

A new pest management research facility: Scion's large-scale precision track sprayer

S.F. Gous¹, T.M. Withers¹ and A.J. Hewitt²

¹Forest Protection, Scion, PB 3020, Rotorua 3046, New Zealand

²Lincoln Agritech Ltd., PO Box 133, Lincoln, Christchurch 7640, New Zealand;

The University of Queensland, Gatton, Queensland 4343, Australia and

The University of Nebraska, North Platte, Nebraska USA

Corresponding author: toni.withers@scionresearch.com

Abstract A new large scale precision track sprayer has been developed and evaluated for spray deposition and pesticide application research under controlled conditions. The spray room is fitted with a 4 m wide electrically driven boom, suspended 4 m above ground, running on a 12 m long I-beam. It is fitted with 9 independently controlled shut off valves and nozzles. Sprays can be applied to live plant canopies up to 3 m tall within a 2 m × 3 m sample area. The number, location and type of nozzle on the boom can be altered, as can spray liquid pressure and boom speed, in order to simulate a wide range of spray application scenarios. Calibration of the large-scale precision track sprayer has been undertaken for a range of droplet spectra, from extremely coarse to very fine. This paper documents the calibration results and discusses the potential use of this facility for pesticide application research.

Keywords pesticide application, spray deposition, calibration, pest management.

INTRODUCTION

Pesticide applications from aerial and ground platforms are important to New Zealand's primary industries (forestry, arable crops, horticulture, viticulture and vegetable farming). Plantation forests cover approximately 1.8 million hectares, comprising an industry valued at 4% of the country's GDP (Forest Owners Association 2011). Annually, approximately 15% of the total plantation area (over 260,000 ha) is aerially sprayed, mostly for weed (150,000 ha) and *Dothistroma* (*Dothistroma pini* Hulbary) control (100,000 ha) (Forest Owners Association 2011). Furthermore, in New Zealand, aerial application of pesticides in urban environments for pest eradication operations is equally, if not more important (Richardson & Thistle 2003;

Brockerhoff et al. 2010). Recent examples of aerial pest eradication operations in and around urban environments in New Zealand include the white spotted tussock moth (*Orgyia thyellina* Butler) and painted apple moth (*Teia anartoides* (Walker)) eradication programmes (Brockerhoff et al. 2010), as well as Southern saltmarsh mosquito (*Aedes camptorhynchus* (Thomson)) (Ryall & Carter 2010) and more recently Eucalyptus leaf beetle (*Paropsisterna beata* Newman) (MPI 2013). From the above it is clear that pesticide application is a very important management tool to grow New Zealand's primary industries and to protect its natural resources.

In weed, pest and disease management operations, an effective spray will accurately

deposit the correct pesticide dose on the target canopy where it will have the maximum biological effect, with minimal off-target deposition (Cross et al. 2001; Richardson & Thistle 2003; Richardson & Thistle 2006). In most cases, application specifications and target characteristics (i.e. droplet size spectra, application volume rate, droplet density and capture efficiency) required to optimise pesticide spray efficacy are highly variable and often unknown without extensive research (Dubs et al. 1985; Kirk et al. 1992; Cross et al. 1997; Barbosa et al. 2009). The ability to define application specifications, such as methods and conditions necessary to maximise plant canopy deposition, is vital for optimum pesticide use, pest control and reduced environmental exposure to pesticides (Kirk et al. 1992; Cross et al. 1997; Ammons et al. 2000; Richardson & Thistle 2006; Fritz & Hoffmann 2008).

One of the most crucial factors to consider is the selection of an appropriate droplet size spectrum to optimise deposition and minimise drift. In New Zealand up until now researchers have relied on either field trials or a small scale track sprayer for spray deposition trials. The problem with field trials is that they are costly, time consuming, and the results highly influenced by ambient weather conditions. This makes the testing of a single parameter, such as droplet size, difficult to conduct and evaluate. The Plant Protection Chemistry NZ track sprayer that has been used for a wide variety of pesticide research projects (Mansfield et al. 2006; Withers et al. 2013) has a number of limitations. The maximum height of the nozzles above the target is approximately 1 m, which can limit spray pattern development and may result in uneven deposition. The boom speed is limited to less than 2 m/s and plant canopies are limited to approximately 50 cm tall.

A new large-scale precision track sprayer was custom built at Scion's Rotorua site in 2013. It consists of a control room, machine room and a fully enclosed spray chamber with dimensions of 12 m (length) \times 6 m (width) \times 6 m (height). The spray boom is fixed 4 m above ground level to ensure full spray pattern development. The boom runs on a 12 m long I-beam track and is fitted

with 9 independently controlled shut-off valves and nozzles, spaced at 50 cm intervals (Figure 1). The boom is electrically driven by a cable and pulley system. There is a dedicated mixing facility located within the machine room where all liquid spray mixes are prepared. The spray liquid is pumped from the agitated spray vessel to the spray boom by compressed air. This air pressure is manually adjustable by the operator in the control room. Both liquid pressure and flow rates are monitored by sensors within the liquid line at the boom and recorded by the control computer. Software was developed to run on an android operating system to control the facility and to provide automated data capture. All input (boom speed, liquid flow rate and liquid pressure) and output (application rate) data from each spray run are recorded. An additional output of litres/ha delivered is calculated by the control computer based on the actual output parameters and measured effective swath width.

