# RETENTION OF SPRAY ON BRACKEN PINNAE: EFFECT OF APPLICATION VOLUME AND FORMULATION

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ABSTRACT

Higher relative spray deposits were found on pinnae of bracken fern (**Pteridium esculentum** (Forst. f.) Ckn.) when herbicides were applied from a helicopter in lower rather than higher volumes of water. At the same application volume a formulation containing less surfactant gave higher relative deposits than surfactant-rich ones. The differences can be explained by assuming that droplets bounce when they fall on a wet surface. This hypothesis has been supported in laboratory experiments.

**Keywords:** aerial spraying; herbicides; application volume; **Pteridium esculentum**.

## INTRODUCTION

Bracken fern is one of the most widespread weeds affecting forest establishment in New Zealand (Preest 1975). Its vigour, growth rate, and foliar density can smother young *Pinus radiata* D. Don and reduce growth rates (Preest & Davenhill 1985). On sites which cannot be cultivated, control is undertaken by the aerial application of herbicides (for a review of control options *see* Preest & Davenhill 1985). Research on bracken control has been limited to screening herbicides and additives with no investigation into the optimum method of application. Traditionally herbicides have been applied in New Zealand forestry in volumes ranging from 160 to 890 *l*/ha (Lamb 1976).

A reduction in the application volume would lead to reduced costs and better utilisation of suitable spraying weather.

Two field trials were therefore carried out to investigate the effect of application volumes on spray deposition on to bracken foliage.

## MATERIALS AND METHODS

### 1983 Bracken Release Trial

The trial site was situated in Cpt 833, Lake Taupo Forest. The area treated was a uniformly steep (approximately 30°), west-facing slope which had been planted with *P. radiata* seedlings in July 1983. A sparse cover of bracken fronds was present over the site before treatment and new fronds continued to emerge after treatment. Various other weed species were also present in low numbers.

*Treatments*

Four 1-ha plots (100 × 100 m) separated by 5-m-wide bulldozed lines were established and treatments (Table 1) were applied on 17 November 1983. An orange water-soluble dye, tartrazine, was added to all of the spray mixtures at a rate of approximately 10 g/*l*.

*Application system*

A Hughes 300 helicopter, spraying down-hill only on a bearing of 240° magnetic and at a speed of approximately 20 knots, was used to apply all treatments. Details of the nozzles used are given in Table 1. The output of the spray boom was checked prior to each treatment and the actual amount of spray applied to each plot was also determined. The flight lines were flagged at 9-m intervals.

Droplet spectra produced from the chosen nozzles using the spray formulations were measured in the laboratory by passing a single nozzle over a line of cast-coated cards in an enclosed room. Droplets were allowed to settle on the cards and the stain sizes were measured and counted on an Optomax Image Analyser. Stain diameters were converted to true droplet diameters by applying the appropriate spread factors.

*Meteorological measurements*

A meteorological station was set up close to the spray area for the duration of the trial. Windspeeds were measured at 10, 5, 2.5, and 1.25 m above the ground and were recorded as the average wind-run over a period of 1 minute, at 5-minute intervals. Wet and dry bulb temperatures at 10 m and 2.5 m and wind direction at 10 m above the ground were also measured at 5-minute intervals.

*Assessments*

Ground spray deposits were measured on traps made from 200 × 70-mm sheets of mylar stapled on to rigid card. Immediately prior to spraying, 50 traps were pegged out at 1-m intervals along a transect running diagonally across the centre section of the plot. Water-sensitive cards (Ciba-Geigy Ltd) were placed at 5-m intervals along the same transects to give an indication of the spray droplet sizes reaching the ground.

After spraying, three pinnae (one from the top, one from the middle, and one from the bottom of each frond) were removed from the frond closest to each mylar trap, regardless of whether they were fully expanded or not. The pinnae and mylar sheets and droplet-sizing cards were sealed in separate labelled plastic cups until required.

