 120-03	Teejet	XR11003VH
Lechler	LU 120-03 C	Teejet	XR11003VK
Lechler	LU 120-03 S	Teejet	XR11003 VP
Lurmark	31-03-F110	Teejet	XR11003 VS

Spray liquid was tap water of 20^{o}C. Measurements were performed in a conditioned room at 20^{o}C and 70% RH. Nozzle height above the measuring volume of the laser was 0.50m. During measurements the nozzle was moved in a 3D-traverse system. Nine tracks were made at distance intervals of 0.03m, sampling the complete fan (Figure 1). Traversing speed was 0.02m s^{-1}.

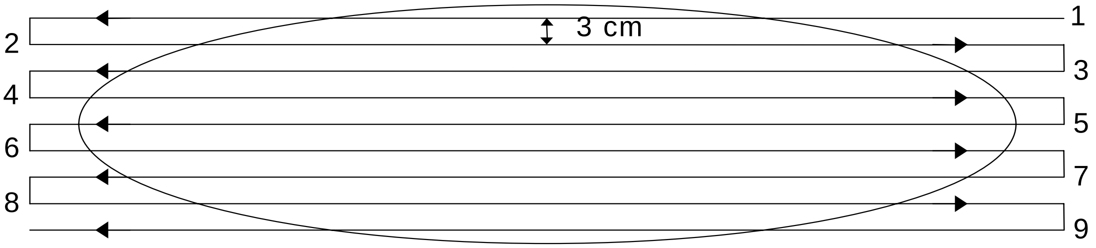

Figure 1. Pattern of tracks sampling the spray in a horizontal plane 0.50m below the nozzle for spray quality

Drop speed was measured at the vertical axis (single measurement) below the nozzle at 8 distances between 0.04m and 0.30m (Figure 2). Each measurement consisted of at least 30000 drops.
At 0.15m distance below the nozzle the fan was sampled (single measurement) also in the short length direction (Figure 3) of the spray in order to quantify the sectioned drop sizes, number of drops and flow rate (flux not presented).

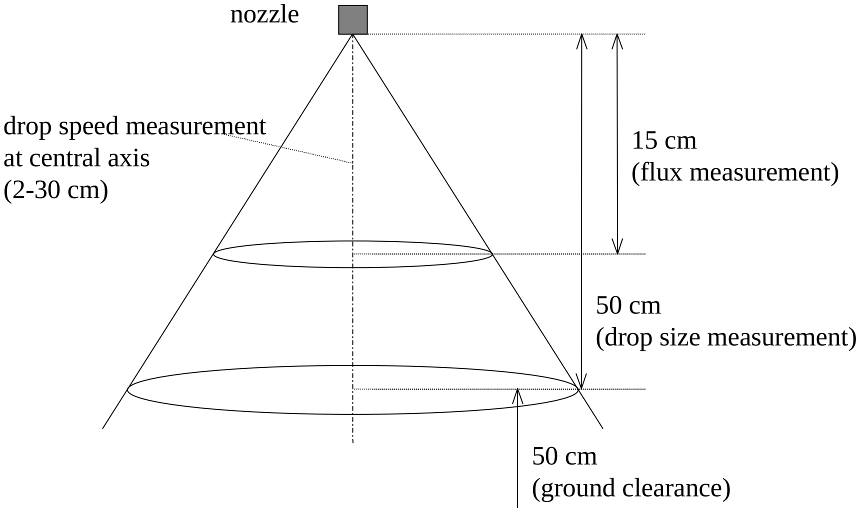

Figure 2. Schematic view of the spray fan and the location where cross section measurements (15 cm; drop size, number and flux) of spray quality (50 cm) and central axes drop speed measurements (4-30cm) were made

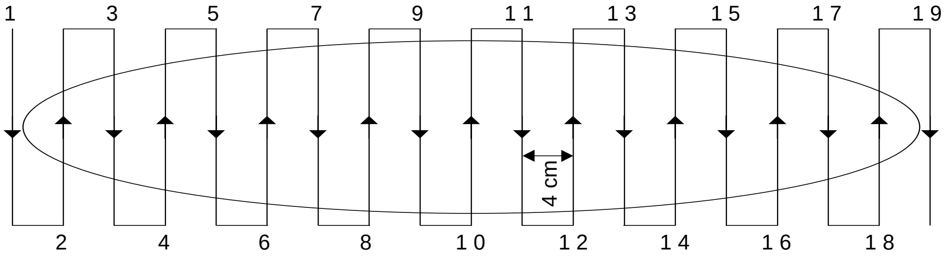

Figure 3. Pattern for nozzle track when used to measure drop size, number of drops and sectioned flow rate (flux) at 0.15m below the nozzle

Results of the drop size measurements (average of three nozzles) are presented as the D_{v10}, $D_{v50,}$ or Volume Median Diameter (VMD), D_{v90} and V_{100}; this latter value being the volume fraction of drops with a diameter smaller than 100 μm.

