FACTORS AFFECTING SPRAY DEPOSITION FOLLOWING THE AERIAL APPLICATION OF HERBICIDES

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Summary. Spray recoveries of over 100% were consistently obtained using table tennis balls as collectors during aerial application trials. Data presented support the hypothesis that the conventional, or linear, model of calculating spray recovery is inappropriate for many situations. Conversely, evidence from trials supports an alternative model for calculating spray recoveries, which accounts for these higher than expected levels of deposition. Factors included in the new model, and their implications are discussed.

INTRODUCTION

To evaluate the efficiency of aerial herbicide applications, measurement of spray deposition within the target area is required. This information is necessary as a basic quality control procedure and is essential if rational judgements on the environmental impacts of spray applications are to be made.

Although it is desirable to measure spray deposition on the actual target (10) which is usually foliage, this is often difficult, expensive and it is not always easy to meaningfully interpret these deposition values. A more common approach to deposit assessment is to sample spray using artificial collecting surfaces. The collectors used are mainly two-dimensional surfaces placed horizontally on the ground, for example mylar sheets, steel or glass plates, paper tapes, 35-mm film and filter papers (1, 6, 9). Less frequently, three-dimensional collectors, such as table tennis balls (9), plastic tubing (2), string (11) and simulated "foliage" (5) have been used. In general, for a given droplet size, spherical and cylindrical collectors intercept spray droplets with equal efficiency independent of droplet trajectory. Two-dimensional collectors placed on the ground, capture spray only when drops settle onto them.

This paper compares estimates of spray recoveries in an experiment using two-dimensional and 3-dimensional collectors. Reasons for the observed differences are discussed and recommendations are made to improve the reliability of spray deposition measurements in the field.

METHODS

Data are taken from an aerial application trial, conducted in 1989 in New Zealand. Throughout this paper deposition is reported as a spray recovery, calculated as :

$$\text{spray recovery (\%)} = \frac{\text{measured spray deposition (l/ha)}}{\text{volume applied (l/ha)}} \times 100$$

This calculation, referred to as the "linear" model (2) assumes that a known total spray volume was spread evenly over a known ground surface area. All values for collector area are therefore based on projected plane areas to equate them to ground area.

Collector location and ground deposition. In an "operational" field trial at Pirongia, a Hughes 500 helicopter applied 6 kg/ha a.e. triclopyr (Grazon, Ivon Watkins Dow Ltd.), and 10 g/l of spray tartrazine, made up to 200 l/ha with water, to a steeply sloping site of approximately 1 ha. The aircraft was fitted with D8-45 nozzles (Spraying Systems Co.), and a doppler radar system to help the pilot maintain a groundspeed of 67 km/hr. Using standard techniques (8), droplet size and meteorological conditions were measured during spraying.

This site consisted of two distinct, but adjacent plots, each of approximately 0.5 ha. One plot was covered with a patchy distribution of gorse (estimated 30-40% ground cover) up to 3 m tall, with large grass patches between gorse bushes; the other plot was mainly short-cropped grass. Multiple flight lines following the contours were flown over the entire area with a separation (bout width) of 6 m marked by a sequence of coloured flags. Spray deposition was assessed along a single 50 m long transect in the approximate centre of the grass plot. Three types of collector, steel plates, table tennis balls and filter papers, were each placed at 1 m intervals along the transect. Table tennis balls were mounted on 200 mm long dowel rods to support them above the ground. In addition, deposition was measured in the gorse plot using 50 table tennis balls attached to the tops of gorse bushes and 50 table tennis balls placed on the ground in open areas between gorse bushes.

Spray deposits on filter papers were quantified using gas liquid chromatography. Deposits on steel plates and table tennis balls were assessed colourimetrically by analysing for tartrazine which has a maximum absorbance at 435 nm.

Comparisons of mean deposition per unit area between collector types and collector locations were made after a logarithmic transformation using two-sample t-tests or, where appropriate, paired t-tests.

RESULTS AND DISCUSSION

Meteorological conditions were favourable. Windspeeds were low (5.4 km/hr at 2.5m above the ground) and wind direction was parallel to the flight lines. Temperatures and relative humidities were moderate (13°C and 95%, respectively) and atmospheric stability was neutral. Droplet size, calculated as vmd (volume median diameter), was 282 μm.

Recoveries of 79 and 85% on horizontal collectors in the grass area were not significantly different, but they were lower than spray recovery measured on table tennis balls (150%) (Table 1). Recoveries on balls in the grass area and on tops of gorse bushes (136%) were not significantly different, but they were both significantly higher than spray recovery on balls placed in large open areas between gorse bushes.

Table 1. Mean spray recoveries measured on two-dimensional and three-dimensional collectors at Pirongia.

