CHARACTERISING LOW VOLUME SPRAY DEPOSITS USING ARTIFICIAL TARGETS

J.W. Nicholls[1], J.H. Combellack[2], and N.D. Hallam[1]
[1] Department of Ecology and Evolutionary Biology, Monash University,
Clayton Vic 3168, Australia
[2] Keith Turnbull Research Institute, PO Box 48, Frankston Vic 3199, Australia

Summary. Using undescribed twin fluid nozzles, quantitative fluorometric studies were used to determine relative retention of sprays as captured by artificial targets. When considering the whole target, changes in boom speed and nozzle orientation had little effect on retention. A uniform static spray distribution for twin fluid nozzles was achieved using 25 L air/min/nozzle, a boom height of 50 cm and nozzles orientated 22.5° above the horizontal. Within targets however, the relative capture by horizontal and vertical collectors was dependent on nozzle orientation and boom height. Using twin fluid nozzles it was shown that application of an aqueous-based spray at 20 L/ha and 10 km/hr is a practical method of applying low volumes of spray solution.

INTRODUCTION

The inefficiencies of using hydraulic nozzles in boom spraying operations (2) results in a limit being reached where volumes can no longer be reduced without detrimental environmental and ecological effects (3, 4). Unevenness in the spray pattern and the high ground speeds required to accomplish low application rates renders conventional low volume systems unreliable. More accurate means of applying herbicides at ultra low volumes (<10 L/ha) were investigated by McWhorter (9) with the development of twin fluid spray nozzles for the application of oil-soluble herbicides in paraffinic oils. These nozzles enabled adequate distribution of herbicide to give season-long control of seedling and rhizomatous johnsongrass (*Sorghum halepense* (L.)) (1).

The major advantage of twin fluid nozzles is their ability to atomise low flow rates of liquid without being prone to nozzle blockages. While herbicide dose rates can be reduced, the expense of adjuvants such as paraffinic oils and emulsifiers raise the operating cost of twin fluid nozzle ULV systems. For this reason, a very low volume aqueous system, ie. 10-40 L/ha, is being investigated which substantially reduces the cost of herbicide application.

The use of artificial targets help define the optimal parameters of spraying (7). In these trials stainless steel rods were used to assess the influence of boom height, sprayer speed, nozzle orientation and target angle on spray retention as measured by quantitative fluorometry (11).

METHODS

Patternator testing. A patternator comprising 25 mm channels was used to establish optimal spraying parameters for a pair of modified *Lurmark* AN 5.0 deflector nozzle tips. Spray pattern uniformity was calculated as coefficients of variation (c.v.%) over 5 boom heights (20, 30, 40, 50, 60 cm), 5 flow rates (20, 22.5, 25, 27.5, 30 L of air/min/nozzle) and two nozzle orientations (horizontal (0°) or directed 45° above the horizontal (+45°)). This equates to spray sheets being 25° and 70° above the vertical respectively. In all cases, the spray sheet was offset 10° to the boom. Using a sprayer speed of 10 km/hr, a nozzle spacing of 50 cm and a liquid flow rate of 166 mL/min/nozzle, application rate corresponded to 20 L/ha. The spray solution used for these studies contained 0.1% (v/v) nonylphenol ethyloxylate wetting agent (*Agral 600*, Imperial Chemical Industries) in tap water (28 ppm CaCO3).

Spray retention studies.

Targets for spray deposition. Artificial targets were constructed from stainless steel rods 5 mm in diameter and 110 mm in length, 100 mm of which was exposed to spraying. The rods were fitted into a rectangular perspex block 160*x*75*x*20 mm, by drilling holes at 7 angles (0°, 15°, 30°, 45°, 60°, 75°, 90°) around the perimeter of the block. In these experiments, 4 rod angles (0°, 30°, 60°, 90°) were used. Six targets were placed on a three row by two column grid pattern on the spraying platform for each spraying event.

