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Bystander and Resident exposure to spray drift from orchard applications: field measurements, including a comparison of spray drift collectors

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Summary

The potential spray drift exposure of bystanders and residents from orchard pesticide applications is likely to be significantly higher than that for boom sprayers, yet the quantity of data available for risk assessment is much less. The BROWSE project aims to estimate bystander exposure from airborne spray drift, which is more plentiful, but will then require some actual exposure data in order to calibrate it. Also, the spray drift data which is available was obtained using different collectors (lines or scouring pads) and therefore there is a requirement to be able to map from one collector type to another in order to use the full range of available data.

This paper describes the field experiments undertaken in 2012 and 2013 which measured spray drift deposits on the ground and on mannequins, as well as airborne spray using three collector types – horizontal lines, vertical lines and scouring pads. An analysis of the data shows the relationship between these three collector types, and between the deposit on mannequins (bystander exposure) and airborne spray

Key words: Spray drift, bystander exposure, orchard spraying, collector types

Introduction

Exposure assessment for agricultural uses of pesticides requires estimation of the potential exposure for bystanders, and new proposals (EFSA Panel on Plant Protection Products, 2010) also recommend assessing the exposure for residents. These exposure assessments include estimates of the potential dermal exposure arising from an airborne spray plume passing a person located immediately downwind of the treated area. The existing UK model of bystander exposure is based on empirical data (Lloyd & Bell, 1983; Lloyd *et al.,* 1987) obtained almost 30 years ago. Spraying practices for boom applications have changed significantly since this work was undertaken, and therefore the model for exposure has been revised (Kennedy *et al.,* 2012) to take account of current practice, as well as including probabilistic elements. A preliminary review of the current model for exposure arising from applications to orchards did not show that UK application practice had changed as much (Defra, 2011), and therefore the original data is likely to be still relevant, but the modelling approaches have developed significantly, and therefore there is a need for further data to support this.

The development of bystander and resident exposure models is now continuing under the BROWSE project, of which exposure to orchard applications is a part. Unlike boom sprayer applications, there is no mechanistic spray drift model for orchards available to underpin this, and therefore the exposure model will be based on empirical spray drift data. There is a significant dataset available in the Netherlands (Zande *et al.,* 2013) and some data from the UK (Cross *et al.,* 2001*a,b*, 2003) that will be used. However, it is not necessarily straightforward to combine these data because the spray collectors were different in each country, and therefore some information is needed to compare their collection efficiency.

In addition, the proposed modelling approach requires empirical data relating bystander contamination to airborne spray to define the collection efficiency of the human body, in the same way that has been used for determining exposure to drift from boom sprayers (Butler Ellis *et al.,* 2010).

Four field trials were undertaken in 2012 and 2013 with the aim of (a) measuring the quantity of spray depositing on bystanders; (b) comparing airborne spray collection techniques and (c) providing information for the BROWSE project that will enable predictions of airborne spray concentrations based on empirical drift measurements to be extrapolated to potential bystander or resident exposure.

Materials and Methods

Four field trials were undertaken (22 March 2012, 21 November 2012, 30 April 2013, 27 September 2013) at orchards located at East Malling Research in the UK. Collectors were aligned according to the site plan (Fig. 1), with distances measured from the last tree row. One child mannequin and one adult volunteer were positioned at 5.0 m and at 10.0 m. Four styles of collectors were selected from those used previously for spray drift measurement, as defined as in Table 1. An example of the horizontal lines with the horizontally-mounted scourers is shown in Fig. 2.

Table 1. *Spray drift collectors used in the field trials*

Collector	Dimension	Location height
Horizontal polythene lines[1]	0.5 m × 1.98 mm	Every 0.2 m from 0.2 to 2.0 m
Vertical polythene line[1]	10.0 m × 1.98 mm	On 10 m vertical masts sectioned into 1.0 m pieces
Chromatography paper[2]	0.5 m × 0.05 m	Mounted on laths on the ground
Vertically-mounted scourers[3]	50 cm^2 (nominal)	Mounted every 1.0 m on 10.0 m vertical lines
Horizontally-mounted scourers[3]	50 cm^2 (nominal)	Every 0.2 m from 0.2 to 2.0 m
Coveralls[4] (adult and child)	*Not measured*	child 1 m ; adult 1.8 m (approx)

[1] Portex Fine Bore Polythene lines – Smiths Medical International Ltd distributed by VWR Ltd
[2] Chromotography paper – Whatman 50mm × 100mm roll
[3] Sibauer Abtriftkollektoren nr. 00140
[4] Coveralls – Cleanroom Supplies Ltd (child coveralls were adult coveralls with arms and legs cut off).