Collector location	Collector type	Spray recovery (%)
Grass	Plates	85^{c}
Grass	Filter paper	79^{c}
Grass	Balls	150^{a}
Gorse	Balls (on gorse)	136^{a}
Gorse	Balls (on ground)	100^{b}

[a] Numbers followed by the same letter are not significantly different at P = 0.05.

Other trials have shown similar results, with recoveries of 89 and 80% on two-dimensional collectors compared with 133 and 153%, respectively, on table tennis balls (9).

Using the conventional method, or linear model, of calculating spray recovery, recoveries greater than 100% are not theoretically possible. Thus, spray recoveries measured on table tennis balls confound this model. No corrections have been made for the low impaction efficiency (7) of small droplets on spherical collectors. With the nozzles used, a relatively small fraction of the spray volume was made up from droplets with diameters small enough to have low impaction efficiencies. Nevertheless, correcting for this factor would slightly increase spray recovery on balls. To be collected on two-dimensional surfaces placed on the ground, droplets must settle out under the force of gravity.

Similar results have been obtained using other types of three-dimensional collectors. Recoveries of up to 696% have been recorded on microtubing, a 3.2 mm diameter cylindrical collector suspended across the flight line (2). An alternative conceptual model for calculating spray recovery has been suggested (2), whereby spray deposition is viewed as a dynamic, time dependent process. The volume, V, of spray collected for a given flux of spray, F, expressed as a function of time, t, is given by:

$$V = A\,E_c \int_0^t F(t)\,dt,$$

where A is collector surface area and Ec is the collection efficiency. In terms of total mass deposited within the target area, Ec is probably not particularly important for large-droplet herbicide applications.

The term F(t) is difficult to quantify because it will be modified by any factor which affects the droplet trajectories. The aircraft wake can be particularly important in this respect. A substantial spray volume can be caught in the aircraft vortices, which impart a complex rotational behaviour to the spray cloud. It has been hypothesised that the rotating vortices can cause spray to repeatedly swirl around three-dimensional collectors giving entrained droplets more than one chance of being intercepted by a three dimensional collector above ground surface (2). The result will be a build up of deposit on these collectors, a fact not accounted for by the linear model.

Data from this and other trials (9) suggest that this may be an oversimplification. In trials where the aircraft flew a single line or multiple lines in one direction, deposition on balls was restricted to one side only; if spray was swirling around the collectors, all-over deposition would be expected. Passage of the aircraft causes a flow of air opposite to the direction of flight. Droplets caught in this airflow are carried parallel to the surface and deposit on the side of the balls facing the back of the aircraft. Droplets with a large horizontal velocity component are collected more effectively by three-dimensional collectors. If droplets are approaching the ground at an angle θ from the horizontal, the effective collecting surface, y, of a three dimensional object, which can be viewed perpendicular to the spray trajectory, will be

$$y = x \sin\theta$$

where x is the equivalent ground area in the 'shadow' of y. In other words, deposition per unit area on y will be $1/\sin\theta$ times larger than on x. It is suggested that both of these mechanisms, which are simply wake effects, contribute to F(t).

Using the new model, it can be predicted that factors which reduce the influence of the wake on spray droplets, would also reduce recovery on three-dimensional collectors and provide a closer approximation to the linear model. For example, as droplet size increases, the influence of the wake on droplet trajectories would be expected to decrease.

Data from this experiment support these concepts. Deposition on table tennis balls placed in open areas between gorse plants was significantly lower than deposition on balls attached to tops of gorse plants (Table 1). A high proportion of spray droplets entrained in the wake will be intercepted by the tops of gorse plants and collectors in the gorse plants. Less spray than expected is therefore available for deposition when the spray cloud reaches the level of table tennis balls supported on dowels approximately 200 mm above the ground in the gorse area.

These findings have several important implications. Past studies which have attempted to quantify spray recovery must be reassessed in the light of this new model. For example, a study following the fate of 2,4,5- T applied to a steep hillside, reported 80% losses of 2,4,5-T, which were attributed to drift (4). Spray deposition was measured on pasture grasses on a site with a sparsely distributed (30%) cover of 1 m tall gorse. A more plausible explanation for at least some of the unaccounted-for spray is that the gorse bushes, acting as three dimensional collectors, captured a high proportion of the falling spray. Thus, collector placement in this type of trial is of paramount importance.

Spray deposition should only be assessed using two-dimensional collecting surfaces placed on the ground if there is a uniform surface, such as an airstrip, with no material projecting above the surface. The minimum distance required to eliminate the influence of projecting material, such as isolated plants or clumps of plants, on spray deposition on two-dimensional collectors depends on a number of factors. The minimum distance will increase as droplet size decreases, airspeed decreases (downwash velocity of wake increases), windspeed increases and plant size increases.

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