Spray deposit determination. For spray cabinet studies, the spray solution also contained 0.5% (w/v) *Fluorescein LT* (Harcros Colours). A pair of modified *Lurmark* AN 5.0 deflector nozzle tips were spaced 50 cm apart and offset 10° to the boom. Unless otherwise stated, spraying was carried out using nozzles oriented horizontally (spray sheet angle of 25° above the vertical), with a liquid flow of 166 mL/min/nozzle and 25 L of air/min/nozzle at 10 km/hr. This equated to an application rate of 20 L/ha. Boom height was adjusted to 50 cm above the target canopy for nozzle angle changes. Spray deposit on the targets were quantified by measurement of a fluorescent tracer (10).

Separate experiments investigated the relationship of retention to nozzle orientation, boom speed, boom height and the interaction of nozzle orientation and boom height. The first experiment investigated the effect of three nozzle orientations (0°, +22.5° or +45°, spray sheet angles of 25°, 47.5° and 70° respectively) on retention, each orientation event being replicated three times. Secondly, relative retention at eight boom speeds (9, 10, 11, 12, 13, 14, 15, 16 km/hr) with nozzles oriented at 0° was investigated. Thirdly, relative retention was quantified at three boom heights (30, 40, 50 cm) and three nozzle orientations (0°, +22.5° or +45°).

RESULTS

Patternator testing. Table 1 gives the coefficient of variation of spray distribution for a pair of twin fluid nozzles when oriented 0° and 45°. A range of air flow rates were tested. A boom height of 50 cm and an air flow of 25 L air/min/nozzle gave the most uniform spray pattern for both nozzle orientations. These operating parameters were then used throughout the remainder of this work. The data indicates that a lowering of air flow by 2.5 or 5 L air/min/nozzle and the raising or lowering the boom by 10 cm, does not greatly affect uniformity. Nozzles orientated 0° were generally more uniform than those orientated +45°. Optimal boom height was between 40 and 60 cm depending on air volume.

Retention studies. There was no significant changes to total spray retention when nozzle angle was altered (Table 2). However, compared with 0° and 45° nozzle orientations, up to 35% more spray was retained by the more vertical targets (60° and 90°) when nozzles were orientated +22.5°. The data also shows that for the three nozzle orientations tested spray retention significantly (P=0.05) increased with decreasing target angle, ie. the more horizontal the target the more spray was retained. For nozzle orientation, boom height and speed studies, retention dramatically decreased with increasing target angle: 0°>30°>60°>90° (Tables 2, 3 and 4). Retention of spray was independent of boom speed and nozzle orientation (Table 3), but dependant on boom height (Table 4).

Table 1. Coefficients of variation (%) of lateral spray distribution for changes in nozzle orientation, boom height and air flow

Boom Height	Air flow (L air/min/nozzle) and nozzle orientation (°) 20		22.5		25		27.5		30	
	0°	+45°	0°	+45°	0°	+45°	0°	+45°	0°	+45°
20 cm	28.2	33.2	29.1	32.5	29.8	33.6	34.3	35.3	39.8	38.6
30 cm	13.8	15.3	9.1	13.7	10.3	14.0	14.2	16.0	17.7	21.0
40 cm	9.1	6.2	10.1	7.4	10.3	7.5	14.2	9.2	9.9	11.5
50 cm	11.4	7.8	9.7	8.0	8.5	6.1	9.6	6.8	10.1	9.0
60 cm	8.9	8.8	7.4	5.9	10.4	7.3	13.9	10.1	15.5	11.4

Table 2. Spray solution retained (mL/sq mm) by artificial targets at various nozzle orientations (l.s.d. P=0.05)

Target angle	Nozzle orientation 0°	22.5°	45°
0°	0.554	0.553	0.560
30°	0.447	0.445	0.420
60°	0.329	0.376	0.344
90°	0.200	0.234	0.173
l.s.d. (angle *x* orientation) = 0.064			
Total	0.384	0.402	0.374
l.s.d. (angle) = 0.033			

The data in Table 4 shows that there were no significant (P=0.05) changes in overall collection by targets if the nozzle orientation was varied from 0° to 45°. However, there were significant changes for some of the interacting parameters. For example, by lowering the boom height from 50 to 40 to 30 cm retention was significantly increased. The data also shows that as target angle decreases from the vertical to 30° retention is significantly increased. Further, when the nozzles were orientated horizontally, the 0° and 30° targets collected as much as 50% less spray at a boom height of 40 cm than at either 30 or 50 cm. However, as nozzle angle was increased the quantity of spray solution retained on horizontal targets decreased by as much as 15% as the boom was raised from 30 to 40 to 50 cm.