In the laboratory all foliage samples and mylar sheets were washed with a known volume of distilled water in their plastic cups to remove the dye deposits. All of the liquid samples were filtered and their absorbances at 435 n.m. were measured using a spectrophotometer. The absorbances of spray samples taken from the helicopter tank after each application were also measured.

An Optomax Image Analyser was used to measure the projected surface areas of the foliage samples and to count and measure the stains on the water-sensitive cards.

TABLE 1—Chemical and water rates, and application parameters

| Plot | Chemical | Chemical rate (kg a.i./ha) | Water rate (*l*/ha) | Nozzles | Droplet sizes (μm) VMD lab. | Droplet sizes (μm) VMD field |
|---|---|---|---|---|---|---|
| **1983 trial** | | | | | | |
| A | Glyphosate | 1.44 | 220 | D7-25* | 204 | 788 |
| B | Glyphosate | 1.44 | 55 | D3-23* | 201 | 188 |
| C | Asulam | 5.6 | 220 | D7-25* | 310 | 528 |
| D | Asulam | 5.6 | 55 | D3-23* | 212 | 220 |
| **1984 trial** | | | | | | |
| A | Oxadiazon | 2.0 | 20 | AU 5000† | 348 | 404 |
| B | Asulam | 5.6 | 20 | AU 5000† | 200 | 550 |
| C | Oxadiazon | 2.0 | 55 | D5-25* | 221 | 481 |
| D | Asulam | 5.6 | 55 | D5-25* | 433 | 841 |
| E | Asulam | 5.6 | 220 | D8-46* | 969 | 1523 |

* Manufactured by Spraying Systems Co. Nozzle orientation 90°, pressure 265 kPa.
† Manufactured by Micronair Ltd, Blade pitch 45°, EX 2021 fan blade.

## 1984 Bracken Release Trial

The trial site was situated in Cpt 842, Lake Taupo Forest. The area treated was a north-east-facing slope of about 20° split by gullies at irregular intervals. The site had a generally patchy coverage of bracken fronds except in the gullies where bracken tended to grow in dense masses. Most of the fronds were soft but fully expanded at the time of treatment, but there was considerable variation. Numerous other weed species were present in low densities.

### *Treatments*

Five 1.5-ha plots (100 m across the slope × 150 m down the slope), separated by 10-m-wide buffer zones, were selected for five different treatments (Table 1). Tartrazine dye was added to the 20-*l*/ha treatments at a rate of 20 g/*l* and to all other treatments at a rate of 10 g/*l* to enable ready measurement of spray recoveries.

### *Application system*

A Hiller Solloy helicopter, spraying downhill on a bearing of 35° magnetic, was used to apply all treatments on 3 December 1984. Details of the nozzles used are given in Table 1. The helicopter spray output was checked immediately prior to spraying each plot. During spraying the pilot was given track-guidance by flagmen at each end of the plot. Flightline separations were 10 m. The requested airspeed was 45 knots.

The total volume of spray applied to each plot was checked after each application. Droplet sizes were measured in the laboratory by placing the nozzles in a 45-knot airstream produced from a ducted fan with an outlet diameter of 40.5 cm. Cast-coated cards were then rapidly passed through spray produced from the nozzles using the actual spray mixtures. All measurements of stain diameters were carried out on an Optomax Image Analyser and converted to droplet size using a spread factor determined using the actual spray solution. Meteorological readings were taken as in the previous trial.

*Assessments*

Foliar and ground spray deposits were determined using similar methods to the 1983 trial. However, cast-coated cards were used for droplet sizing rather than water-sensitive cards.

*Laboratory experiments*

A laboratory metering pump was used to feed spray solutions to a Micron Herbi atomiser mounted over a conveyor belt running at constant speed. Bracken pinnae or table-tennis balls mounted on sticks were passed repeatedly under the sprayer until the required volume of spray had been applied. The deposit was measured as previously described.

## RESULTS

The actual volume applied to each plot (*l*/ha) is listed in Table 2. For the 220-*l*/ha glyphosate treatment excessive frothing in the tank prevented measurements from being made. For subsequent calculations it was assumed that the desired application rate was achieved.