Spray drift potential was calculated using the IDEFICS (V3.1) spray drift model. Standard conditions were: nozzle spacing 0.50m, boom height above crop 0.50m, crop height 0.50m, last nozzle distance 0.50m from crop edge, sprayer velocity 1.5 ms^{-1}, wind direction perpendicular to driving direction, wind speed 3 m s^{-1}, RH 60%, air temperature 15^{o}C. Drift deposition was evaluated at 2.125-3.125m from the last nozzle; this being a critical distance in Dutch agriculture where, for example in potato spraying, this would resemble the location of surface water in a standard ditch (Huijsmans *et al*., 1997).

Results

Spray distribution for a representative nozzle of each nozzle type is presented in Figure 4. Sometimes the distribution is unimodal – that is triangular shaped (Lurmark BCPC, Lechler nozzles) and sometimes two further peaks appear at more distal points within the nozzle's swath (Lurmark 31-03-F110, Lurmark TR03-F110, Teejet XR11003VH).

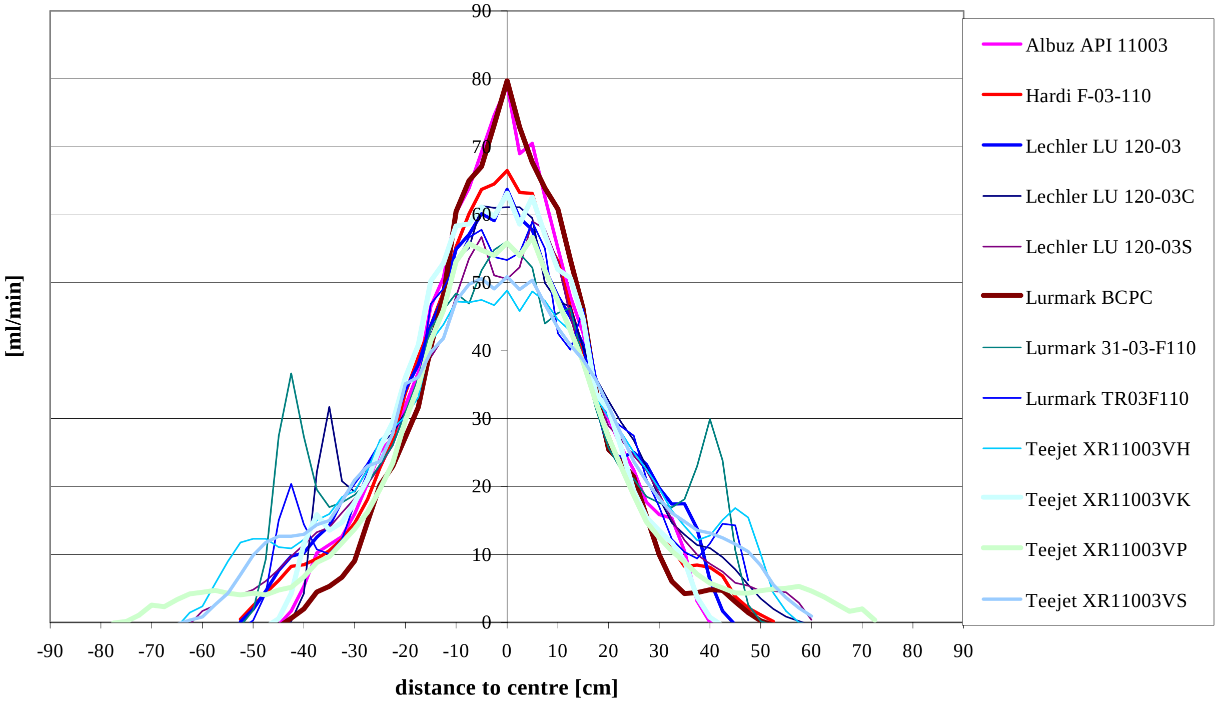

Figure 4. Spray distribution (ml/min) on a patternator (25mm grooves, nozzle height 0.30m) for a commercial range of 03 nozzle types sprayed at 300 kPa pressure

