Use of an organosilicone surfactant to minimise spray application volumes for forestry scrubweed herbicides in New Zealand

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Summary Weed control at forest establishment is undertaken predominantly by aerial application of herbicide sprays at 100 L ha^{-1} or higher and organosilicone surfactant addition is essential for achieving evenness and consistency of kill. Bioassays were used to compare the performance of sub-lethal doses of glyphosate and metsulfuron herbicides, applied separately in sprays of varying volume, on potted gorse and broom. A gantry tracksprayer was used to simulate aerial application. An organosilicone superspreader adjuvant improved the cost-effectiveness of scrub weed control by lowering spray application volumes by up to 75%. Maintaining a constant rate of adjuvant per ha in concentrated sprays (i.e. increasing the adjuvant concentration as spray volume decreased) provided control of gorse and broom better than, or equal to, typical high volume sprays. There are potential cost savings and efficacy benefits to be realised by use of low-volume, concentrated aerial herbicide sprays.

Keywords Herbicides, organosilicone adjuvant, aerial application, gorse, broom.

INTRODUCTION

Pre-plant herbicide sprays, containing an organosilicone adjuvant to ensure evenness and consistency of weed control, are essential to guarantee survival and growth of tree crops on forest sites. In New Zealand, site preparation is undertaken predominantly by aerial application of herbicide sprays at 100–150 L ha^{-1} and there is pressure on forest managers to lower aerial spray application volumes to reduce operational costs. The work efficiency and cost of weed control operations would be improved if sprays could be concentrated and applied in lower spray volumes without compromising herbicide efficacy. The relatively low volumes now used for pre-plant sprays appear to have led to increased herbicide loadings to achieve acceptable weed control, compared to the higher volume sprays applied in earlier years. In 1993, glyphosate sprays were typically applied at 3.6 kg in 200–300 L ha^{-1} with addition of 0.25% v/v (550–750 mL ha^{-1}) organosilicone adjuvant, or metsulfuron sprays were applied at 170 g in 200–400 L ha^{-1} plus 0.1% v/v (200–400 mL ha^{-1}) organosilicone, to control scrubweeds on forest cutovers before planting (Anon. 1993, Davenhill *et al.* 1994). Typical site preparation use rates in 2008 were up to 4.5 kg and 200 g glyphosate plus metsulfuron, respectively, plus 500–750 mL organosilicone in 100–150 L ha^{-1} water, (M. Watt pers. comm.). These increases in herbicide use rate are contrary to the ‘environmental’ certification schemes and international market requirements that require the New Zealand forest industry to reduce its herbicide inputs. They have probably been driven by the large decrease in cost of these herbicides since they came off-patent and the increased consistency of scrubweed control that the higher rates ensure.

Superspreader adjuvants have been employed successfully in horticulture in recent years to reduce pesticide spray application volumes up to 8-fold with equivalent or increased efficacy against target pests and diseases (Gaskin *et al.* 2004). Their potential to reduce herbicide application costs and improve herbicide efficacy has not been exploited in forestry. This study was undertaken to investigate (1) whether spray application volumes of commonly used forestry herbicides, glyphosate and metsulfuron, could be reduced below 100 L ha^{-1}, and (2) if optimising such sprays with an organosilicone adjuvant could improve scrubweed control and ultimately lead to reduced herbicide inputs.

MATERIALS AND METHODS

Plants Gorse (*Ulex europaeus*) and scotch broom (*Cytisus scoparius*) plants were raised outdoors from cuttings or seedlings, in 4 L pots. Plants were at least 2 years old, carrying mature summer-hardened foliage and >50 cm tall at the time of treatment in early autumn (March 2009).

Chemicals Metsulfuron-methyl (Escort; 60% a.i., DuPont) and glyphosate IPA salt (Agpro Green 510, 51% a.i., Agpro) were prepared at the sub-lethal rates of 102 g a.i. ha^{-1} and 3.2 kg a.i. ha^{-1}, respectively, to identify and enhance any differences between the treatments. Current practice is to combine both glyphosate and metsulfuron together in pre-plant sprays, but in this study the herbicides were applied as individual sprays and not mixed together, to better understand the effects of volume and adjuvant addition on their ability to control the target weeds. The organosilicone superspreader adjuvant used was Break-Thru S240 (Evonik). The treatments are shown in Table 1.

Spray application Individual potted plants were randomly allocated to treatments (15 replicates of each species) and all plant heights were measured. Spray applications were made through hydraulic nozzles (Billericay Air Induction 01 fan; 150 kPa, ASAE S-572 classification coarse, VMD 350 µm) that are suitable for aerial herbicide sprays. Spray was delivered via a calibrated gantry tracksprayer with nozzles mounted *c.* 2 m above the pot surface. The droplets generated were at terminal velocity on impact, approximating aerial application. Plants were maintained under cover for 48 h after treatment, and then placed outdoors. Replicates were arranged in a completely randomised block design, which was re-randomised every 4 weeks.

