UPTAKE OF GLYPHOSATE INTO WHEAT: SURFACTANT INTERACTION AND MECHANISTIC IMPLICATIONS

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ABSTRACT

Glyphosate uptake into wheat in the presence of Mon 0818, a tallow amine surfactant, varied with both ai and surfactant dose on the leaf surface. A high level of uptake ($> 80\%$ at 24 h) was recorded when the glyphosate dose was $\geq 0.24 \mu\text{g}/\text{mm}^2$ or when the Mon 0818 dose was $\geq 0.48 \mu\text{g}/\text{mm}^2$. When Mon 0818 and Silwet L-77 were used together, although droplet spread area and ai dose changed, glyphosate uptake was still dose dependant and the threshold dose for 80% uptake (at 24 h) was still between $0.2\text{--}0.3 \mu\text{g}/\text{mm}^2$. This suggests that L-77 has no negative effect *per se* on glyphosate uptake in the presence of Mon 0818 apart from affecting droplet spreading.

Key words: glyphosate, uptake, grass, surfactant, spread area.

INTRODUCTION

Tank-mixing of surfactants with commercial glyphosate formulations has often enhanced the efficacy of this herbicide. This was believed to be through improved spray retention and/or improved foliar uptake. It was found that some conventional surfactants, when mixed with MON 0818, a tallow amine surfactant used in the original 'Roundup' formulation, could actually produce a synergistic effect on glyphosate uptake into grasses (Liu and Zabkiewicz 1999). However, when Silwet L-77 (L-77), a widely used organosilicone surfactant, was added to Roundup, glyphosate uptake into a number of grass species was frequently reduced (Gaskin and Zabkiewicz 1989; Field *et al.* 1992; Gaskin and Stevens 1993).

Previous work (Liu and Zabkiewicz 1997; 1998) has shown that when L-77 was added to unformulated glyphosate IPA salt, uptake of this herbicide into grasses depended on the ai dose on the leaf surface. Uptake was below 20% after 24 h when the dose was under $0.1 \mu\text{g}/\text{mm}^2$ and over 90% when the dose was $2 \mu\text{g}/\text{mm}^2$. Excessive spreading caused by L-77 reduced the glyphosate dose on the leaf surface and contributed to the lower uptake.

When L-77 is added to Roundup, glyphosate uptake is expected to be influenced by both the silicone surfactant and the co-formulant tallow amine surfactant, Mon 0818. The objective of this work was to investigate the influence of the two surfactants, Mon 0818 and L-77, on glyphosate uptake into the foliage of wheat, a model grass species.

MATERIALS AND METHODS

Plant material

Wheat (*Triticum aestivum* L. cv. Advantage) seedlings were grown from seed in 70 mm square pots containing the peat-based Bloom Potting Mix (Yates NZ Ltd) in a controlled environment (20°C / 15°C , day/night temperatures, 70% RH, 12 h photoperiod with light intensity ca $500 \mu\text{mol}/\text{m}^2/\text{s}$). Four week-old plants (4-5 leaf stage) were used for all experiments.

Chemicals

Surfactants used were Silwet L-77 (trisiloxane ethoxylate, Witco, USA) and Mon 0818 (tallow amine ethoxylate, Monsanto, USA). ^{14}C -glyphosate (Amersham, specific activity: $1.9 \text{ GBq}/\text{mmol}$) was added to unlabelled glyphosate IPA salt of known

concentrations. Aqueous solutions or dispersions of surfactants were then added to form the required treatment formulations containing 0.004%-2.5% glyphosate and 0.01%-0.5% surfactant.

Spread area measurement

Droplets (0.24 μ l) of treatment formulations containing 0.5% fluorescent dye (Blankophor, Bayer) were applied to the adaxial surfaces of wheat leaves. The spread area was measured using a V for Windows image analysis system. A minimum of eight replicates were used for each set of determinations.

Determination of glyphosate uptake

Eight to 12 droplets (0.24 μ l) of treatment solutions containing 14 C-glyphosate (10000-20000 dpm) were applied by microsyringe to the adaxial surface of the youngest fully expanded leaf of each wheat plant. Each treatment consisted of five replicates of individual plants. Uptake was determined by washing residual glyphosate from the treated leaves after 24 h and calculating the amount absorbed as described previously (Gaskin 1995). All uptake results were subjected to analysis of variance and treatments were compared using least significant difference (LSD) tests.