Wind measurements were recorded during each run using the Metpak II 1723 PK-100 (Gill Instruments Ltd) which was mounted at 10.0 m above ground level, upwind of the spray area. Data captured included wind velocity, direction, temperature and dew point. While traditionally measurements of drift from orchard sprayers are made with the wind at 90 degrees to the tree rows,

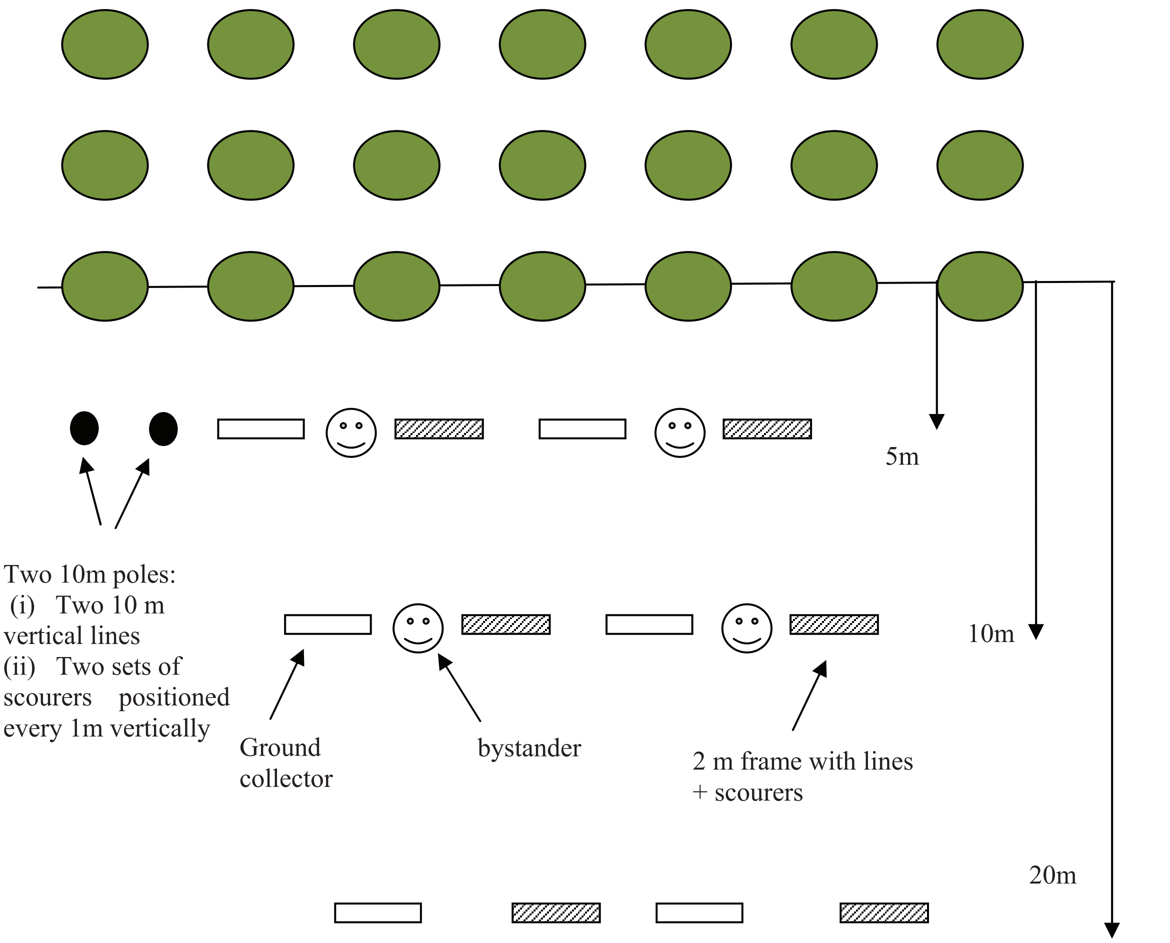

Fig. 1. Field lay-out (not to scale) showing locations of the different collector types. Distances are from the downwind tree row.

