CONTROLLING PERENNIAL RYEGRASS WITH GLYPHOSATE IN SPRING

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SUMMARY

Spring tolerance of perennial ryegrass (*Lolium perenne*) to glyphosate was overcome by the addition of 0.1–0.5% Silwet L77 surfactant. The most effective treatment was 0.72 kg ai/ha glyphosate plus 0.5% Silwet L77. The rapidity of foliar uptake of glyphosate was enhanced with Silwet L77 when applied to the upper leaf surface but not the lower. The enhanced rate of uptake by the upper surface was associated with rapid leaf surface wetting and stomatal penetration. The results have major implications for full season control of perennial ryegrass with glyphosate and for reductions in the critical period between spray and the onset of rainfall.

INTRODUCTION

The performance of glyphosate in the full season control of perennial ryegrass (*Lolium perenne* L.) is poor and there is a marked period of spring tolerance. (Bishop and Field 1983; Rolston and Sedcole 1983). The physiological basis for this tolerance has been attributed to the interaction of seasonal changes in the environment and plant growth stage rather than specific environmental changes close to the time of spraying (Bishop 1987). Ontogenetic changes in perennial ryegrass, particularly the transition from vegetative to reproductive apex development have been implicated as major reasons for tolerance to glyphosate (Bishop 1987).

Spring tolerance to glyphosate may be reduced by additional surfactant. Agral LN (Rolston and Sedcole 1983) and Silwet L77 (Field and Bishop 1987) have improved glyphosate efficacy. The explanation of improved herbicide performance with additional surfactant usually relates to improved leaf contact, cuticle penetration or transfer across the plasmalemma membrane of epidermal cells (Wyrill and Burnside 1977; Grossbard and Atkinson 1985).

This paper examines the performance of Silwet L77 in reducing the spring tolerance of perennial ryegrass to glyphosate and offers physiological and physico-chemical explanations for its mode of action.

MATERIALS AND METHODS

Field experiments

Experiments were conducted on a 3-year-old perennial ryegrass (cv. Grasslands Ruanui) pasture from which white clover (*Trifolium repens*) had been removed with dicamba (0.5 kg ai/ha). The main spring trial was a four replicate, randomised block, split plot design, with seven times of chemical application as the main plots and five chemical treatments as sub-plots. Each plot measured 2 x 5 m and chemical treatments were applied with a CO₂ pressurized sprayer delivering 250 litres water/ha. Glyphosate (Roundup) was applied at 0, 0.36, 0.72 kg ai/ha, $\pm$ 0.5% Silwet L77 surfactant, and at 1.08 kg ai/ha at approximately 10 day intervals commencing 2 September 1981. The trial was grazed until 16 August 1981 and received no further grazing or mowing. Pasture was less than 5 cm high at the first application. A winter trial with the same chemical treatments was sprayed on 15 June 1982. The pasture was previously grazed until 17 May 1982 and was less than 5 cm high when sprayed. The growth and development of unsprayed pasture was determined at regular intervals by apical dissection. Treatment performance was assessed 6 and 9 weeks after spraying by cutting green herbage to ground level in 0.24 m² quadrats and determining the number of living tillers with at least one expanding green leaf and the herbage dry weight.

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Foliar uptake and contact angle measurements

All experiments were carried out in a controlled environment chamber maintained at 15 °C, a 12 h photoperiod, a PPFD of 300 $\mu\text{mole/m}^2/\text{s}$ and relative humidity of 75%. Plants of perennial ryegrass (cv. Grasslands Ruanui) were raised in washed river sand and watered twice weekly with a complete nutrient solution. At the time of treatment plants possessed three fully expanded leaves on the main tiller and two to eight daughter tillers.

Radioactive glyphosate (^{14}C) was formulated as the isopropylamine salt to be equivalent to 0.72 kg ai/ha glyphosate in 250 litres water/ha $\pm 0.1\%$ Silwet L77. A single 1 μl droplet of solution containing 7000 dpm was applied to the mid section of the upper or lower surface of the lamina of the youngest expanded leaf on the main tiller. Uptake was determined at pre-determined intervals by washing the treated leaf with water and scintillation counting of the washings (Bishop and Field 1983). Uptake data are expressed as a percentage of the total activity applied. The experiment had six replicates.

The measurement of contact angles was determined by projecting the image from 3 μl droplets applied to either the upper or lower surfaces of the youngest fully expanded leaves (Furmidge 1965). A minimum of 20 replicates was used.

RESULTS

Field Experiments

Glyphosate treatment rate and the date of spring application both affected efficacy when applied to unmown pasture (Figure 1), as assessed by dry weight of green perennial ryegrass herbage. A similar response was found when the number of live tillers was used as the index of response.

Fig. 1: Dry weight of perennial ryegrass swards cut to ground level 9 weeks after spraying with glyphosate at dates and rates shown. Vertical bars represent one standard error of the mean.

Performance improved as the glyphosate rate increased from 0.36 to 1.08 kg ai/ha. The addition of 0.5% (v/v) Silwet L77 substantially improved the performance of 0.72 kg ai/ha glyphosate, which was similar to 1.08 kg ai/ha, without surfactant.

The effect of treatments varied with application date, with control being less from early spring applications, particularly on 14 September, than at other times. The transition of apices from vegetative to reproductive development occurred close to 14 September. The most consistently effective treatment during spring was 0.72 kg ai/ha plus 0.5% Silwet L77.

