EVALUATION OF TECHNIQUES TO MEASURE AERIAL SPRAY DEPOSITION

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SUMMARY

No significant differences in mean spray deposition per unit area were found using four types of horizontal collecting surfaces placed on the ground during aerial applications. Spray deposition was significantly increased and the variance in deposition decreased using table tennis balls as collectors. Two methods of measuring spray deposition, colourimetry and chemical analysis, produced identical results after correcting for dye degradation. The mean deposit and its variance remained relatively stable as the distance between samples varied from 0 - 4 m. To assess total deposition within a spray block, random placement of collectors is preferable to a line of targets placed across the flight lines for statistical reasons.

INTRODUCTION

Measurement of spray deposition and distribution from aerial pesticide applications is an important element in operational quality control. The spray distribution across a single aircraft swath (i.e. a single flightline) is often measured as part of the calibration procedure. By overlapping this single swath with itself, usually using a computer simulation, an estimate can be made of the expected application variability. If the calculated level of variation is unacceptable, the deposit pattern across the swath must be improved. In addition, to verify the accuracy of an operational application, the amount and distribution of spray deposited within the target area needs to be measured.

Many methods are available to measure the distribution of spray deposits (Barry *et al*, 1978; Carlton and Bouse 1987; Whitney and Roth 1985). Generally, spray is caught on a line of artificial collectors placed at equal intervals across the flight line(s). Deposition on the collector surface is usually measured using either a fluorescent or a colourimetric tracer rather than direct chemical analysis of the pesticide active ingredient.

The goal of this research was to determine the influence of the type of collector, method of deposit analysis and sampling pattern on the resulting estimate of spray deposition and its distribution.

Data presented in this paper are taken from five aerial application trials conducted between 1983 and 1985.

MATERIALS AND METHODS

In three trials, two at Rotorua airport and one at an airstrip in Tokoroa, a helicopter was flown over uniformly mown grass and tarmac surfaces; the fourth and fifth trials were conducted under field conditions at Kaingaroa forest. In the Rotorua and Tokoroa trials the helicopter flew a single pass across lines of collectors placed at 90 degrees to the flight line and with equal distances between collectors. A similar sampling technique was used for the Kaingaroa field trials except that the helicopter flew multiple, half-overlapping flight lines in a grass-releasing operation. The block was flat and had a patchy distribution of grass and logging debris. All collectors were placed in the middle of a road running through the centre of the site. In all trials the nominal boom height was 5 m above the ground.

At each trial location spray deposition on various collectors was compared (Table 1). In addition, at the first Rotorua trial an estimate of absolute deposition was

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TABLE 1: The type of collectors, number and length of the sampling lines and the sampling interval, for each trial location.

Trial location	Collector	Number of lines	Length of lines (m)	Sampling interval (m)
Rotorua 1	Mylar	4	28	0
	Balls	1	50	1
Rotorua 2	Mylar	4	50	1
	Cups	2	50	1
Tokoroa	Mylar	6	50	1
	Balls	3	50	1
	Cups	3	50	1
Kaingaroa 1	Glass	1	63	1
	Cups	1	63	1
	Mylar	1	63	1
	Filter paper	1	61	5
Kaingaroa 2	Cups	1	63	1
	Mylar	1	63	1

obtained by placing four continuous strips of mylar (acetate sheet, 70 mm wide by 28 m long) across the swath.

Collectors

Of the various collectors, table tennis balls, which were mounted on 200 mm long dowels to support them above the ground, were unique in that they presented a constant surface area viewed from any projection. Thus, they can capture spray droplets with equal efficiency independent of their trajectory. The other two-dimensional collectors, mylar sheets, glass plates and plastic cups, which were placed horizontally on the ground, capture spray only when droplets settle onto them. Although cups are three-dimensional structures, their effective collecting surface was a horizontal plane at the cup mouth, because deposits were measured only from within. Potential advantages of cups include no spray losses through runoff.

Spraying system

Application factors differed in some experiments (Table 2). Thus comparisons of collector effectiveness were made only within experiments.

Tracers and deposit analysis

Spray deposits were measured using a variety of tracers. In both the Rotorua and the Tokoroa trials tartrazine at 10 g/litre was added to the spray mixes which consisted of water and water plus 0.44% Delafoam respectively. Deposits were washed off the collector with an appropriate volume of water, and the samples were analysed by colourimetry, measuring the absorbance at 435 nm. Deposition was calculated by comparing the absorbance with known standard values.