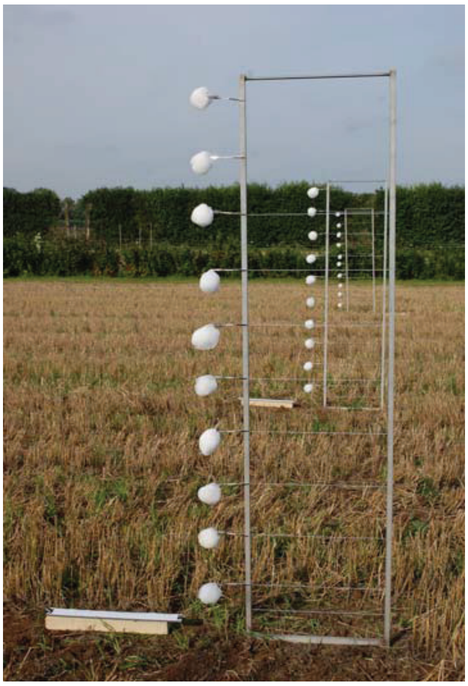

Fig. 2. Side view of the 2m frame with horizontal lines at 0.1 m and every 0.2 m, and scourers at every 0.2 m. Ground collector is shown to the left of the frame.

there is no reason why a bystander cannot be exposed to spray when the wind direction is along the rows, and it was felt important to identify whether the usual 90 degree wind direction does provide a worst case for bystander exposure. Some experimental runs were therefore undertaken with the wind approximately parallel to the tree rows, and the collectors for one of the experiments (Expt 3) were therefore positioned at the end of the tree rows, rather than to the side.

A conventional Hardi Axial Fan sprayer was used with the configuration shown in Table 2. A tank mix was prepared with approximately 0.5 g L^{-1} sodium fluorescein in tap water, with 1.0 mL L^{-1} wetter (Activator 90).

Table 2. *Operating parameters of the Hardi axial fan sprayer, operating at 5.8 km h^{-1} at 7 bar using six of the eight nozzles. Top nozzle each side was switched off*

	Mean flow rate, L min^{-1}	Applied volume, L ha^{-1}	Expt 1	Expt 2	Expt 3	Expt 4
Orange 02 Albuz ATR hollow cone nozzle	1.14	202	1 run	4 runs	3 runs	2 runs
Yellow 02 Albuz TVI air induction nozzle	1.23	219			3 runs	2 runs
Growth stage			Dormant	Dormant	Blossom	Full leaf
Air flow rate			8 m^3/s	8 m^3/s	8 m^3/s	12 m^3/s
Rows sprayed			6	7	7	6
Collector position, relative to tree row			side	side	end	side

Experimental controls were used to monitor degradation during each run by spiking 0.076 mL of the tank mix onto three 90 mm diameter discs of coverall material. These were exposed to field conditions for the duration of each spray session, then compared against three unexposed spiked disks to determine degradation. All collectors were stored in the dark at ambient until deposits were extracted, after which they were refrigerated without light, prior to analysis.

Each sample collectors were extracted into a known volume of buffered diluent using agitation. A standard curve was prepared from the tank mix liquid and all samples referenced against the curve in terms of µl spray liquid extracted. A Perkin Elmer 50B spectrofluorimeter was used to quantify fluorescence at an excitation of 480 nm and emission of 520 nm. The instrument was validated using a sealed water standard.

Results

The quantity of spray liquid on bystander coveralls for each experimental run is given in Table 3. Run 6 has very high levels of exposure due to the sprayer stopping when a problem occurred.

