SURFACTANT EFFECTS ON THE UPTAKE OF DIFFERENT HERBICIDES BY GORSE

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SUMMARY

The effect of surfactants with different chemistry on the uptake of six herbicides by gorse (*Ulex europaeus* L.) was tested. Radioisotope studies showed that the organosilicone surfactant, Silwet L77, and one of the pyrrolidone-based compositions, Agrisolve 3, enhanced the uptake of dicamba, glyphosate, metsulfuron, picloram and triclopyr amine measured 24 h after application. The effect of the surfactants were in most cases concentration-dependent. None of the treatments increased the uptake of triclopyr ester. The results are discussed with regard to specific herbicide-surfactant interactions.

Keywords: adjuvant, gorse, herbicide uptake, surfactant, *Ulex europaeus* L.

INTRODUCTION

Surfactants are important components of pesticide formulations and can also be mixed as an in-tank addition to improve the effectiveness of active ingredients (Chow and Grant 1992; Field and Dastgheib 1994).

Gorse is one of the most serious brush weed problems in New Zealand (Bascand and Jowett 1982). Various strategies for controlling gorse include mechanical, biological and chemical methods. Recommended herbicides for gorse in New Zealand include glyphosate, metsulfuron, picloram and triclopyr (Anonymous 1993). However, due to its spiny morphology and the significant deposition of epicuticular wax, it is a very difficult spray target which requires specialised formulations to optimise retention, uptake and translocation (Zabkiewicz and Gaskin 1989). This study was undertaken to evaluate the efficacy of novel surfactants in improving the foliar uptake of several herbicides by gorse.

MATERIALS AND METHODS

Gorse plants were grown from 10-15 cm cuttings and maintained in a glasshouse at min/max temperatures of 10/24°C for 2 weeks then moved outdoors and kept for 4 weeks. Plants were taken into the laboratory 24 h before the application of radiolabelled herbicides. Conditions in the laboratory were min/max temperatures of 10/24°C, 65-70% R.H. and 15 h daylength. Artificial lighting was provided by mercury vapour lights with a minimum photosynthetic photon flux density of 150 $\mu\text{mol}/\text{m}^2/\text{s}$.

Surfactants tested were the pyrrolidone complexes Agrisolve 3, Agrimax 3 and Agrimax 5 (Parker 1993), plus the non-ionic surfactants Citowett and Silwet L77, the latter being an organosilicone compound. Treatments were applied 3 h into the photoperiod. One droplet (1 μl) of the radiolabelled herbicide solution was applied to a single tagged spine. Stock solutions of herbicides were prepared by mixing the radiolabelled material with the formulated product. Surfactant solutions were made up with distilled water as diluent and added to the herbicide stock solutions just before application to give final concentrations of 0.05, 0.10 and 0.25 % (v/v). The concentration of the herbicides in the final solutions were within the recommended rate (Table 1). Concentrations of ^{14}C -solutions for different herbicides are given in Table 1.

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Uptake was measured 24 h after application by washing the treated spine with 15 ml aqueous wash to determine the gross uptake and with 10 ml chloroform wash for determining the wax incorporation. Dilute solutions of the formulated products of each herbicide (0.05% for metsulfuron and 1% for other herbicides) were used in the aqueous wash. A sample at time zero was taken where washing of the treated spine was carried out immediately following application to ensure a satisfactory recovery of radioactivity.

Radioactivity in the water wash solution was determined by adding a 1 ml aliquot of the wash solution to 10 ml Bray's scintillation fluid. For the metsulfuron and chloroform wash, which had low activity, radioactivity was determined by evaporating the wash solution and adding 10 ml Bray's scintillation fluid to the vials. Radioactivity was measured by liquid scintillation spectrometry using an LKB beta counter.

Gross uptake was calculated as the difference between the applied radioactivity and the radioactivity recovered in the wash solution. Wax incorporation was calculated from the radioactivity recovered in the chloroform wash. Net uptake was defined as the difference between gross uptake and wax incorporation. All uptake values were expressed as a percentage of the applied radioactivity.

Experiments were randomized complete block designs with ten replicates. Analysis of variance was performed on the data and the least significance difference at 5% probability level (LSD 0.05) was calculated.

TABLE 1: Details on herbicide rates, and the concentrations of radioisotopes used.

Herbicide	Rate (g ai/litre)	¹⁴ C concentration
dicamba (Banvel 200)	0.6	6x10 ⁻³
glyphosate (Roundup)	4.0	1.2x10 ⁻³
metsulfuron (Escort)	0.02	5x10 ⁻⁴
picloram (Picloram)	1.1	7.6x10 ⁻³
triclopyr amine (Garlon)	1.2	25x10 ⁻³
triclopyr ester (Grazon)	1.2	20x10 ⁻³

RESULTS

Gross uptake of ¹⁴C-dicamba by gorse spines was 22.6% without surfactant, of which 1.8% was recovered in wax (Figure 1). The two higher rates of Agrisolve 3, the two lower rates of Agrimax 5 and all rates of Agrimax 3 and Silwet L77 increased the gross uptake of dicamba significantly. Marked increases of 2.2 to 3.1 fold were obtained with Silwet L77 at all rates and with Agrisolve 3 at the two higher rates. Penetration of dicamba into wax was increased significantly by Agrisolve 3 at 0.05% and 0.25%.

