SILWET L-77: A NEW DEVELOPMENT IN SPRAY ADJUVANTS**P.J.G. STEVENS, R.E. GASKIN and J.A. ZABKIEWICZ***Forest Research Institute, Private Bag, Rotorua***SUMMARY**

The literature is reviewed and previously unpublished data presented to demonstrate that Silwet L-77 surfactant often outperforms other spray adjuvants. Silwet L-77 was more effective than the commonly used adjuvants Agral 90 and Triton X-45 at enhancing the uptake and translocation of glyphosate in bracken. Foliar applications of Silwet L-77 solutions were less phytotoxic, resulting in less evolution of ethylene by bean leaf, than those of Agral 90 and Triton X-45. Silwet L-77 increased the uptake of clopyralid into young and old gorse foliage to a greater extent than did an emulsified diesel oil formulation.

INTRODUCTION

Surfactants are almost universal in pesticide formulations and, increasingly, are also being used as spray adjuvants. The New Zealand climate promotes prolific growth of large, tenacious weeds such as gorse (*Ulex europaeus*), bracken (*Pteridium esculentum*) and pampas grass (*Cortaderia* spp.). These weeds are often not controlled adequately by the herbicide formulations which are available commercially and which, generally, have been developed for the agricultural and horticultural markets. Forestry cannot afford the weed control regimes which are cost-effective in agriculture and horticulture. Large areas of rugged terrain are utilised for forestry necessitating aerial spray applications, which are less precise and more costly than ground-based applications. These factors have made the use of adjuvants almost obligatory to maximise herbicide effectiveness.

An extensive research programme, investigating surfactants as spray adjuvants, was instigated at the Forest Research Institute initially to provide improved control of gorse with 2,4,5-T and latterly to enable effective use of other chemicals. The results of this programme (Zabkiewicz *et al* 1985) have contributed to the introduction of Silwet L-77 as a recommended adjuvant for use with glyphosate on gorse. Because Silwet organosilicone surfactants are a new class of spray adjuvants, research is continuing with additional species and chemicals.

Literature arising from the widespread use of Silwet L-77 as a spray adjuvant has appeared only over the last few years. This literature, which is largely fractional and dispersed, is reviewed here. However, because the literature is incomplete, certain new data has been generated and also included. The purpose of this paper is thus to provide a coherent overview of the potential value of Silwet L-77, in comparison with other adjuvants, at all stages of the spray process; viz. spray atomisation, retention on and wetting of foliage, uptake and translocation of ai, formulation phytotoxicity, biological activity.

METHOD**1. Effect of surfactants on foliar uptake and translocation of glyphosate in bracken**

The uptake of glyphosate (Roundup) into, and translocation within, bracken (*Pteridium aquilinum*) was determined using the methods of Gaskin and Kirkwood (1987).

2. Phytotoxicity of aqueous surfactant solutions applied to bean foliage

Beans (*Vicia faba*) were grown as described by Zabkiewicz *et al* (1987). Water, aqueous Agral 90, Silwet L-77 (Pulse) or Triton X-45 (1%v/v) was applied (15x5µl) to the adaxial surface of a single leaflet of the youngest, fully expanded leaf (6 replicates) 1 ± 0.25 h after the start of the light period. The surface of the treated leaflet was

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washed with 50% aqueous ethanol (2 x 3ml) 6 h post-application to remove residual surfactant, allowed to dry, excised and carefully curled into a boiling tube (1200 x 200 mm) abaxial surface outwards. The tubes, containing water (1 ml) to maintain humidity, were sealed and incubated at 30°C. After 19 ± 1 h a headspace sample (2ml) was removed and the ethylene content determined by gas chromatography on a 1.5m x 0.46mm i.d. alumina column, 120°C, 40ml/min He.