Fig. 3 shows the relationship between the quantity of spray liquid recovered from vertical lines (as used previously in the UK, e.g. Cross *et al.,* 2001*a*) and from scourers mounted on vertical lines (as used in the Netherlands, Zande *et al.,* 2013). Data is not adjusted for the area of the collectors, but the solid black line shows the expected relationship for a scourer area of 50 cm^2 and a line area of 20 cm^2, assuming identical collection efficiency.

Fig. 4 shows the relationship between the quantity of spray liquid recovered from horizontal lines (as used previously in the UK to measure drift from boom sprayers, Butler Ellis *et al.,* 2010) and from scourers mounted adjacent to the frames containing the horizontal lines, as shown in Fig. 2. Again, the data is not adjusted to account for the area of the collectors, but the solid black line shows the expected relationship.

Table 3. *The quantity of spray liquid recovered from coveralls for the different experimental runs, and the wind conditions for each run. Run 6 was an abnormal run, and is therefore excluded from the calculation of the mean and standard deviation*

		Canopy	Wind		Adult exposure, mL		Child exposure, mL	
			Speed	Direction to tree row	5 m	10 m	5 m	10 m
Mar 2012 Run 1	Standard ATI nozzle	Dormant	3.47	14	1.007	0.515	0.483	0.314
Nov 2012 Run 1		Dormant	3.33	73	0.465		0.265	
Nov 2012 Run 2		Dormant	3.14	63	0.407		0.192	
Nov 2012 Run 3		Dormant	2.63	90	0.397		0.185	
Nov 2012 Run 4		Dormant	3.02	66	0.475		0.201	
Apr 2013 Run 1		Blossom	3.57	26	1.962	1.224	0.025	0.013
Apr 2013 Run 2		Blossom	3.43	44	0.227	0.065	0.251	0.011
Apr 2013 Run 6		Blossom	5.21	3	*4.473*	*4.300*	*2.133*	*1.248*
Sep 2013 Run 1		Full leaf	4.34	69	0.578	0.298	0.195	0.115
Sep 2013 Run 2		Full leaf	4.35	36	0.506	0.279	0.371	0.135
Mean					0.670	0.476	0.241	0.117
St. deviation					0.529	0.447	0.129	0.124
Apr 2013 Run 3	TVI Air induction nozzle	Blossom	3.79	21	0.357	0.245	0.211	0.120
Apr 2013 Run 4		Blossom	4.87	28	0.682	0.310	0.410	0.126
Apr 2013 Run 5		Blossom	4.98	44	0.265	0.142	0.154	0.143
Sep 2013 Run 3		Full leaf	3.98	40	0.358	0.062	0.060	0.041
Sep 2013 Run 4		Full leaf	4.06	52	1.310	0.122	0.163	0.053
Mean					0.594	0.176	0.200	0.096
St. deviation					0.430	0.100	0.130	0.046