With no surfactant glyphosate uptake by gorse was 17.1% of the applied dose (Figure 1). Silwet L77 at 0.25% increased the uptake more than two fold. Agrisolve 3 and Agrimax 3, both at 0.25% and Agrimax 5 at 0.10% and 0.25% as well as Citowett at 0.10% caused significant increases in uptake of ¹⁴C-glyphosate by gorse. Incorporation of glyphosate into wax was small in all treatments and comprised only between 0.5 to 1.2% of the gross uptake.

Uptake of ¹⁴C-metsulfuron by gorse spines was 16.1% in the absence of surfactants (Figure 1). Silwet L77 at all rates increased the uptake by at least four times. Other treatments which resulted in significant increases in gross uptake of metsulfuron were Agrisolve 3 at the two higher rates and Citowett at the highest rate. Wax incorporation of metsulfuron was increased by Agrisolve 3 at the two higher rates, Agrimax 3 at the highest rate, Citowett at the lowest rate and Silwet L77 at the two lower rates.

Figure 1: Net uptake (open bars) and wax uptake (filled bars) of dicamba, glyphosate and metsulfuron by gorse 24 h after application. Error bars are $LSD_{0.05}$ for gross (net+wax) uptake.

Uptake of ^{14}C -picloram by gorse was 12.9% of the applied dose without surfactant (Figure 2). All rates of Silwet L77 increased the uptake by at least four times. The two high rates of Agrisolve 3 also increased picloram uptake significantly. The only treatment with a significant increase in wax incorporation was Silwet L77 at 0.05%.

Uptake of triclopyr amine was 48.0% of the applied radioactivity in the absence of surfactant (Figure 2). Treatments with a significant increase in gross uptake were Silwet L77 at all rates used and Agrisolve 3 at 0.25% rate. Wax incorporation was not increased by any treatment, but was reduced by the two lower rates of Agrisolve 3 and Silwet L77, by Agrimax 5 at 0.05 and 0.25% and by Citowett at 0.25%.

Triclopyr ester had an uptake value of 48.9% without added surfactants (Figure 2). None of the treatments caused an increase in triclopyr ester uptake. Agrisolve 3 at 0.10% and 0.25% as well as Silwet L77 at 0.10% showed a decrease in uptake. Wax incorporation of triclopyr ester by gorse was 20.7% without addition of surfactant and this was reduced by all rates of Agrisolve 3 and Silwet L77 and by 0.25% Citowett.

DISCUSSION

This study compared the efficacy of surfactants with different chemistry in promoting herbicide uptake. Addition of surfactant in most cases produced a positive response in herbicide uptake, although this depended on the herbicide tested. Silwet

Figure 2: Net uptake (open bars) and wax uptake (filled bars) of picloram, triclopyr amine and triclopyr ester by gorse 24 h after application. Error bars are $LSD_{0.05}$ for gross (net+wax) uptake.

L77 showed the greatest effect in increasing the uptake of herbicides tested and the effect was greater with higher rates. Instantaneous droplet spreading was observed when Silwet L77 was added to the herbicide formulations and fluorescence tracer studies carried out in conjunction with the radioisotope work indicated rapid movement of the fluorescent dye to the internal plant tissues including the vascular bundles. Rapid uptake of glyphosate and triclopyr amine in the presence of Silwet L77 was correlated with rapid infiltration of stomata (Field and Bishop 1988; Buick 1990).

Silwet L77 increased the uptake of triclopyr amine but did not result in greater uptake of triclopyr ester, with the 0.10% surfactant rate reducing ^{14}C -triclopyr ester uptake. Similarly, Buick (1990) found that Silwet L77 hardly enhanced the uptake of the ester formulation. The greater responsiveness of the amine formulation to added surfactants has also been observed in other studies on gorse and might reflect the inherent potency of the lipophilic ester formulation to penetrate the apolar cuticle and wax (Price 1982; Buick 1990).

Among the other surfactants, Agrisolve 3 showed the greatest effect in increasing the uptake of several herbicides, while Agrimax 3 usually performed at a lower level. More detailed studies are needed to determine the mechanism of action of pyrrolidone-based surfactants.

The effect of surfactant rate on increasing uptake of different herbicides tested was usually positive. However, in a few herbicide-surfactant combinations, for example Agrisolve 3 and Agrimax 3 with dicamba and picloram, there was a flat response to concentrations above 0.10% or even a negative effect with the highest rate used.

Incorporation of the herbicides into the cuticular wax did not show a consistent pattern with respect to surfactant effects. This probably shows dependency of wax uptake on numerous plant and formulation factors. Wax incorporation was a small proportion of the gross uptake in most cases and presumably could provide a small reservoir for continued herbicide uptake (Thompson *et al.* 1986).

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