The entire spray system including the chamber, tank and lines are flushed with tap water or appropriate liquid cleansing agents to decontaminate. All liquid produced by the facility is collected via concrete bunds and drains into a waste water storage tank. Periodically the waste water is removed for disposal by a certified chemical waste company. The spray chamber is fitted with a large extractor fan system that vents the entire volume of the chamber air to the outside prior to human entry.

Maximum boom speed is currently limited to 5 m/s (18 km/h). The scale of the facility allows testing of plant canopies up to a maximum of 3 m tall sitting within a 2 m \times 3 m sample area. To ensure accurate deposition measurements and minimise human exposure to spray, adequate time is allowed after each spray run for droplets to settle and dry.

This paper reports on the calibration and setup tests for the large-scale precision track sprayer. The main objective was to characterise the spray deposition pattern for different droplet size spectra and to assess to what extent deposition is independent of location within the sampling volume.

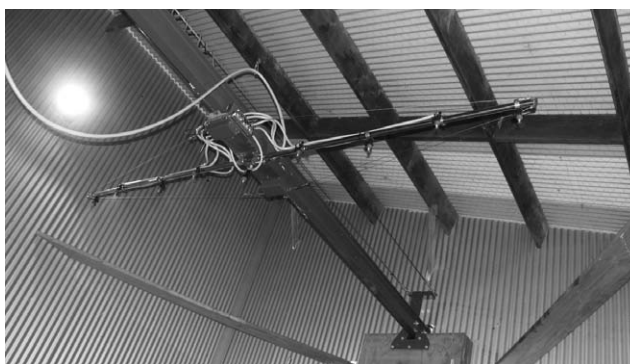


Figure 1 Running gear and boom of the large-scale precision track sprayer.

MATERIALS AND METHODS

The characterising of variability in spray deposition onto collectors positioned within the 2 m wide \times 3 m long sample area was undertaken by the following series of experiments. Deposition from different treatments was measured by spraying tartrazine dye at a rate of 10 g/litre onto stainless steel plates with dimensions of 76 mm wide \times 152 mm long. The plates were placed at three different heights, 0 m (ground level), 1 m (middle) and 2 m (upper) above the ground, on an array of custom-built collector stands designed to have minimum impact on droplet trajectory. On any one stand, the three collectors were positioned at angles around the axis to avoid shadowing. Plates were spaced in a row at 0.5 m intervals outwards 1 m either side from the centre perpendicular to the boom direction. A minimum of three replicate measurements of spray deposition profiles was undertaken for all nozzles tested. Deposition was assessed by standard colorimetric methods (Richardson et al. 1989). A general linear model (SAS/STAT, version 9.1. SAS Institute Inc., Cary, North Carolina, USA) was used to test the main and interactive effects of collector height and collector position on dye deposition. When main effects were significant, means were separated with a Tukey comparison at $P=0.05$.

Droplet size spectra tests

All nozzles were acquired from Spraying Systems Co. (Wheaton, Illinois, USA; Teejet Catalog 51-M), and spray nozzle classification follows

that used by the American Society of Agricultural and Biological Engineers (ASABE 2009). Three droplet size spectra were tested: (1) A very fine spray (volume median diameter or $D_{v0.5}$ of $<136 \mu\text{m}$) was produced by using nine flat fan tip TJ60 11002 nozzles spaced 0.5 m apart, operated at 401 kPa at an average boom speed of 3.0 m/s; (2) A fine spray (with $D_{v0.5}$ of 136–177 μm) was produced by using nine even spray flat fan tip TP80015EVS nozzles spaced 0.5 m apart, operated at 335 kPa and average boom speed of 1.75 m/s; and (3) After first undertaking preliminary trials with a range of nozzles, an extremely coarse spray with an even spread pattern was produced by a range of Turbo Teejet air induction or TTI nozzles. According to the manufacturer, all TTI nozzles produce an extremely coarse droplet spectrum through their full range of recommended operating pressures. Therefore nozzles with different orifice sizes can be used together without compromising the droplet size spectra. The nozzle arrangement used for this calibration trial was: 3 \times TTI 110015 nozzles in the centre 3 positions, either side of these were 2 \times TTI 110 02 nozzles, outside of these were 2 \times TTI 110 025 nozzles and at the extreme outside 2 \times TTI 110 03 nozzles, all spaced 0.5 m apart. The spray boom was operated at 260 kPa and an average boom speed of 3.0 m/s.