3. Foliar uptake into gorse at two growth stages from emulsified oil and surfactant based formulations.

Gorse plants were grown as described by Zabkiewicz and Gaskin (1982). 30µl of [¹⁴C]clopyralid-butoxyethanol ester (1 kg/300 litres, Ivon Watkins-Dow) formulated with either Silwet L-77 (0.5% v/v) or with diesel oil (16% v/v) emulsified with Triton X-45 (2% v/v) was painted onto 10 spines on each of three plants. Both "young" (< 3 months old) and "current" (> 3 months old) foliage was treated and harvested as described previously (Zabkiewicz and Gaskin 1982). Foliar uptake was defined as that [¹⁴C] recovered from within the foliage and expressed as a proportion of total [¹⁴C] recovered.

RESULTS AND DISCUSSION

Surfactants are used as spray adjuvants for a variety of purposes (Seaman 1982). One of these is their ability to increase the retention of spray on foliage. Both Silwet L-77 and Triton X-45 have been shown to increase the proportion of a spray retained (SRI) on bracken foliage (Table 1.A). This was achieved by Silwet L-77 at a concentration (0.25%) only half that of Triton X-45 (0.5%). Silwet L-77 did not reduce the droplet size to such a great extent as Triton X-45. Because the effect of air currents on flight path is inversely related to droplet size, spray drift may be less likely to occur with Silwet L-77. Although there was no significant difference in SRI between the two sprays the effectiveness of the herbicide spray with Silwet L-77 was significantly better than with Triton X-45, as measured by frond emergence 5 months after spraying. The implication is that Silwet L-77 was more effective at increasing the uptake into the bracken foliage of the applied glyphosate. This was demonstrated in our experiments for *P. aquilinum*, the species of bracken predominant in Britain (Table 1.B). Silwet L-77 increased the foliar uptake of glyphosate relative to both Triton X-45 and Agral 90.

Increased foliar uptake of chemicals has been correlated with increased wetting of leaf surfaces provided by surfactants (Sands and Bachelard 1973; Stevens and Baker 1987). The wetting ability of Silwet L-77 is greater than that of other adjuvants (Vitelli 1987). In work by Zabkiewicz *et al* (1987), the surface area of bean, eucalypt and citrus leaf surfaces wetted by Silwet L-77 (0.5%) exceeded that wetted by solutions of Agral 90 and Triton X-45 by 12-to 40-fold (Table 1.C). This was attributable to the very low aqueous surface tension of Silwet L-77 (20mN m⁻¹) at >0.1%: Neumann and Prinz 1974), lower than that of Agral 90 and Triton X-45 (>30mN m⁻¹) and calculated to be sufficiently low to enable spray solutions to infiltrate stomata (Schonherr and Bukovac 1972). Infiltration of stomata by Silwet solutions has been observed with perennial ryegrass (*Lolium perenne*; Field and Bishop 1987) and bean (N.Z. Ministry of Forestry videofilm "Spray Application with Silwets"). The ai rapidly taken up in this manner is rainfast. The addition of Silwet L-77 reduces the period during which rain must not fall after spraying ryegrass with glyphosate to ensure adequate performance (Blowes *et al* 1987). Stem dessication and apical death of gorse has resulted from sprays of glyphosate with Silwet L-77 when heavy rain fell within 30 minutes of spraying (Balneaves 1986).

The translocation of absorbed herbicide is particularly important for control of rhizomatous species such as bracken. In our experiment the largest proportion of applied glyphosate was translocated in bracken in the presence of Silwet L-77 (Table 1.B). This was attributable to both enhanced uptake and increased translocation of the glyphosate absorbed in the presence of Silwet L-77. Translocation may be impaired by the phytotoxicity of adjuvants (Bland and Brian 1972). Silwet L-77 has been shown to be less damaging to cell membranes, as measured by leakage of anthocyanins from beetroot tissue, than several other surfactants (Neumann and Prinz 1974). This method provides an indication of innate phytotoxicity but is of limited relevance to sprays

TABLE 1: Effects of Silwet L-77, in comparison with other adjuvants, on factors affecting the efficacy of foliar applied sprays.

