INFLUENCE OF ADJUVANTS ON THE ACTIVITY OF ASULAM AND GLYPHOSATE IN BRACKEN (*PTERIDIUM* SPP.)

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SUMMARY

When asulam and glyphosate were applied to two bracken varieties (*Pteridium aquilinum* and *P. esculentum*) at intervals during a growing season, the addition of non-ionic surfactants was generally found to enhance absorption and movement of both herbicides in the plants. This was particularly so with fully-expanded, mature fronds, where uptake could be improved up to five (asulam) and eight (glyphosate) times. Herbicide translocation could be similarly increased by factors of 10 and 18 respectively, with the surfactant combinations tested. Glyphosate demonstrated greater uptake and movement in the plant over a wider range of frond development, than did asulam.

INTRODUCTION

The most successful herbicides currently used for bracken control are asulam and glyphosate. The efficacy of both is known to be increased when formulated with appropriate surfactants. Overall, glyphosate appears to be more effective than asulam in controlling bracken (Herrman 1981; Gaskin *et al* 1985) but is less selective. In the United Kingdom and New Zealand it is used at lower rates than asulam (Table 1), but both herbicides have proved less effective in countries with longer growing seasons (Williams 1980). It has been stated that UK bracken (*Pteridium aquilinum*) is more susceptible to asulam than the New Zealand variety (*P. esculentum*) (Heywood 1982), but no direct experimental comparisons have been made. This paper reports work done with both bracken varieties to compare the effect of surfactant addition and plant development on herbicide uptake and translocation in an 'explant' system.

TABLE 1: Recommended manufacturers' herbicide rates (kg ai/ha) for bracken control.

	United Kingdom (<i>P. aquilinum</i>)	New Zealand (<i>P. esculentum</i>)
asulam	4.4	4.4-5.6
glyphosate	1.2-2.0	3.24

METHODS

Rhizome fragments of *P. aquilinum* (UK) and *P. esculentum* (NZ) were potted up in glasshouses in mid-winter in Scotland and then reared outside throughout the 1985 growing season. Fronds were sampled for herbicide treatment at four stages of development: (1) growing juvenile — expanding fronds, (2) mature — full frond expansion, (3) sporulating — fronds beginning to set spores, (4) senescing — fronds yellowing and breaking down. *P. esculentum* was only sampled at stages (1) and (2) due to limited plant growth within the available time.

Bracken explants (excised frond portions) have been found to be representative of the whole plant in terms of herbicide uptake and translocation (Kirkwood and Archibald 1985) and were consequently used in this study. Explants consisted of pinnae removed from the base of fronds, their stems placed in water in a vial, and conditioned in a growth cabinet (24°/17° day/night, 75% RH, 14 h photoperiod) for 24 h prior to treatment. The apical pinnules of the explants were covered with aluminium foil to

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create a photosynthate sink, simulating the “source to sink” movement (of foliage applied herbicide to rhizome apices) in the whole bracken plant (Gaskin and Kirkwood 1986).

Glyphosate (Roundup at 9 litres in 300 litres water) was applied alone, and in combination with Silwet L-77 (Union Carbide), Triton X-45 (Rohm and Haas) or Agral 90 (ICI). Asulam (Asulox) was mixed at 7.5 litres in 300 litres water with the same adjuvants. The surfactant concentrations (Table 2) were selected on the basis of recommended field rates and wetting properties of the formulation (Gaskin, unpublished). Radioactive glyphosate and asulam were added to their respective formulations prior to herbicide application to the bracken explants. The herbicide

TABLE 2: Effect of frond development on % uptake and (% translocation)* of herbicides applied.

Herbicides applied					
Herbicide Surfactant additive		[¹⁴ C]-glyphosate			
Frond stage	Nil	Silwet 0.2%	Triton 0.5%	Agral 0.1%	
<i>P. aquilinum</i>					
(1) Juvenile	8.1 a (2.5)	19.9 (6.0)	12.5 b (6.4)	9.7 ba (8.2)	NS
(2) Mature	8.5 (9.4 a)	66.9 (21.5 b)	62.2 (18.6 b)	45.1 (7.1 a)	
(3) Sporulating	8.1 (4.9 a)	51.9 (14.8 b)	37.9 (4.0 a)	21.0 (9.0 ba)	
(4) Senescing	5.8 (0.2)	10.1 (3.0)	16.2 (6.2)	8.4 (0)	NS
<i>P. esculentum</i>					
(1) Juvenile	47.5 b (2.9)	48.7 b (6.6)	41.2 ba (8.3)	38.4 a (6.7)	NS
(2) Mature	17.3 (9.8)	66.1 (17.9)	56.5 (21.8)	29.4 (13.6)	NS
Herbicide Surfactant additive		[¹⁴ C]-asulam			
Frond stage	Nil	Silwet 0.05%	Triton 0.5%	Agral 0.01%	
<i>P. aquilinum</i>					
(1) Juvenile	Not tested				
(2) Mature	10.3 (3.9)	50.5 a (4.8)	47.6 a (1.9)	32.8 (2.7)	NS
(3) Sporulating	1.4 (0)	11.9 (4.2 a)	24.2 (2.5 a)	17.3 (2.4 a)	
(4) Senescing	2.3 a (0)	2.8 a (10.7)	4.0 (0.3)	2.0 a (15.0)	NS
<i>P. esculentum</i>					
(1) Juvenile	11.5 a (4.3)	21.4 (5.1)	25.4 (8.7)	10.7 a (8.4)	NS
(2) Mature	23.7 (4.2 a)	68.9 (14.9)	47.8 a (9.2 a)	48.5 a (7.6 a)	