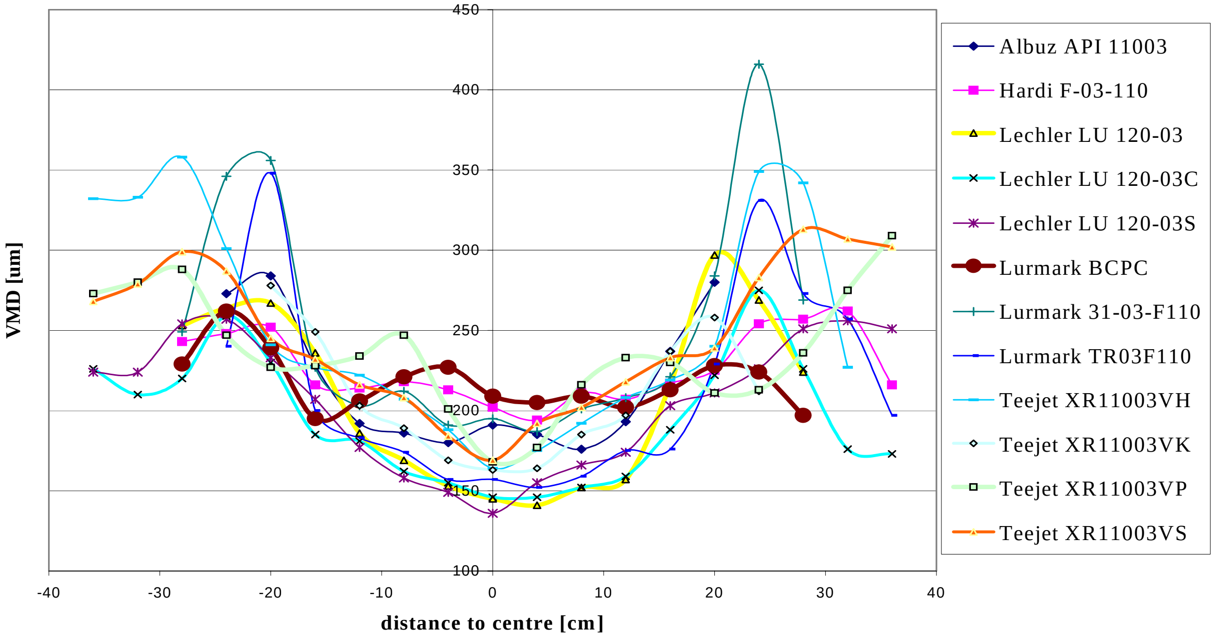

Figure 5. Cross-sectionnally measured VMD (short axes) for selected 03 nozzles (spray pressure 300 kPa) at 0.15m below the nozzle

The sectioned drop size measurements from the short axes of the fan at 0.15m below the nozzle are also presented in Figure 5 for one representative sample of each nozzle type. VMD in the centre below the nozzle was between 150-200µm and generally increases towards the edges of the spray fan.

The peaks at the outsides of the fan (20-25cm from center) for the Lurmark 31-03-F110, TR03F110 and Teejet XR11003VH were unexpectedly and atypically high.

Spray quality can differ very much. Table 2 shows that for the Albuz, Hardi, Lurmark 31-03-F110 and Teejet VP and VS nozzles D_{v50} differed less than 5% from the BCPC F/M reference nozzle. In addition, for V_{100} values the Hardi, Lurmark 31-03-F110 and Teejet VH, VP and VS nozzles differed less than 10% from the BCPC F/M reference nozzle. The Lechler nozzles, the Lurmark TR03F110 and the Teejet XR11003VK in general had finer spray quality than the BCPC F/M reference nozzle.

Table 2. Spray quality characteristics of the 03 nozzle types (spray pressure 300 kPa, nozzle height 0.50m) and the BCPC Fine/Medium threshold nozzle (*) and calculated spray drift (% of application rate) for standardised conditions at 2.125 to 3.125metres from the last nozzle

Nozzle		Spray quality				Top angle (**)	spray drift (%)
Manufacturer	Type	D_{v10} [µm]	D_{v50} [µm]	D_{v90} [µm]	V_{100} [%]		
Albuz	ISO API 11003	97	226	372	10.7	110	1.8
Hardi	ISO F-03-110	103	232	372	9.4	110	1.5
Lechler	LU 120-03	96	219	360	10.9	110	1.9
Lechler	LU 120-03 C	94	216	364	11.2	120	2.3
Lechler	LU 120-03 S	94	213	344	11.4	130	2.6
Lurmark	**31-03-F110 ***	**107**	**236**	**387**	**8.8**	**110**	**1.3**
Lurmark	31-03-F110	111	255	453	8.2	110	1.3
Lurmark	TR03F110	94	221	385	11.3	110	1.9
Teejet	XR11003VH	110	249	412	8.3	120	1.5
Teejet	XR11003VK	97	218	352	10.7	110	1.8
Teejet	XR11003 VP	112	247	394	7.9	120	1.4
Teejet	XR11003 VS	108	243	389	8.7	120	1.6