TABLE 2—Spray Recovery Index (SRI) for bracken pinnae and mylar sheets (figures with the same subscript letter are not significantly different at p = 0.05)

| Plot | Chemical | Volume applied (*l*/ha) | SRI | | | |
|---|---|---|---|---|---|---|
| | | | Bracken | | Mylar | |
| | | | X | CV % | X | CV % |
| **1983 trial** | | | | | | |
| A | Glyphosate | * | $0.68_a$ | 34 | $0.4_x$ | 43 |
| B | Glyphosate | 55.5 | $0.91_b$ | 33 | $0.3_y$ | 26 |
| C | Asulam | 210.0 | $1.0_b$ | 34 | $0.6_z$ | 29 |
| D | Asulam | 53.0 | $1.5_c$ | 35 | $0.7_z$ | 48 |
| **1984 trial** | | | | | | |
| A | Oxadiazon | 24.0 | $0.5_d$ | 38 | $0.3_r$ | 43 |
| B | Asulam | 24.5 | $0.8_e$ | 44 | $0.6_s$ | 41 |
| C | Oxadiazon | 60.0 | $0.5_d$ | 54 | $0.3_r$ | 62 |
| D | Asulam | 60.0 | $0.8_e$ | 29 | $0.6_s$ | 41 |
| E | Asulam | 252.0 | $0.6_f$ | 27 | $0.4_t$ | 29 |

* Volume applied not measured because of foaming. Values based on assumption that volume applied = 220 *l*/ha.

To compensate for variations in the application rate and to make all spray recovery figures directly comparable, the actual deposit of spray measured on both the bracken and the mylar has been mathematically converted to a Spray Recovery Index (SRI).

$$\text{Spray Recovery Index} = \frac{\text{Spray recovered } (\mu l/cm^2)}{\text{Volume applied } (l/ha)} \times 100$$

The higher the SRI, the greater the proportion of the spray recovered.

For statistical analysis a log transformation was used and means with the same subscript are not statistically different ($p = 0.05$).

There was clearly a higher recovery of spray on the bracken at the lower application volumes (Table 2). Also, spray recovery was higher for asulam than glyphosate at the same application volumes.

The results of the laboratory trials are summarised in Tables 3 and 4. Percentage recoveries were calculated assuming that at the minimum application volume 100% of the spray landing on the target was retained. For each spray mixture tested less spray was retained on the table tennis balls at the higher application volume. On bracken pinnae increasing application volume led to a lower spray recovery, with the effect becoming more pronounced with increased surfactant concentrations (Table 4).

An inversion existed during all spray applications in the 1984 trial and for the 220-*l* applications in 1983 (Table 5). The two low-volume applications in that year were made under neutral conditions. The meteorological readings for both trials were taken on ridge tops adjacent to but just above the trial blocks.

## DISCUSSION

In all trials the volume median diameter of the spray drops in the laboratory was smaller than that measured in the field. This merely reflects the difference between the droplet spectrum produced by the nozzle and what actually lands on the ground after the spray cloud has interacted with the vegetation. For the 1983 trial, droplet sizes were measured in still air in the laboratory as it was thought that the wind shear at 20 knots would not significantly alter the droplet spectrum. At the higher speeds used in the 1984 trial the atomisers were placed in a 45-knot airstream.

For each spray application the bracken pinnae collected more spray than the mylar sheets, which were always placed on the ground in an open position. For this to happen suggests that the spray was being moved sideways by the wake from the helicopter's rotor and the bracken filtered out the droplets. The smaller the droplets, the more they will be affected by this air movement. This could be an explanation of the higher recovery of spray at the low application volumes; smaller nozzles were used, smaller droplets produced, therefore higher collection due to the wake-induced air movement. Although this may be a contributing factor to the decreased SRI with high volume application, the loss of droplets due to bounce from wet surfaces is still the major factor. This is clearly demonstrated by the higher recovery of asulam than the surfactant-rich glyphosate at the 55-*l*/ha application for the 1983 trial, and by the difference between asulam and oxadiazon in the 1984 trial at both 50 and 20 *l*/ha.