TABLE 2: Spraying systems used for each trial

Trial location	Aircraft ¹	Nozzles	VMD ² (µm)	Nominal volume (litres/ha)
Rotorua 1	Jet Ranger	D7-25 ³	282	100
Rotorua 2	Jet Ranger	D7-25	325	100
Tokoroa	Jet Ranger	Foam ⁴	— ⁵	160
Kaingaroa 1	Llama	AU3000 ⁶	953	75
Kaingaroa 2	Hughes 500	Foam	1141	160

¹ All aircraft were flown at 45 knots except Hughes 500 which flew at 40 knots.

² Volume median diameter.

³ Spraying Systems Co.

⁴ Delavan Co.

⁵ Not measured.

⁶ Micronair Ltd.

At Kaingaroa, deposition was assessed in a similar manner except the tracer was Rhodamine B and absorbance was measured at 554 nm. The spray mix was a standard triazine grass control spray with the addition of 0.44% Delafoam in the foaming nozzle treatment. Rhodamine B proved to be a less than suitable tracer because less than 100% of the quantity applied to the collecting surfaces could subsequently be recovered. A correction factor accounting for this reduced recovery was therefore used in analyses involving Rhodamine B. Spray was also collected on filter papers and the triazine content in the deposit was analysed using gas liquid chromatography.

Droplet sizing

Spray droplets were sampled in the field, using cast-coated (similar to Kromekote) cards placed on the ground, and sized in the laboratory using standard techniques (Richardson *et al* 1986).

Meteorological conditions

In all trials the relative humidity, temperature and windspeed were measured at several heights above the ground. In most cases, spray applications were made in stable-neutral atmospheric conditions, with low windspeeds (< 5.3 km/h at 5 m), temperatures below 12.8°C and humidities above 91%. The most extreme conditions occurred at Tokoroa with crosswind speeds of up to 9.3 km/h at 2.5 m above the ground, relative humidity down to 71% and a maximum temperature of 18.7°C.

Data analysis

Within each experiment, differences in both the quantity of spray deposited on collectors and the associated variance were identified, after a natural log transformation of the data, using a two-sample t-test and an F-test, respectively.

To estimate the maximum acceptable sampling interval, the four continuous strips of mylar used in the first Rotorua trial were cut into 200 mm lengths. After determining the deposit pattern across each sampling line, each swath pattern was overlapped with itself, using a computer simulation, to give an estimate of operational deposition (i.e. where successive swaths are flown). To estimate the effect of sampling interval on the calculated mean spray recovery and its variance, the data were repeatedly analysed after increasing the sampling interval, in a step-by-step manner, by successively dropping 200 mm lengths from the analysis. In other words, the first analysis of mean recovery and its variance assumed a sampling interval of 0 m (i.e. a continuous sample); the second analysis assumed a sample interval of 0.2 m (every second sample), the third assumed a sampling interval of 0.4 m (every third sample), and so on.

RESULTS AND DISCUSSION

All horizontal collectors were equally effective in capturing spray, but were inferior to table tennis balls (Table 3). Deposition calculated using tracers was not significantly different to the estimate obtained using chemical analysis. The variance in mean spray deposition was always smallest using table tennis balls as collectors (Table 3). In most trials, deposit variation appeared to be independent of horizontal collector type. In the Kaingaroa trial, however, variation followed the hierarchy: Cups > Glass > Mylar = Filter Paper. The reason for these differences is not known because, although the sampling surfaces of glass and cup collectors were much smaller than the mylar, the internal collecting surface of cups was greater than the glass (Table 3). Furthermore, in the other trials no significant differences in the variance between the deposit using mylar or cups were observed.

Variation in spray recoveries among treatments have not been discussed because of differences in application parameters among treatments.

Any omni-directional collector, such as a table tennis ball or foliar element, which projects above the ground or canopy surface will tend to capture more spray than expected based on a simple calculation of theoretical deposition per unit ground area. This calculation assumes drops follow linear, more-or-less vertical trajectories from the point of release to the ground. In reality, however, a significant fraction of the droplets from typical spray applications will move horizontally, or be entrained in the wake of the aircraft and follow a non-linear, often swirling trajectory (Carlton and Bouse 1987). Thus, any collector positioned above the ground or canopy surface, and able to

TABLE 3: Natural logarithm of mean spray deposition and variance per unit collector surface area.