RESULTS

Very fine droplet spectrum

The average output was 99.8 litres/ha with a coefficient of variance of 4.6% for all collection

plates. The analysis of variance of the main and interactive effects revealed a significant effect of collector height on dye deposition, but no significant effect of collector position, interaction or replicate effects (Table 1). There was a significant difference ($P<0.05$) in deposition measured at the three heights above ground, with the ground level receiving significantly more spray (111.1 litres/ha) than the middle (94.6 litres/ha) and upper levels (93.9 litres/ha), which were not different from each other) (Figure 2).

Fine droplet spectrum

The average output was 121.1 litres/ha with a coefficient of variance of 1.61% for all plates. There were no significant main or interaction effects for differences of collector height above ground or collector position placed perpendicular

to the spray path on dye deposition or replicate effects (Table 2, Figure 3).

Extremely coarse droplet spectrum

The average output was 92.4 litres/ha with a coefficient of variance of 1.88 % for all plates. There were no significant main or interaction effects for differences of collector height above ground or collector position placed perpendicular to the spray path on dye deposition, or replicate effects (Table 3, Figure 4).

DISCUSSION

Optimisation of spray applications is the method of choosing the correct pesticide, adjuvant and application technique to ensure efficacy. One of the most crucial factors in pesticide application research is to select the most appropriate droplet

Table 1 ANOVA table summarising significance of results of very fine spray volume collected by height, collector position, their interaction, and replicate at $P=0.05$. Also shown are the numerator (Num df) and denominator (Den df) degrees of freedom.

Source	Num df	Den df	F-value	P-value
Height	2	102	18.69	< 0.001
Collector	4	102	2.52	0.06
Height \times collector	8	102	1.18	0.32
Rep	3	102	2.36	0.08

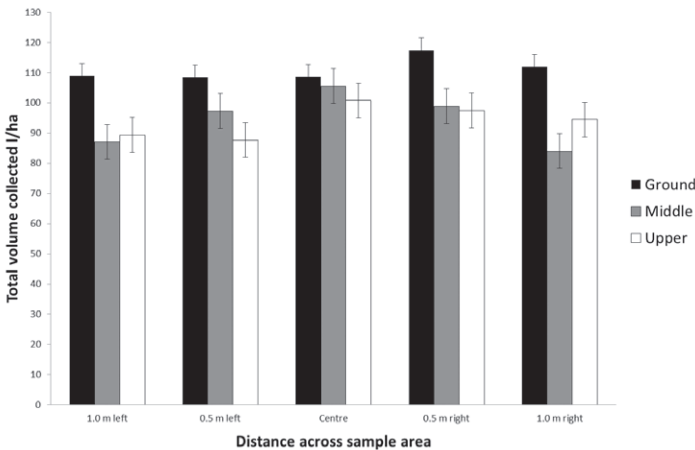


Figure 2 Mean (\pm SE) deposition volume onto collector plates using the TJ60 11002 nozzles, which produced a very fine droplet spectrum. Values are presented for collectors placed at ground level, 1 m and 2 m above ground level, and at the centre of the spray path and distances of 0.5 or 1.0 m on either side of the centre.

Table 2 ANOVA table summarising significance of results of fine spray volume collected by height, collector position, their interaction, and replicate at $P=0.05$. Also shown are the numerator (Num df) and denominator (Den df) degrees of freedom.

Source	Num df	Den df	F-value	P-value
Height	2	73	0.21	0.81
Collector	4	73	0.39	0.81
Height \times collector	8	73	0.45	0.89
Rep	2	73	2.53	0.09

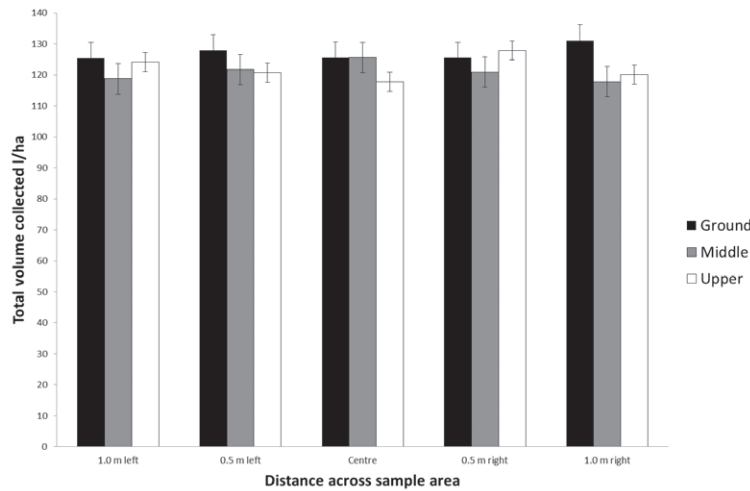


Figure 3 Mean (\pm SE) deposition volume onto collector plates using the TP80015EVS nozzles, which produced a fine droplet spectrum. Values are presented for collectors placed at ground level, 1 m and 2 m above ground level, and at the centre of the spray path and distances of 0.5 or 1.0 m on either side of the centre.