TABLE 3—Spray deposition on table-tennis balls in laboratory

| Solution | No. of passes | Application volume (l/ha) | Deposit ± SD (μl) | Recovery* (%) |
|---|---|---|---|---|
| Water | 6 | 56 | 6.4 (0.0) | 100 |
| | 24 | 223 | 21.6 (1.0) | 84 |
| Water + asulam (25% Asulox) | 6 | 56 | 4.8 (0.3) | 100 |
| | 24 | 223 | 18.0 (0.5) | 94 |
| Water + asulam (6% Asulox) | 6 | 56 | 5.6 (0.9) | 100 |
| | 24 | 223 | 18.1 (0.2) | 81 |
| Water + glyphosate (7% Roundup) | 6 | 56 | 6.2 (1.1) | 100 |
| | 24 | 223 | 18.4 (0.5) | 75 |
| Water + glyphosate (2% Roundup) | 6 | 56 | 5.9 (0.4) | 100 |
| | 24 | 223 | 21.3 (0.8) | 91 |

* Recovery calculated assuming that 100% of the spray is retained at the lower application volume.

TABLE 4—Spray deposition on bracken pinnae in laboratory

| Solution | No. of passes | Application volume (l/ha) | Deposit ± SD (μl/cm²) | Recovery (%) |
|---|---|---|---|---|
| Water + tartrazine | 1 | 16 | 0.16 (0.02) | 100.0 |
| | 2 | 32 | 0.31 (0.04) | 96.9 |
| | 3 | 48 | 0.43 (0.05) | 89.4 |
| | 4 | 64 | 0.57 (0.01) | 89.1 |
| | 8 | 128 | 1.02 (0.02) | 79.7 |
| | 16 | 256 | 2.11 (0.11) | 82.4 |
| Water + tartrazine + 0.05% X90* | 1 | 29 | 0.29 (0.02) | 100.0 |
| | 2 | 58 | 0.56 (0.05) | 96.6 |
| | 3 | 87 | 0.87 (0.03) | 100.0 |
| | 4 | 116 | 0.98 (0.05) | 84.5 |
| | 8 | 232 | 1.76 (0.14) | 75.9 |
| | 16 | 464 | 3.41 (0.07) | 73.4 |
| Water + tartrazine + 0.1% X90* | 1 | 37 | 0.37 (0.03) | 100.0 |
| | 2 | 74 | 0.64 (0.03) | 86.5 |
| | 3 | 111 | 0.83 (0.04) | 74.8 |
| | 4 | 148 | 1.02 (0.04) | 68.9 |
| | 8 | 296 | 1.63 (0.04) | 55.1 |
| | 16 | 592 | 3.08 (0.07) | 52.0 |

* Multifilm X-90 non-ionic spreader sticker ex Ivon Watkins Dow.

TABLE 5—Meteorological measurements averaged over a period of 10 minutes prior to and 10 minutes after each application