Trial location	Collector	Projected area (cm ²)	Ln mean deposit ln (μl/cm ²)	Ln variance ln (μl/cm ²)
Rotorua 1	Mylar	14.0	3.13b ¹	3.52a
	Balls	11.3 ²	4.14a	0.73b
Rotorua 2	Mylar	140.0	2.39a	5.47a
	Cups	65.8	2.82a	3.68a
Tokoroa	Mylar	140.0	3.54b	2.10a
	Balls	11.3	4.47a	0.98b
	Cups	65.8	3.53b	2.24a
Kaingaroa 1	Glass	60.0	3.39a	1.14b
	Cups	65.8	3.38a	1.37a
	Mylar	140.0	3.72a	0.92c
	Filter paper ³	122.7	4.15a	0.29c
Kaingaroa 2	Cups	65.8	3.59a	0.36a
	Mylar	140.0	3.74a	0.33a

¹ For a given trial, numbers followed by the same letter are not significantly different ($P > 0.05$).

² Plan area of table tennis ball.

³ Because filter papers for chemical analysis were placed at 5 m intervals but other collectors were at 1 m intervals, comparisons involving the filter papers were based on using every fifth collector.

intercept spray moving in any direction, will reveal a large increase in deposition. Data from this and other studies (Carlton and Bouse 1987; Carlton *et al* 1985; Goering and Butler 1975; Richardson *et al* 1986) support this hypothesis.

From Figures 1a and 1b, it appears that mean spray deposition and its variance were relatively insensitive to sampling intervals between 0 and 4 m. With sampling intervals greater than 4 m the estimates became progressively more unreliable.

If the objective is to estimate mean spray deposition in the sprayed area, there is a statistical problem with sampling in a straight line across the swath(s). Placing the collectors in such a manner means that the deposit on one collector is highly correlated to the deposit on adjacent collectors. In addition, there tends to be a larger scale repetition of the deposit across the block due to the imperfect distribution pattern of a single swath. Thus, the assumption of independence of samples, required for most types of analysis, is violated. A second problem with this design is that variation is measured in one direction only, across the swath(s), for that one location. No account is taken of variation along the flightlines and variation at different locations. It is suggested that random placement of collectors would avoid these problems.

These findings indicate that spray deposition measured on horizontal collectors placed on the ground is not equivalent to spray deposition on three-dimensional collectors. The latter collectors are likely to more closely approximate spray deposition on foliage, which is effectively a three-dimensional collector. Horizontal collectors have value for identifying the uniformity of the spray pattern and estimating deposition in the absence of foliage, but for information on deposition on the target, usually foliage, there is no substitute for sampling the target itself. Unless the goal is to measure the spray distribution across the swath or deposition within a localised area, random placement of collectors is preferable to a single line. Horizontal collectors placed above the foliage and randomly within the sprayed area will give a representative estimate of deposition in the whole block. Table tennis balls placed outside the target area will give an improved estimate of off-target drift.

Fig. 1: Effect of sampling interval on estimate of (a) mean deposit and (b) standard deviation, measured using four sampling lines of continuous mylar from Rotorua 1 trial. Each line on the graphs represents a separate sampling line.

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REFERENCES

- Barry, J.W., Ekblad, R.B., Markin, G.P. and Trostle, G.C., 1978. Methods of sampling and assessing deposits of insecticidal sprays released over forests. *USDA Technical Bulletin No. 1596*.
- Carlton, J.B. and Bouse, L.F., 1987. Exploring aerial spray sampling with a cylindrical collector. *ASAE Paper No. 87-1070*. ASAE St. Joseph, MI., 49085, USA.
- Carlton, J.B., Bouse, L.F., Witz, J.A. and O'Neal, H.P., 1985. Automating aerial spray deposit analysis. *Transactions of the ASAE* 28(5): 1401-1405.
- Goering, C.E. and Butler, B.J., 1975. Paired field studies of herbicide drift. *Transactions of the ASAE* 18(1): 27-34.
- Richardson, B., Ray, J. and Vanner, A., 1986. Retention of spray on bracken pinnae: Effect of application volume and formulation. *N.Z.J. For. Sci.*, 16(1): 87-95.
- Whitney, R.W. and Roth, L.O., 1985. String collector for spray pattern analysis. *ASAE Paper No. 895-1005*. ASAE, St. Joseph, MI., 49085, USA.