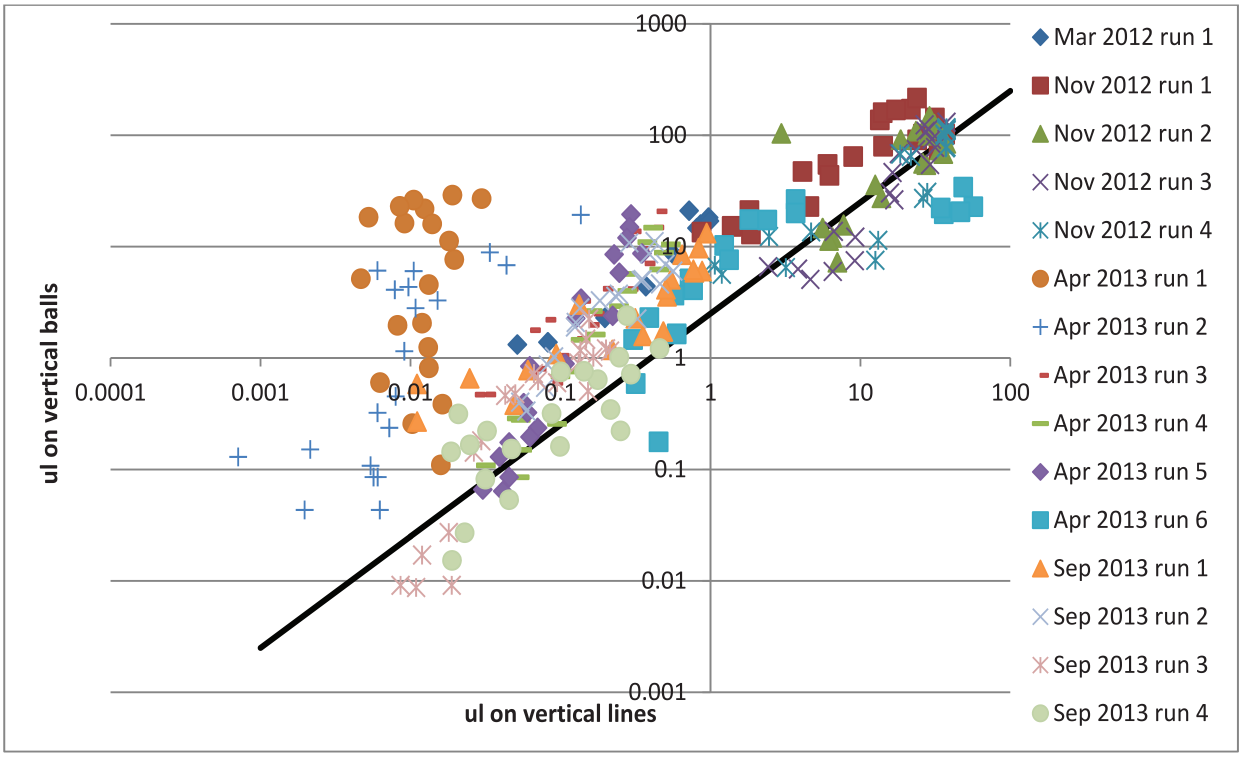

Fig. 3. The relationship between the quantity of spray liquid recovered from vertical lines and from scourers mounted on vertical lines for all experimental runs.