| Time (a.m.) | Plot | Mean wind direction (degrees magnetic) | Mean windspeed (m/s) at | | | | Mean temperature (°C) at | | | | Stability ratio | RH (%) at | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10 m | 5 m | 2.5 m | 1.25 m | 10 m | | 2.5 m | | | 10 m | 2.5 m |
| | | | | | | | Wet | Dry | Wet | Dry | | | |
| **1983 trial** | | | | | | | | | | | | | |
| 8.35– 9.10 | A | 85 | 1.85 | 1.74 | 1.49 | 0.79 | 9.7 | 11.3 | 8.7 | 10.4 | +3.0 | 80 | 78 |
| 9.20– 9.50 | C | 99 | 2.28 | 2.08 | 1.95 | 1.79 | 9.6 | 11.8 | 9.0 | 11.5 | +0.7 | 74 | 69 |
| 10.10–10.30 | D | 81 | 3.46 | 3.24 | 2.88 | 2.36 | 11.0 | 12.8 | 10.0 | 13.0 | —0.2 | 79 | 66 |
| 11.00–11.20 | B | 79 | 5.00 | 4.74 | 3.99 | 3.35 | 14.7* | 14.3 | 10.3 | 15.0 | —0.3 | — | 52 |
| **1984 trial** | | | | | | | | | | | | | |
| 6.25– 6.45 | A | 92 | 3.37 | 2.83 | 2.29 | 1.68 | 11.3 | 11.7 | 11.2 | 11.0 | +0.97 | 95 | 100 |
| 6.50– 7.10 | B | 85 | 2.14 | 1.96 | 1.65 | 1.10 | 12.3 | 12.8 | 12.3 | 12.2 | +1.51 | 94 | 100 |
| 8.00– 8.20 | C | 93 | 3.52 | 3.17 | 2.77 | 2.06 | 14.0 | 15.2 | 14.6 | 14.7 | +0.54 | 87 | 99 |
| 8.20– 8.40 | D | 78 | 2.96 | 2.71 | 2.33 | 1.70 | 14.2 | 15.5 | 15.0 | 15.2 | +0.49 | 86 | 98 |
| 9.40–10.00 | E | 85 | 3.75 | 3.16 | 3.38 | 2.56 | 16.7 | 18.2 | 18.0 | 18.1 | +0.10 | 85 | 99 |

* Liquid reservoir probably ran dry at this point.

The retention of droplets on surfaces is governed by many factors. Brunskill (1956) showed that three droplet parameters – size, surface tension, and speed of travel – had a major influence on whether a drop was retained on or bounced from a surface. Small droplets which impacted on a surface were retained whereas large ones bounced off. Addition of surfactants increased the size of droplet which would be retained, as did increased velocity at the time of impact. However, increasing the amount of surfactant would also increase the area of leaf wetted by a single droplet. Spillman (1984) stated that if a surface is wet then all the drops striking it will bounce. Thus the addition of a surfactant will initially increase retention but if large volumes of spray are used there will be a reduction in spray retention as droplets fall on to previously wetted areas and bounce off.

Glyphosate is formulated containing surfactants whereas asulam is not. Droplets of a given size containing glyphosate will wet a larger area than those containing asulam. The recovery of glyphosate was lower than that of asulam at the same rate suggesting that, in a situation where the foliage is sparse, serious losses can occur due to droplet bounce from wetted surfaces. The same argument can be advanced to explain the higher recoveries of asulam compared with oxadiazon which is formulated as an emulsifiable concentrate. With both asulam and glyphosate, increasing the application volume from 55 to 220 *l*/ha also decreased the recovery of the active ingredient on the foliage, owing, it is suggested, to droplet bounce from a previously wet surface.

Miles (1976) has also reported a greater recovery of asulam on bracken sprayed at 44 *l*/ha using a helicopter than when the same rate of active ingredient was applied in 330 *l* water/ha using a tractor. The increase was of the order of 1.8 to 2.8 times more asulam at the lower application volume.

In the laboratory experiments with the bracken pinnae the change in application volume with a single pass occurred because, as more surfactant was added, smaller droplets were produced. The smaller droplets were thrown a shorter distance from the spinning disc and consequently the spray cloud became more concentrated. This resulted in an increase in application rate per pass. As has been pointed out from Brunskill's work (1956) smaller droplets are retained more efficiently than larger ones. Despite this, producing smaller droplets by increasing the surfactant concentration in fact leads to a lower spray recovery with increased application volume, which can only be explained by droplet bounce from a wet surface.

Thus, since lower spray volumes gave increased on-target deposition, it is recommended that application volumes be reduced when bracken foliage is being sprayed. A volume of 50 *l*/ha applied using D5-25 hollow cone nozzles would be more effective than those currently used (viz, 220 *l*/ha using D8-46 or D8-45 nozzles). Although there is evidence to suggest that even lower volumes would be effective, it is not practical with existing spray gear fitted to aircraft to apply lower volumes accurately.

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