RESULTS

Glyphosate uptake in the presence of Mon 0818

Twenty-five formulations were prepared by varying ai concentration (0.004%-2.5%) and surfactant concentration (0.01%-0.5%). Glyphosate dose and Mon 0818 dose on the leaf surface and percentage uptake of glyphosate for each of the 25 formulations are shown in Table 1. Regardless of surfactant concentration, the Mon 0818 solutions had a small spread area (1 mm²), so dose of ai and surfactant on the leaf surface was totally dependent on their respective concentration. Glyphosate uptake varied with both ai concentration and surfactant concentration. A high level of uptake (> 80%) was obtained whenever glyphosate concentration was $\geq$ 0.1% (dose $\geq$ 0.24 μ g/mm²) or when Mon 0818 concentration was $\geq$ 0.2% (dose $\geq$ 0.48 μ g/mm²).

TABLE 1: Glyphosate uptake (%) into wheat 24 h after treatment.

Mon 0818 Conc. (%)	Mon 0818 dose (μ g/mm ²) ¹	Glyphosate conc. (%) and dose (μ g/mm ² , in brackets)				
		0.004 (0.01)	0.02 (0.05)	0.1 (0.24)	0.5 (1.20)	2.5 (6.00)
0.01	0.024	27	64	81	88	90
0.05	0.12	61	70	86	90	93
0.1	0.24	72	86	91	90	94
0.2	0.48	81	85	90	91	95
0.5	1.2	89	92	92	93	95

¹Dose = mass of glyphosate or surfactant in one droplet / spread area.

LSD (P<0.05) = 7 for glyphosate uptake results.

TABLE 2: Influence of Mon 0818 and L-77 concentrations on droplet spread area (mm²) on wheat leaves.

L-77 conc. (%)	Mon 0818 concentration (%)			
	0.05	0.1	0.2	0.5
0	1.0	1.0	1.0	1.0
0.02	1.9	1.0	1.0	1.0
0.05	4.8	3.8	2.1	1.0
0.1	9.8	7.9	5.8	1.7
0.2	19.6	15.7	11.8	7.8

LSD (P<0.05) = 0.9 for spread area results.

Interaction of Mon 0818 and L-77 on droplet spread

Twenty formulations containing 0.5% glyphosate, 0 to 0.2% L-77 and 0.05 to 0.5% Mon 0818 were prepared and their spread areas on wheat foliage determined. It was found that droplet spread area was affected by the concentration of both surfactants. It increased with increasing L-77 concentration and decreased with increasing Mon 0818 concentration (Table 2).

The glyphosate and Mon 0818 doses produced on leaf surfaces following droplet spread were derived for each formulation using the spread area data from Table 2. These are presented in Table 3. Both ai dose and Mon 0818 dose were inversely correlated with droplet spread areas. They both increased with increasing Mon 0818 concentration and decreased with increasing L-77 concentration. Thirteen out of 20 formulations produced a glyphosate dose on the leaf surface $> 0.24 \mu\text{g}/\text{mm}^2$, which was the threshold dose to provide 80% uptake when Mon 0818 was used alone.

TABLE 3: Doses ($\mu\text{g}/\text{mm}^2$) of glyphosate and Mon 0818 (in brackets) produced on leaf surface in the presence of L-77 from a glyphosate concentration of 0.5%.

L-77 conc. (%)	Mon 0818 concentration (%)			
	0.05	0.1	0.2	0.5
0	1.20 (0.12)	1.20 (0.24)	1.20 (0.48)	1.20 (1.20)
0.02	0.63 (0.06)	1.20 (0.24)	1.20 (0.48)	1.20 (1.20)
0.05	0.25 (0.03)	0.32 (0.06)	0.57 (0.23)	1.20 (1.20)
0.1	0.12 (0.01)	0.15 (0.03)	0.21 (0.08)	0.71 (0.71)
0.2	0.06 (0.01)	0.08 (0.02)	0.10 (0.04)	0.15 (0.15)

Influence of Mon 0818 and L-77 mixtures on glyphosate uptake

When a constant glyphosate concentration (0.5%) was used, uptake varied with both Mon 0818 concentration and L-77 concentration (Table 4). At low concentration (0.02%), L-77 had no negative effect relative to glyphosate in the presence of Mon 0818 only, whereas with 0.2% L-77, glyphosate uptake was reduced regardless of Mon 0818 concentration. Percentage uptake for each formulation followed the same trend as the glyphosate dose produced on the leaf surface, namely, uptake increased with increasing Mon 0818 concentration and decreased with increasing L-77 concentration. All but one formulation that produced ai doses $> 0.24 \mu\text{g}/\text{mm}^2$ (see Table 3) showed $> 80\%$ uptake (Table 4).