Assessment Plants were assessed by two assessors at regular intervals for up to 21 weeks after treatment, by which time the effects of herbicide treatment had developed fully. Individual plant health status was assessed and a damage rating assigned, where:

1 = completely dead (no live tissue);
2 = severely damaged by herbicide, with no regrowth but some green stem;
3 = severely damaged by herbicide, regrowth may be normal or herbicide affected;
4 = damaged by herbicide, but normal regrowth exhibiting no herbicidal effects;
5 = healthy, no herbicidal effects.

The mean damage score was determined as the average of all replicates in a treatment. At harvest, above-ground plant material was destructively sampled to accurately determine live stem height. Post-spray plant height was calculated as a percentage of the original pre-spray height and used as the primary indicator of treatment efficacy. Weight assessments of gorse and broom at harvest provide no useful information due to the inability to account for pre-spray plant variation. Plants exhibiting normal (as opposed to herbicide-affected) regrowth at harvest were recorded.

Statistics Analysis of variance, for a completely randomised design, was performed on the mean vigour score and the mean live stem height at harvest as a proportion of the original plant height prior to treatment. Treatments were compared using the LSD test.

RESULTS

Broom Control of broom with glyphosate was similar for all treatments, except that the standard treatment applied in 150 L ha^{-1} was less effective than all others (Table 2). While all treatments were visually scored as completely dead and had no live regrowth at harvest (Table 2), destructive sampling revealed all had some live stem remaining which would potentially allow the plants to regrow in spring. Glyphosate spray volumes of 50 and 100 L ha^{-1} were similarly effective when optimised with the organosilicone adjuvant and controlled broom better than 150 L ha^{-1} sprays.

All low volume metsulfuron treatments, from 25–100 L ha^{-1}, controlled broom similarly to the high volume (400 L ha^{-1}) that is recommended for aerial application. The trend was for lower volume to induce more mortality and the 50 L ha^{-1} treatment containing 1 L ha^{-1} adjuvant recorded the lowest live stem and most visible damage at harvest (Table 2). With lower spray volumes, there was an indication that higher adjuvant addition increased efficacy of both herbicides on broom.

Gorse The herbicides had different relative effects on gorse and broom. While the efficacy of the two herbicides cannot be directly compared due to their sub-lethal use rate, glyphosate was more damaging than metsulfuron on broom (Table 2) and vice-versa on gorse (Table 3). This illustrates the difficulty in selecting a single sub-lethal rate for each herbicide to evaluate on both species and may indicate their different susceptibilities to the herbicides.

The most effective glyphosate treatment on gorse was the high volume standard (150 L ha^{-1}) (Table 3). Spray volumes of 50–100 L ha^{-1} could provide similar efficacy, but green stem was increased (i.e. efficacy reduced) with sprays containing lower adjuvant

Table 1. Summary of glyphosate (3.2 kg ha^{-1}) and metsulfuron (102 g ha^{-1}) treatments applied to gorse and broom potted plants.

		S240 adjuvant		Spray volume
Tmt#	A.I.	% v/v	L ha^{-1}	L ha^{-1}
1	glyphosate	1.0	1.0	100
2		1.3	1.3	100
3		1.3	1.0	75
4		1.3	0.65	50
5		2.0	1.0	50
6		0.5	0.75	150
7	metsulfuron	1.0	1.0	100
8		1.3	1.0	75
9		2.0	1.5	75
10		2.0	1.0	50
11		4.0	1.0	25
12		0.4	1.6	400
13	nil, untreated	–	–	–

volumes. The trends suggest that higher volume sprays are more beneficial for gorse control with glyphosate, but that more adjuvant may improve control with low volume sprays. Metsulfuron treatments all controlled gorse similarly (Table 3), although higher spray volumes tended to reduce live stem more. Higher adjuvant addition appeared not to benefit metsulfuron efficacy on gorse.

Table 2. Effect of glyphosate (3.2 kg ha^{-1}) and metsulfuron (102 g ha^{-1}) treatments on broom at 21 weeks after treatment.

A.I.	S240 volume L ha^{-1}	Spray volume L ha^{-1}	Live stem height %[A]	Normal regrowth %	Mean vigour score
Glyphosate	1.0	100	1.3 c	0	1.0 b
	1.3	100	1.5 c	0	1.0 b
	1.0	75	2.4 c	0	1.0 b
	0.65	50	1.9 c	0	1.0 b
	1.0	50	1.5 c	0	1.0 b
	0.75	150	6.4 b	0	1.0 b
Nil	–	–	103 a	93	5.0 a
Metsulfuron	1.0	100	21.5 b	17	1.7 b
	1.0	75	32.3 b	17	1.8 b
	1.5	75	23.2 b	17	1.8 b
	1.0	50	18.0 b	10	1.6 b
	1.0	25	18.6 b	20	1.9 b
	1.6	400	32.4 b	30	2.2 b
Nil	–	–	103 a	93	5.0 a

[A] as a % of pre-spray mean height.
Means, within each a.i. and column, sharing common postscripts are not significantly different (LSD, P = 0.05).