(**) visual measurement

Table 2 also shows that calculated spray drift was lowest for the BCPC F/M nozzle compared to the selected 03 nozzles. Indeed, spray drift from the Lechler LU120-03S was twice the drift of the BCPC F/M reference nozzle.

It is therefore obvious that the differences in spray drift deposition for the suggested reference nozzle influences the classification towards spray drift reduction. In table 3 the calculated spray drift reduction is shown for theoretical values of spray drift deposition when different nozzles were chosen as a reference. A drift reduction classification scheme could be based on the class threshold values suggested by Porskamp *et al* (1999); i.e. 10% to 17.5% for class 0, 17.5% to 45% for class 25, 45% to 72.5% for class 50, 72.5% to 89% for class 75 and >89% for class 90.

Table 3 shows the effects of different threshold limits. A drift deposition of 1.33% (i.e. the calculated spray drift for the BCPC F/M threshold nozzle) is classified as drift reduction class 25 for 5 nozzle types and up to a reduction class of 50 for the Lechler LU120-03S nozzle type as a reference. For 0.33% drift all reference nozzles come to an identical classification. 0.66% drift is classified as a drift reduction class of 50 except for the Lechler LU120-03S. For 0.17% drift deposition some reference nozzles come to a classification of a spray drift reduction class of 75 (as of the BCPC F/M) and some to 90.

In general the Hardi ISO F-03-110, the Teejet XR11003VP and XR11003VH and the Lurmark 31-03-F110 come to a similar drift reduction classification as the BCPC F/M reference nozzle.

Table 3 Drift reduction and drift reduction classes for drift deposition threshold limits of 0.17, 0.33, 0.66 and 1.33 % of the sprayed volume.

Nozzle		threshold limits [%]				threshold limits [%]			
Manufacturer	Type	0.17	0.33	0.66	1.33	0.17	0.33	0.66	1.33
		Drift reduction				Reduction classes			
Albuz	ISO API 11003	91	82	64	27	90	75	50	25
Hardi	ISO F-03-110	89	78	56	13	75	75	50	0
Lechler	LU 120-03	91	82	64	28	90	75	50	25
Lechler	LU 120-03 C	93	85	71	41	90	75	50	25
Lechler	LU 120-03 S	94	87	74	49	90	75	75	50
Lurmark	**31-03-F110 ***	**88**	**75**	**50**	**0**	**75**	**75**	**50**	**0**
Lurmark	31-03-F110	87	75	49	-2	75	75	50	0
Lurmark	TR03F110	91	82	65	30	90	75	50	25
Teejet	XR11003VH	89	78	57	14	75	75	50	0
Teejet	XR11003VK	91	82	63	27	90	75	50	25
Teejet	XR11003 VP	88	76	52	4	75	75	50	0
Teejet	XR11003 VS	90	80	59	19	90	75	50	25

* BPCP F/M reference nozzle

Conclusions

The comparison of performance of twelve flat fan nozzles from different manufacturers, made of different materials and perhaps with subtle design differences, but all conforming with the 03 colour coding (ISO) for flow rate, clearly demonstrates that their spray distribution on a patternator and drop size distribution will differ. The volume fraction of drops smaller than 100 μm is, for 5 out of 11 nozzles, more than 10% different than that determined for the BCPC Fine/Medium reference nozzle.
Spray drift predictive calculations based on these data with the drift model IDEFICS, that has standardised conditions for drift deposition at 2.125 to 3.125 m from the last nozzle, range from 1.3 % for the present BCPC F/M threshold nozzle to 2.6 % with alternative designs.

Nozzles from different manufacturers will vary in type, design and material, so thereby differ too much in performance, despite having the same specification (F110/1.2/3.0 or ISO 03), to be arbitrarily chosen for a national or internationally acceptable datum to be used with a drift reduction evaluation protocol. It will be critically important to specify one nozzle (manufacturer, type, size, material) as a reference for calculating spray drift reduction when classifying sprayers and atomisers into drift reduction classes.

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