It can be concluded that the large variations in spray retention measured reflect the interactions between target orientation, spray sheet angle and boom height. Optimum retention was obtained on a horizontal target using horizontal nozzles. the lowest collection (29% of the highest), was on a vertical target with a 22.5° nozzle angle.

Table 3. Spray solution retained (L/sq mm) by artificial targets at various boom speeds (l.s.d. P=0.05)

Target angle	Speed (km/hr)								
	9	10	11	12	13	14	15	16	Mean
0°	1.113	1.245	1.158	1.147	1.112	1.035	1.262	1.145	1.155
30°	1.021	.988	1.054	.908	1.002	1.116	1.255	1.061	1.049
60°	.823	.710	.906	.664	.966	.624	.848	.605	.786
90°	.418	.352	.614	.797	.731	.545	.520	.534	.564
Mean speed	.846	.824	.933	.879	.953	.830	.971	.836	.884

l.s.d. (speed) = 0.313
l.s.d. (leaf *x* speed) = 0.316

Table 4. Interaction of nozzle orientation and boom height on retention (L/sq mm) of spray solution by artificial targets (l.s.d. P=0.05).

Target angle height (cm)	Nozzle orientation									Mean
	0°			22.5°			45°			
	50	40	30	50	40	30	50	40	30	
0°	.661	.489	.718	.566	.584	.650	.533	.596	.644	.604
30°	.614	.467	.610	.500	.525	.487	.500	.508	.586	.533
60°	.434	.353	.464	.425	.496	.491	.370	.459	.467	.440
90°	.242	.244	.363	.207	.257	.340	.290	.210	.442	.288
Mean nozzle		.472			.461			.467		
Mean height	.488	.388	.539	.424	.465	.492	.423	.443	.535	.466

l.s.d.. (leaf *x* angle *x* height) = 0.123
l.s.d.. = (angle *x* height) = 0.109

DISCUSSION

Artificial targets are useful in identifying sources of variation in deposits over a given area, but are not reliable substitutes for estimating retention on leaves (5, 6). Of the possible artificial targets available, rods and cylinders are preferred as they are the most efficient collectors (8).

The patternating studies presented demonstrate the complex interactions that boom height, nozzle orientation and air flow rates have on the uniformity of the spray pattern. Interestingly, minor adjustments to these parameters did not appreciably alter the uniformity of retention, but would presumably have influenced drop diameter, velocity and trajectory. The work of Elliott *et al.* (5) indicates that any increase in retention, eg. by lowering boom height or reducing air flow rate, is at the expense of uniformity in spray distribution.

In contrast to the studies of Richardson (11), where spray retention of flat fan nozzles was increased by more than 200% when nozzles were directed forward 45°, overall retention of spray deposits in this study were not influenced by nozzle orientation. However, retention on the vertical targets was significantly increased (50-64%) when the boom was lowered from 50 to 40 to 30 cm. The reason for the lower increase in retention compared with Richardson (11) could be the nozzles (twin fluid *vs.* flat fan), the case of artificial *vs.* natural targets or sprayer speed (6 *vs.* 10 km/hr). Retention by horizontal target rods was generally independent of nozzle orientation. Vertical targets typically retained less than half the amount of spray of horizontal rods. This indicates that the relative proportion of spray intercepted by targets is related to their angle (0°>30°>60°>90°) (12). The data showed that a low c.v.(%) on a patternator does not necessarily equate to maximum retention.

From the results it can be concluded that boom height and target orientation are the two most important parameters affecting increased retention. A boom height of 30 cm when spraying vertical targets can be expected to increase spray retention by up to 60%. However, collection on horizontal targets is unlikely to be greatly affected.

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