Live tiller counts after mid-spring (30 September) application confirmed the advantage of adding Silwet L77 (Table 1). Full control was achieved by the addition of 0.5% Silwet L77 to 0.72 kg ai/ha glyphosate. In an adjacent main plot application the addition of 0.1% Silwet L77 to 0.72 kg ai/ha resulted in acceptable control with 112 tillers/m² in the untreated control. In the absence of surfactant significant tiller regrowth occurred even when the glyphosate rate was raised to 1.08 kg ai/ha. In contrast the same treatments applied in early winter (15 June) gave very acceptable control of tillers (Table 1).

TABLE 1: The effect of glyphosate and Silwet L77 treatments on live tiller numbers 6 weeks after spraying. Standard errors of the mean are in brackets.

glyphosate kg ai/ha	Live tillers/m ² Date of Application			
	30 September 1981		15 June 1982	
0	4790	(550)	7550	(630)
0.36	6560	(430)	990	(380)
0.72	2200	(450)	19	(3)
0.72 + 0.5% Silwet L77	0		0	
1.08	520	(160)	27	(9)

Foliar Uptake and Contact Angle Measurements

The mechanism of action of Silwet L77 is associated with rapid foliar penetration and incorporation into leaf tissues. Droplets of a solution equivalent to 0.72 kg ai/ha glyphosate in 250 litres of water make a 118° (s.e. 2.1) contact angle with the upper surface and 36° (s.e. 4.0) contact angle with the lower surface. Addition of Silwet L77 gave complete wetting of the upper leaf surface in 5-20 seconds with 0.05% and in 2-5 seconds at higher concentrations. In contrast addition of 0.1% Silwet L77 to solutions applied to the lower surface did not give complete wetting and a contact angle of 31° (s.e. 3.5) was measured.

Addition of 0.1% Silwet L77 stimulated the rate of glyphosate uptake by the upper leaf surface (Table 2). There was rapid glyphosate uptake within 3 h but by 48 h there was no significant difference between Silwet L77 and control treatments, both achieving approximately 50% foliar incorporation. In contrast absorption by the lower leaf surface was minimal within 5 h and by 48 h there was apparent antagonism associated with the addition of Silwet L77, (Table 2).

TABLE 2: The uptake of ¹⁴C- glyphosate by upper and a lower leaf surfaces, with and without the addition of Silwet L77.

Duration of uptake (h)	Presence of 0.1% Silwet L77	Percentage of applied glyphosate absorbed	
		Upper surface	Lower surface
3	—	1.3	0.1
	+	26.0	2.9
5	—	13.0	1.0
	+	29.0	0.5
48	—	53.0	11.5
	+	48.0	4.5
s.e. mean		6.4	3.3

In further experiments addition of 0.05-0.5% Silwet L77 resulted in 7.5-16.5% (s.e. 2.0) uptake by the upper leaf surface after 5 minutes. No detectable uptake occurred after 5 minutes in the absence of Silwet L77.

DISCUSSION

The difficulties of controlling perennial ryegrass with glyphosate during spring can be partially overcome by increasing the rate of application to 1.08 kg ai/ha, which is above the recommended rate (Figure 1, Table 1). The addition of Silwet L77 to 0.72 kg ai/ha enhanced efficacy and is clearly an effective means of smoothing out the seasonal performance of glyphosate. Earlier Rolston and Sedcole (1983) had shown the benefits of additional surfactant (Agral LN) or ammonium sulphate for the improved control of perennial ryegrass during spring. While these treatments improved the control of perennial ryegrass, particularly in early spring applications, their overall performance was inferior to Silwet L77.

The physiological basis for improved performance of glyphosate with added Silwet L77 suggests enhancement of a critical uptake mechanism. There is no evidence to support the hypothesis that Silwet L77 increases the passage of solution and/or solutes across the cuticle and incorporated wax. However, Bishop (1987) and Field and Bishop (1987) have demonstrated with sodium fluorescein that Silwet L77 promotes rapid stomatal infiltration of glyphosate solutions. Previously Schonherr and Bukovac (1972) had proposed that stomatal entry of solution may occur when the contact angle of the solution was less than the wall angle of the stomatal aperture. The addition of 0.1% Silwet L77 to glyphosate solutions reduced the contact angle to zero within 5 seconds and thus meets the theoretical requirements established by Schonherr and Bukovac (1972). The observation in the present experiments that up to 16.5% of applied glyphosate would be incorporated into leaf tissue within 5 minutes of application would tend to support a rapid route of entry, such as through stomata.

Uptake by the lower leaf surface was clearly different and could be attributed to the surface being astomatous and to differences in wax deposition and cuticle thickness. The lower surface possesses a thick cuticle covered with an amorphous wax sheet, while the upper surface has a thinner cuticle and a dense arrangement of crystalline wax projections (Bishop 1987). Crystalline wax surfaces are typically the least wettable of plant surfaces with solutions of high surface tension (Holloway 1970). Silwet L77 was able to overcome the highly repellent nature of the upper surface and reduce the contact angle. That Silwet L77 did not improve lower leaf surface wetting suggests a difference in wax composition as well as organisation (Bishop 1987) and no improved cuticle and wax penetration by Silwet L77 solutions *per se*.

The use of Silwet L77 provides a simple solution to the problem of seasonal tolerance of perennial ryegrass to glyphosate. In addition its use would reduce the critical period after application in which rainfall can disrupt the efficacy of glyphosate.

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