TABLE 4: Influence of L-77 and Mon 0818 mixtures with 0.5% glyphosate on uptake (%) 24 h after treatment.

L-77 conc. (%)	Mon 0818 concentration (%)			
	0.05	0.1	0.2	0.5
0	85	94	92	93
0.02	87	91	96	96
0.05	73	81	88	97
0.1	73	74	79	90
0.2	54	59	69	77

LSD ($P < 0.05$) = 5 for glyphosate uptake results.

When the percentage uptake of glyphosate (from Table 4) was plotted against its dose on the leaf surface (from Table 3), a non-linear relationship was observed between these two factors (Fig. 1). There was a very rapid increase in uptake as the

dosage rose from 0.06 to about 0.2 mg/mm². After that point, uptake increased slowly with increasing dose and reached a maximum ($\approx 90\%$) with a dose of approximately 0.6 mg/mm².

FIGURE 1: Relationship between glyphosate dose and uptake.

DISCUSSION AND CONCLUSIONS

Previous work (Liu and Zabkiewicz 1997) had demonstrated that glyphosate uptake into wheat, in the presence of L-77 as the only surfactant, was highly dose dependant. A dose of about 1 mg/mm² on the leaf surface was required to achieve 80% uptake. Current work showed that when Mon 0818 was used as the only adjuvant, glyphosate uptake was also dose-dependant. However, the threshold dose required to obtain 80% uptake was much lower, 0.24 mg/mm² with 0.01% Mon 0818, and as little as 0.01 mg/mm² with higher Mon 0818 concentrations (Table 1). This reflects the differences in the influence that these surfactant types also have on the uptake of glyphosate into wheat foliage. It has been well established that glyphosate uptake is strongly influenced by its concentration but the influence of surfactant type on threshold dose has not been quantified previously.

In the presence of a mixture of Mon 0818 and L-77, the uptake of glyphosate varied with both Mon 0818 concentration and L-77 concentration. However, the controlling factor was still the glyphosate dose on the leaf surface (Tables 3 & 4 and Fig. 1). Regardless of Mon 0818 concentration and L-77 concentration, > 80% uptake was achieved whenever the glyphosate dose reached or exceeded 0.24 mg/mm², the same value as was observed when Mon 0818 was used as the only adjuvant. This indicates that apart from affecting droplet spreading and consequently ai and Mon 0818 doses, L-77 had no negative effect *per se* on glyphosate uptake.

Addition of the super-wetting surfactant L-77 to 'Roundup' formulation is expected to improve the retention of spray by grass foliage. However, its effect on glyphosate uptake depends on the droplet spread area produced on the leaf surface. It is necessary to optimise the ratio of L-77:Mon 0818 in order to achieve good spray retention and good uptake at the same time.

REFERENCES

- Field, R.J., Dobson, N.N. and Tisdall, L.J., 1992. Species-specific sensitivity to organosilicone surfactant-enhancement of glyphosate uptake. Pp 423-431 *In*: Adjuvants for Agrochemicals, C.L. Foy (Ed); CRC press, Boca Raton.
- Gaskin, R.E. and Zabkiewicz, J.A., 1989. The effect of surfactants on the uptake and translocation of glyphosate on Yorkshire fog. *Proc. 42nd NZ Weed and Pest Control Conf.*: 128-131.
- Gaskin, R.E. and Stevens, P.J.G., 1993. Antagonism of the foliar uptake of glyphosate into grasses by organosilicone surfactants. Part 1: Effect of plant species, formulation, concentrations and timing of application. *Pestic. Sci.* 38: 185-192.
- Gaskin, R.E., 1995. Effect of organosilicone surfactants on the foliar uptake of herbicides: stomatal infiltration versus cuticular penetration. Pp 243-248 *In*: Proc. 4th Int. Symp. on Adjuvants for Agrochemicals, R.E. Gaskin (Ed); Melbourne, NZFRI Bulletin No.193.
- Liu Z.Q. and Zabkiewicz J.A., 1997. Cuticular uptake of glyphosate into wheat with organosilicone surfactant. *Proc. 50th NZ Plant Prot. Conf.*: 129-133.
- Liu Z.Q. and Zabkiewicz J.A., 1998. Organosilicone surfactant mediated cuticular uptake of glyphosate into grasses. Pp 119-124 *In*: Proc. 5th Int. Symp. on Adjuvants for Agrochemicals, P. McMullan (Ed); Memphis.
- Liu Z.Q. and Zabkiewicz J.A., 1999. Influence of surfactant mixtures on cuticular uptake of glyphosate into grasses. *Proc. 52nd NZ Plant Prot. Conf.*: 228-233.