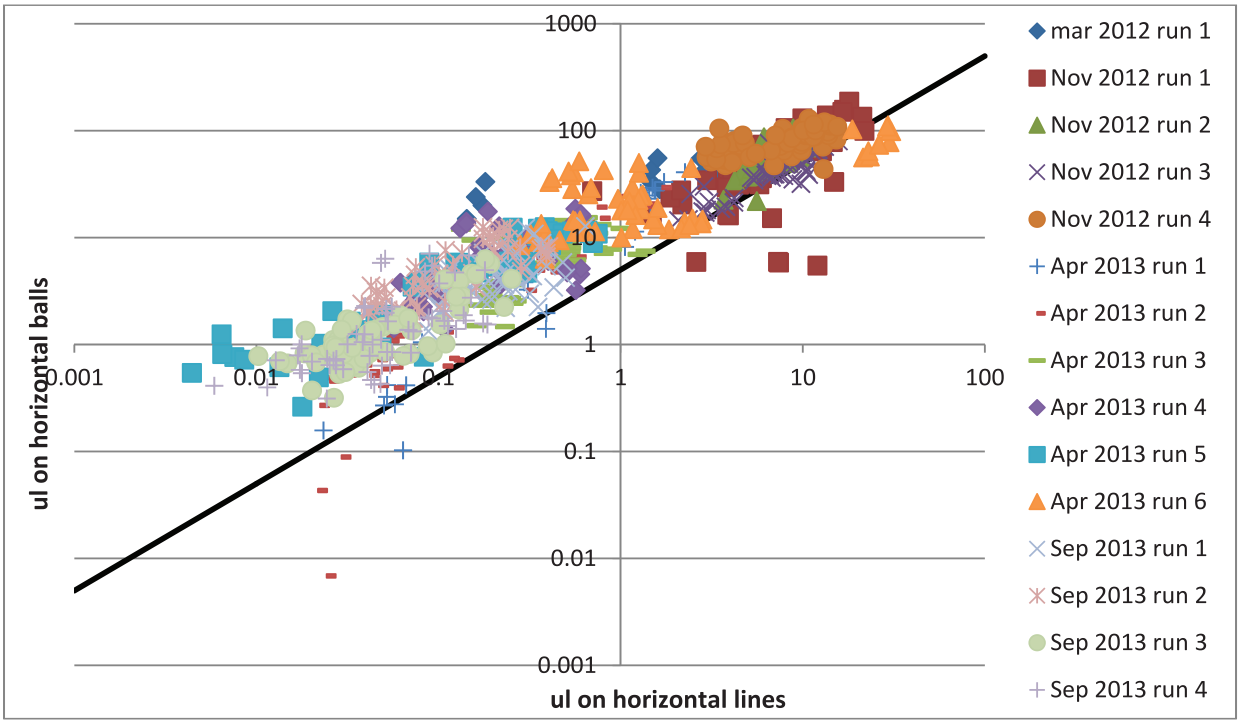

Fig. 4. The relationship between the quantity of spray liquid recovered from horizontal lines and from scourers mounted on horizontal frames for all experimental runs.

Discussion

The mean level of spray liquid on bystanders was lower than the only previous UK study (Lloyd *et al.,* 1986), and the mean exposure for children was less than half that for adults. Although there are insufficient data for a formal statistical analysis of the effect of nozzle type, wind speed and wind direction, the average bystander exposure was slightly less with the low drift TVI nozzle than with the ATI nozzle, and exposures were higher when the wind was directed approximately along the rows. Run 6, where the sprayer stopped and re-started during the downwind pass, has been excluded from any analysis of bystander exposures, although such events could occur in practice. The presence of a bystander during such an event would be very unlikely, however.

Figs 3 and 4 show that scourers collect more than either horizontal or vertical lines, based on their nominal cross section area. This might be as a result of a greater collection area than the 50 cm^2 average assumed in Zande *et al.* (2013) or a greater collection efficiency than the polythene lines. This is particularly noticeable at smaller quantities of measured drift. Further work under controlled wind tunnel conditions is investigating the relative collection efficiencies of the two collector types. Fig. 3 suggested that the April 2013 experiment, runs 1 and 2, were unusual in some way as there was a very poor correlation between the scourers mounted vertically and the vertical lines. However, this behaviour was not apparent for the horizontally-mounted scourers and the horizontal lines, (Fig. 4). Run 6 was included in this analysis, as we are interested in the relative quantities collected and starting and stopping the sprayer would be expected to affect all collectors similarly.

The BROWSE project requires data for the relationship between airborne spray measured with vertically-mounted scourers (how data was obtained in the Netherlands) and the spray deposited on a bystander. This data is shown in Fig. 5. There is no apparent correlation between these two parameters, which causes difficulties in extrapolating airborne spray data measured using such collectors to bystander exposure. A similar analysis for bystander exposure to airborne spray from a boom sprayer, measured with horizontal lines, had a correlation coefficient of 0.73 (Kennedy *et al.,* 2013). This probably arises from the greater number of measurement points for airborne spray when using horizontal lines (i.e. 5 or 10 per metre above the ground), rather than the smaller number of measurements when using scourers (one per m above the ground), as well as a much larger dataset being available. A better correlation for exposures from orchard sprayers (0.38) is achieved when comparing bystander exposure to spray collected on lines mounted horizontally.