spectrum to optimise deposition and minimise drift according to the environment and target (Hewitt 1997; Cross et al. 2001; Richardson & Thistle 2003; Richardson & Thistle 2006). To the best of our knowledge there are no similar facilities in the world where spray deposition research can be conducted to this scale under controlled conditions. In order to use this facility for deposition research it was first essential to characterise spray deposition patterns throughout the sample area for a range of droplet size spectra. Thus allowing for an understanding of droplet pattern and expected results in a controlled environment.

The track sprayer was accurate, reliable and produced consistent results with deposition coefficients of variance for the three reported

droplet spectra of less than 5%. In the fine through to extremely coarse droplet spectra there was a pleasing consistency of volume throughout the spray chamber. There was a slight tendency that the two outer collectors received less deposition than the three inner collectors, but these differences were very small and in all tests non-significant. Unfortunately at the very fine droplet spectra tested (Figure 2) the collectors placed at ground level received significantly more spray volume than those above. This is probably due to minor air disturbance caused by the boom movement that has since been detected using smoke. Air movement will have a much greater influence on very fine droplets than the other droplet sizes tested. The results of this work will enable characterisation of spray deposition and

Table 3 ANOVA table summarising significance of results of extremely coarse spray volume collected by height, collector position, their interaction, and replicate. Also shown are the numerator (Num df) and denominator (Den df) degrees of freedom.

Source	Num df	Den df	F-value	P-value
Height	2	73	1.41	0.25
Collector	4	73	0.66	0.62
Height × collector	8	73	1.03	0.42
Rep	2	73	0.69	0.51

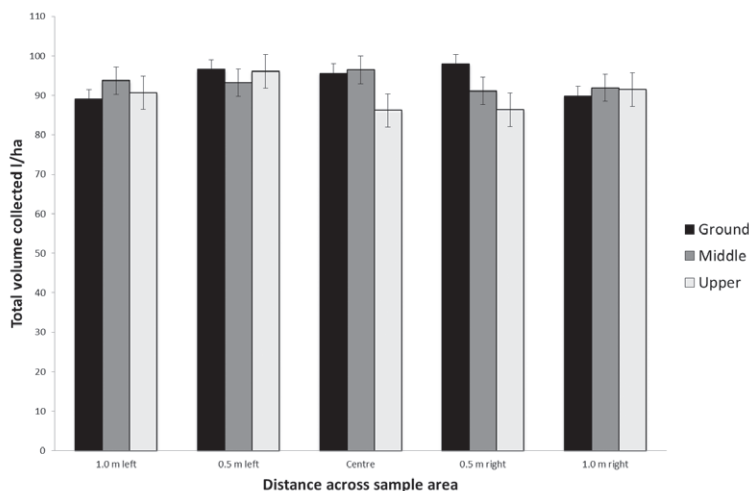


Figure 4 Mean (\pm SE) deposition volume onto collector plates using a range of Turbo Teejet air induction nozzles, which produced an extremely coarse droplet spectrum. Values are presented for collectors placed at ground level, 1 m and 2 m above ground level, and at the centre of the spray path and distances of 0.5 or 1.0 m on either side of the centre.

subsequent compensation for inconsistencies prior to the introduction of plant canopies.

Over time it is intended to increase the database of calibration setups by adding additional nozzle and droplet spectra tests (especially in the medium to coarse droplet size ranges).

Results from these calibration tests suggest that the new large-scale precision track sprayer can be used with confidence within the sample area for which it was designed and built (2 m wide \times 3 m long \times 3 m high). Because the area is entirely enclosed it eliminates air movement and allows for single spray parameters to be evaluated and tested for their influence on deposition on live plant canopies up to 3 m tall. Research is currently being initiated to validate spray deposition models, in particular to compare actual spray

deposition to current canopy description models within AGDISP (Agricultural Dispersion Model) (Richardson & Thistle 2006). AGDISP is a computer model that is used by regulators, aerial applicators and researchers to understand and predict the impacts of weather, application equipment and other factors on the deposition and movement of applied crop protection materials within and around the intended target site. For this and other uses, the precision track sprayer is going to be an invaluable research tool.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Tara Strand, Brian Richardson and Carol Rolando for their continued constructive inputs and contributions to the development and calibration of the facility.

To Caro Gous and Sara Carey a special thanks for developing a precise protocol for collector handling and data collection. The facility was a joint design by Allister Keast (ADM engineers) and Scion.

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