Details	Adjuvant	%v/v	Factor 1	Factor 2	Factor 3
A.					
glyphosate (3.6kg ai/ 20 litres/ha) applied to bracken			spray recovery index ($\mu\text{l}/\text{cm}^2 \div$ litres/ha)	droplet size vmd (μm)	frond emergence (No./ 0.79m ²)
abstracted from Ray <i>et al</i> (1986)	none	—	0.36a	336	13.0a
	TritonX-45	0.5	0.45b	233	9.8a
	SilwetL-77	0.25	0.42ab	258	6.1b
B.					
Method 1	% of [¹⁴ C] glyphosate:	uptake	applied	translocation applied	absorbed
	none	—	9a	1a	9a
	Agral 90	0.1	45b	3b	7a
	Silwet L-77	0.1	60c	7d	12a
	Triton X-45	0.2	57c	5c	9a
	Silwet L-77	0.2	67d	14e	22b
C.					
0.5 μl droplets applied to adaxial surface			spread area (mm ²) on:		
			bean	eucalyptus	citrus
	none	—	2.8a	1.6a	1.8a
abstracted	Agral 90	0.5	3.1a	2.7b	3.3b
from	Triton X-45	0.5	4.3b	3.7c	3.1c
Zabkiewicz <i>et al</i> 1987	Silwet L-77	0.5	79.6c	146.9d	50.8d
D.					
Method 2			ethylene (ppm)		
	none	—	0.51a		
	Agral 90	1.0	1.2 bc		
	Triton X-45	1.0	1.5 c		
	Silwet L-77	1.0	0.86ab		
E.					
Method 3			uptake over 48h into (% of [¹⁴ C]clopyralid recovered)		
	none	young	current		
	diesel	—	82a	43a	
	+	16			
	Triton X-45	+	89a	82b	
	Silwet L-77	2.0			
		0.5	78a	90c	

treatments with no letters in common are significantly different at $p = 0.05$

because the process of foliar absorption is not included. Plant foliage produces ethylene in response to a range of factors which cause stress (Yang and Hoffman 1984) and this has been employed as a measure of phytotoxicity of surfactants (Stevens and Bukovac 1987; Lownds and Bukovac 1988). Our experiments showed that bean produced less ethylene in response to foliar applications of Silwet L-77 solution than was produced by applications of Agral 90 and Triton X-45 solutions (Table 1.D).

The advantages of Silwet L-77 have been reported for a range of chemicals and species. Silwet L-77 has significantly enhanced foliar uptake of haloxyfop into pampas grass relative to a 5-fold higher concentration of Triton X-45 (Gaskin and Murray 1988). Silwet L-77 also enhanced herbicidal effectiveness of metsulfuron on gorse over that obtained with Triton X-45 at 2-fold higher concentration (Davenhill and Preest 1986). The use of Silwet L-77 has not been restricted to sprays of herbicides and this surfactant has been shown to be of value when incorporated in sprays to treat iron chlorosis in citrus (Neumann and Prinz 1974).

An important effect of surfactants is that of overcoming seasonal variations in susceptibility to herbicide sprays exhibited by many weeds. Gaskin and Kirkwood (1986) demonstrated that Silwet L-77 was generally better than Agral 90 and Triton X-45 at enhancing the uptake and translocation of glyphosate and asulam in bracken at all stages of seasonal development. Silwet L-77 (0.25%) and Triton X-45 (0.5%) have both increased the control of gorse by glyphosate applied in autumn to a level equivalent to that achieved by spring applications (Lane and Park 1984). A similar effect was demonstrated here for uptake of clopyralid into young and current gorse foliage (Table 1.E). This example illustrated that while adjuvants may be of little value for sprays applied to young foliage, they can be of great advantage on older, hardened foliage and that Silwet L-77 can surpass the results achieved with an emulsified diesel oil formulation.

CONCLUSION

It is apparent that the properties of Silwet L-77 are markedly different from those of "conventional" (non-organosilicone) surfactants. Silwet L-77 often outperforms other spray adjuvants in many aspects of behaviour when utilised with a wide range of herbicides on a diversity of plants. Silwet L-77 is non-ionic and therefore it also has enormous potential as an adjuvant for sprays of fungicides, insecticides, growth regulators and foliar nutrients.

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