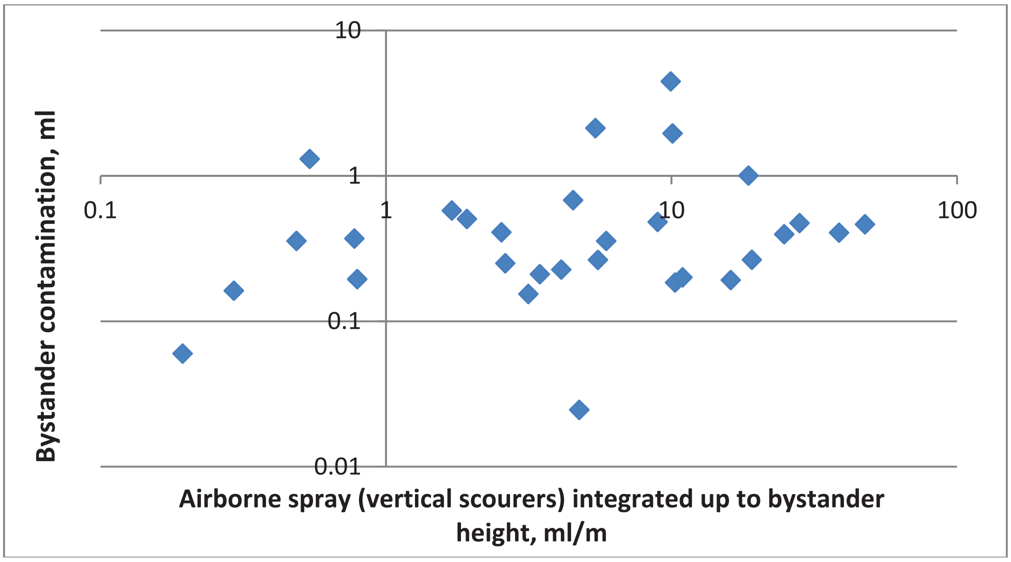

Fig. 5. The relationship between the quantity of spray liquid recovered from vertically mounted scourers and from bystander coveralls, taking account of the height of the bystander.

Conclusions

The different collector types used in trials for the measurement of airborne drift from orchard spray applications have been compared and shown to be broadly comparable, although the collection surface area of the scourer balls and/or collection efficiency of either lines or balls are not sufficiently well characterised to be able to map from one to the other.

Measurements of bystander exposure showed a high level of variability, as is typical with measurements relating to drifting spray, with reduced exposure from the use of a drift-reducing air induction nozzle, and greater exposure when the wind was travelling along the tree rows. Further data is needed to adequately describe the relationship between airborne spray and bystander exposure to orchard drift for modelling purposes.

Acknowledgements

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References

BROWSE. 2013. https://secure.fera.defra.gov.uk/browse/index.cfm.

Butler Ellis M C, Lane A G, O'Sullivan C M, Miller P C H, Glass C R. 2010. Bystander exposure to pesticide spray drift: New data for model development and validation. *Biosystems Engineering* **107**:162–168.

Cross J V, Walklate P J, Murray R A, Richardson G M. 2001*a*. Spray deposits and losses in different sized apple trees from an axial fan orchard sprayer: 1. Effects of spray liquid flow rate. *Crop Protection* **20**:13–30.

Cross J V, Walklate P J, Murray R A, Richardson G M. 2001*b*. Spray deposits and losses in different sized apple trees from an axial fan orchard sprayer: 2. Effects of spray quality. *Crop Protection* **20**:333–343.
Cross J V, Walklate P J, Murray R A, Richardson G M. 2003. Spray deposits and losses in different sized apple trees from an axial fan orchard sprayer: 3. Effects of air volumetric flow rate. *Crop Protection* **22**:381–394.
Defra. 2011. *Final Project Report PS2024*. Options for the development of a model for evaluation of bystander and resident exposures to pesticides used in orchard, hop and bush fruit application.
EFSA Panel on Plant Protection Products and their Residues (PPR). 2010. Scientific opinion on preparation of a Guidance Document on pesticide exposure assessment for Workers, Operators, Bystanders and Residents. *EFSA Journal* **8**(2):65 pp.
Kennedy M C, Butler Ellis M C, Miller P C H. 2012. BREAM: A probabilistic Bystander and Resident Exposure Assessment Model of spray drift from an agricultural boom sprayer. *Computers and Electronics in Agriculture* **88**:63–71.
Lloyd J, Bell G J, Samuels S W, Cross J V, Berrie A M. 1987. *Orchard sprayers: comparative operator exposure and spray drift study*. London: MAFF Report.
Lloyd G A, Bell G J. 1983. Hydraulic nozzles: comparative drift study. *MAFF report SC 7704*.
Zande J C van de, Butler Ellis M C, Wenneker M, P Walklate P J. 2014. Spray drift and bystander risk from fruit crop spraying. *Aspects of Applied Biology* **121**, *International Advances in Pesticide Application*, pp. 177–185.