* Translocation as % of absorbed herbicide.

Common postscripts within individual herbicide treatment rows indicate no significant difference at 5% level

NS = no significant difference between any treatments.

formulations were applied as droplets ($5 \times 0.5 \mu\text{l}$) to each of the lowest two pinnules of each explant. Treatments were replicated five times. Treated explants were maintained in the growth cabinet for 48 h prior to harvest at which time the treated pinnules were removed from the explant and washed with Tween 80 solution (0.05% v/v), then chloroform, to remove residues. The aqueous and chloroform washes were radioassayed in a Packard Liquid Scintillation Spectrometer (300C); an aliquot of explant vial water was also assayed for radioactivity.

The treated pinnules and explant tissues were oven-dried (50°C), weighed, pelletised and combusted in a Packard Sample Oxidiser (B306). The radioactive CO_2 was trapped on Carbosorb II and subsequently radioassayed. Recoveries of radiolabelled herbicides ranged from 83-98% of that applied (approximately $0.1 \mu\text{Ci/treatment}$). Percentage uptake was calculated as the total recovered from all explant tissue, and percent translocation was the percentage of absorbed herbicide recovered from the untreated portions only (Table 2).

RESULTS AND DISCUSSION

The results from the various treatments are given in Table 2.

Juvenile (Stage 1), unfurling fronds are generally more susceptible to herbicides, with less developed barriers to penetration and preferential apical accumulation of the herbicide in the developing frond (Veerasekaran 1975). Visible scorching of juvenile foliage at the site of application was evident in most treatments; for that reason uptake was low and surfactants did not enhance it to the same extent as in mature fronds. This was the case for both herbicides and in both bracken varieties.

In contrast all three surfactants substantially enhanced the uptake of asulam and glyphosate in both bracken varieties when applied at the optimum spray time of full frond expansion (Stage 2). The addition of surfactants also improved uptake in older fronds which were beginning to set spores and/or undergo senescence (Stages 3 and 4). However, in both these cases uptake was generally reduced, showing that frond development greatly influences herbicide absorption.

Translocation of both herbicides was found to be significantly correlated with uptake ($p=0.001$), confirming that efficient translocation ultimately depends on efficient absorption, which is in turn dependent on plant age. As previously stated, glyphosate has been found to be more effective in controlling bracken than asulam. With surfactant addition, both herbicides show similar improvements in uptake but the movement of glyphosate in the plants is generally greater than that of asulam. Uptake of glyphosate is also improved over a wider period of plant maturity; thus timing of spraying will be less critical with this herbicide.

Without the addition of surfactants *P. esculentum* consistently absorbed and translocated at least twice the amount of herbicide as did *P. aquilinum*. This was unexpected, since this variety has long been considered less susceptible to both herbicides because of the higher rates required for its control. The greater resistance of *P. esculentum* has been attributed to differences in plant surface character, i.e., amount of wax and cuticle thickness, but no evidence was found to support this in this study. Wax extractions and detailed chemical analyses (Baker and Gaskin 1987) showed remarkable similarity in amount and type. Measurements of cuticle thickness revealed no significant difference between the two varieties; both are in the 1-2 μm range. Some morphological and physiological differences were apparent and these, combined with differing environmental conditions in the two host countries, could account for the variation in herbicide susceptibility of the two varieties. However, formulation of herbicides with suitable surfactants can effectively overcome the varietal differences in uptake and translocation, as shown by these results.

CONCLUSIONS

The addition of appropriate non-ionic surfactants can considerably enhance the efficacy of glyphosate and asulam in bracken. The optimum time to apply herbicide/surfactant combinations is when fronds are fully expanded and the bracken is undamaged and actively growing. However, adjuvants can increase herbicide penetration into older pre-senescent foliage with a subsequent increase in translocation,

effectively extending the field spraying season and improving control in mixed-age stands. With the addition of surfactants, glyphosate was generally absorbed and transported to a greater extent than asulam. Of the surfactants tested, Silwet L-77 proved to be a superior additive for both herbicides for the control of bracken in full frond.

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