Table 3. Effect of glyphosate (3.2 kg ha^{-1}) and metsulfuron (102 g ha^{-1}) treatments on gorse at 21 weeks after treatment.

A.I.	S240 volume L ha^{-1}	Spray volume L ha^{-1}	Live stem height %[A]	Normal regrowth %	Mean vigour score
Glyphosate	1.0	100	27.0 b	23	1.8 b
	1.3	100	12.8 bc	13	1.5 b
	1.0	75	13.9 bc	10	1.4 b
	0.65	50	29.4 b	20	1.8 b
	1.0	50	20.9 bc	20	1.8 b
	0.75	150	8.6 c	10	1.4 b
Nil	–	–	100 a	97	5.0 a
Metsulfuron	1.0	100	1.4 b	0	1.0 b
	1.0	75	2.0 b	0	1.0 b
	1.5	75	5.6 b	0	1.0 b
	1.0	50	7.0 b	0	1.1 b
	1.0	25	7.3 b	0	1.0 b
	1.6	400	4.0 b	0	1.1 b
Nil	–	–	100 a	97	5.0 a

[A] as a % of pre-spray mean height.
Means, within each a.i. and column, sharing common postscripts are not significantly different (LSD, P = 0.05).

DISCUSSION

The potential for lowering spray volumes for scrubweed herbicides using organosilicone adjuvants was reported over 20 years ago (Ray *et al*. 1986), and the reasons for this are well documented (Balneaves *et al.* 1993). The study reported here confirms this potential. On broom, spray volume was not critical to herbicide efficacy and control of this weed could be accomplished with application volumes as low as 25 L ha^{-1} if organosilicone adjuvant rate of addition was optimised. At ≥1 L ha^{-1}, this will be higher than the adjuvant rate currently used in pre-plant sprays. On gorse, higher spray volume appeared to be more critical to herbicide efficacy and spray volumes may need to be higher than for broom control, reflecting the more difficult-to-wet surface of the former at the time of spraying (Forster and van Leeuwen 2010). However, it may be that glyphosate could be applied in low volume sprays with no loss of efficacy on gorse if the organosilicone adjuvant rate is correctly prescribed at a sufficiently high rate. The herbicidal effect of glyphosate on gorse was reported to be improved by increasing amounts of organosilicone adjuvant, up to 3 L ha^{-1}, in high volume (300 L ha^{-1}) sprays as long ago as 1993 (Balneaves *et al*. 1993). This knowledge was not exploited at the time due to the very high cost of the adjuvant. Retail competition has resulted in a large reduction in price of organosilicone adjuvants in recent times and removed that constraint. While off-patent herbicides cost significantly less now than a decade ago, environmental concerns dictate that it is better to improve weed control by using more adjuvant than by increasing herbicide use.

Higher organosilicone adjuvant rates will improve spray retention and coverage on scrubweed species (Forster and van Leeuwen 2010) and provide increased uptake of herbicides (Gaskin *et al.* 1996). The cost of additional adjuvant may be offset by increased productivity achieved in applying lower aerial spray volumes. Further work is currently under way to optimise application volumes and organosilicone rates for glyphosate plus metsulfuron spray mixes on these scrubweeds.

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REFERENCES

Anon. (1993). ‘NZ Agrichemical Manual, 4th edition’. (WHAM Chemsafe, Wellington, New Zealand).

Balneaves, J.M., Gaskin, R.E. and Zabkiewicz, J.A. (1993). The effect of varying rates of glyphosate and an organosilicone surfactant on the control of gorse. *Annals Applied Biology* 122, 531-6.

Davenhill, N.A., Ray, J.W. and Vanner, A.L. (1994). Forest weed control manual, FRI Bulletin No. 180. NZ Forest Research Institute, Rotorua, New Zealand.

Forster, W.A. and van Leeuwen, R.M. (2010). Characterisation of forest weed species and herbicide formulations to predict droplet adhesion and optimise spray retention. Proceedings of the 17th Australian Weeds Conference, ed. S.M. Zydenbos, pp. 348-51. (New Zealand Plant Protection Society, Christchurch, New Zealand).

Gaskin, R.E., Manktelow, D.W. and Elliott, G.S. (2004). Adjuvant prescriptions to lower water volumes and improve pest control in vineyards. Proceedings of the 7th International Symposium on Adjuvants for Agrochemicals, ISAA2004, published by the ISAA Society on CD-ROM, ISBN 1-920-01716-X.

Gaskin, R.E., Murray, R.J. and Ray, J.W. (1996). Interaction of organosilicone surfactant concentration and spray application factors in glyphosate efficacy. Proceedings of the 49th New Zealand Plant Protection Conference, pp. 183-7.

Ray, J.W., Vanner, A.L. and Richardson, B. (1986). Effect of application volume and spray additive concentration on the control of bracken. Proceedings of the 39th Weed and Pest Control Conference, pp. 89-91.