ESTER FORMULATION AND SURFACTANT AFFECT RESPONSE OF RADIATA PINE AND GORSE SEEDLINGS TO 2,4,5-T

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ABSTRACT

In a replicated 2 (**ester**) × 4 (**rate**) × 2 (**surfactant**) factorial experiment the iso-octyl ester of 2,4,5-T was found to be more effective in controlling seedling gorse (**Ulex europaeus** L.) and less damaging to radiata pine (**Pinus radiata** D.Don) seedlings than the butyl ester. The addition of 0.5% v/v surfactant significantly enhanced the activity of the iso-octyl ester against the gorse, but not that of the butyl ester, and resulted in marginally less tree growth suppression by 2,4,5-T. Further investigation of the effects of ester formulation and surfactant on 2,4,5-T activity in relation to gorse control and tree selectivity appears warranted.

INTRODUCTION

2,4,5-Trichlorophenoxyacetic acid (2,4,5-T) has long been the major herbicide for gorse control in New Zealand forestry and agriculture. In the past a fairly wide range of ester formulations have been marketed (including butyl, octyl, iso-octyl, butoxyethanol, ethyl hexyl, iso-propyl) but there has never been a clear understanding of their relative merits as far as gorse control and selectivity towards trees (principally radiata pine) are concerned. On the basis of extensive field observations it seems to have been accepted that there are no differences of practical significance between the esters. Even volatility (short chain esters *v.* long chain esters) is not thought to be a significant factor in New Zealand with generally mild summer temperatures. Non-volatile formulations are often specified in forestry applications, but only as an environmental precaution. More recently the number of esters available commercially has diminished so that today only the butyl and iso-octyl esters are marketed, and it seems possible that only the butyl ester may be commercially available in the future.

It is well known that there are marked differences in the absorption of 2,4-D and 2,4,5-T depending on formulation and molecular configuration (Norris and Freed, 1964, 1966). More specifically the "heavy" (less volatile) esters of 2,4-D are more effective against certain perennial weeds than the "light" (volatile) alkyl esters (Crafts, 1961). Despite the fact that in operational use differences between the effects of various esters of 2,4,5-T on gorse have not been detected, there are good grounds for suspecting that differences worth exploiting may exist. The different alcohol moieties vary greatly in size and structure, and confer on the formulated esters marked differences in volatility, in longevity as liquids in the air and on leaf surfaces, and in their ability to dissolve in the leaf waxes — the latter probably being of particular significance for gorse (Rolston, 1974; Zabkiewicz and Gaskin, 1978).

If significant ester-dependent variation in herbicidal effectiveness and/or selectivity of 2,4,5-T were found this could be a factor in determining which esters should be manufactured and marketed for gorse control in New Zealand.

Surfactant enhancement of herbicide activity is a well-known phenomenon (Jansen *et al.,* 1961; Jansen, 1964; Bland and Brian, 1975) but it may be less pronounced in the case of emulsifiable ester formulations which already contain surface active agents in the form of emulsifiers (Corns and Dai, 1967). Adding surfactant is sometimes recommended to improve wetting and coverage of dry or dusty foliage by aqueous emulsifiable ester sprays of 2,4,5-T, but otherwise no recommendation is usually given. Although Rolston (1974) found that surfactants could double the amount of 2,4-D dimethylamine salt and picloram potassium salt absorbed by gorse foliage, no information was available on the effect of additional surfactant on the activity of 2,4,5-T emulsifiable esters on gorse and radiata pine. Information on this point was a further objective of the work reported here.

METHODS

Only two esters were procurable, the butyl and the iso-octyl (supplied by Ivon Watkins-Dow Ltd, New Plymouth: butyl ester, 360 g a.e./litre, batch no. 106/76; iso-octyl ester, 360 g a.e./litre, batch no. 107/76). These were each applied at four rates, 0.5, 1.0, 2.0 and 3.0 kg a.e./ha, both with and without 0.5% v/v surfactant ("Multifilm X-77"), to small 2 m × 2 m nursery plots each containing nine 1/0 radiata pine and 16 1/0 gorse transplants within the central 1 m × 1 m area. The treatments were applied as aqueous sprays in two passes of 150 litres/ha each, using an overhead, CO_2-powered boom sprayer. The experiment was a thrice replicated, 2 (*ester*) × 4 (*rate*) × 2 (*surfactant*) factorial of fully randomised design. The plots were planted in August 1976 and sprayed on December 6 1976, when both gorse and trees were well established and new growth well underway. The gorse plants were 15-30 cm tall with 5-15 cm of soft, new growth. The first post-application rain, 50 mm, fell three days after treatment.

Tree heights were measured at the time of treatment and percent foliage brown-off was estimated eight weeks later. The experiment was terminated after ten months when height and the number of terminal leaders were recorded for each tree, and tree and gorse survival and shoot fresh weights were determined.

Three-factor analyses of variance (ANOVA) of the foliage brown-off, survival, height increment, fresh weight and terminal leader data were made.

RESULTS AND DISCUSSION

The ANOVA results, in terms of the probability levels associated with the main effects and interactions of the factors, are summarised in Tables 1 and 2. Arcsin and logarithmic transformations of the gorse survival and fresh weight data (respectively) were performed before ANOVA in order to stabilise the variance. Although this tended to increase the F-values obtained, the conclusions drawn were essentially the same as those using the untransformed data. Some of the effects and interactions are plotted in Figs. 1-14. The main effects of the factors on gorse seedling survival are shown in Table 3.

TABLE 1—Probabilities (p) associated with the variance ratios (F-values) from the three-way analyses of variance of the radiata pine individual tree data

Source of variation	d.f.	Variable: Foliage brown-off	Number of leaders	Height increment	Shoot fresh weight
Ester	1	0.006	0.170 NS	0.099 NS	0.591 NS
Rate	3	<0.001	0.126 NS	<0.001	<0.001
Surfactant	1	0.024	0.570 NS	0.028	0.321 NS
Ester × Rate	3	<0.001	0.280 NS	0.040	0.001
Ester × surfactant	1	0.262 NS	0.010	0.211 NS	0.737 NS
Rate × surfactant	3	0.078 NS	0.109 NS	0.067 NS	0.008
Error	401				

NS = not significant at the 0.05 probability level
d.f. = degrees of freedom

TABLE 2—Probabilities (p) associated with the variance ratios (F-values) from the three-way analyses of variance of the transformed gorse plot mean data

Source of variation	d.f.	Variable: Survival % (arcsin-transformed)	Shoot fresh weight (Log_e-transformed)
Ester	1	<0.001	<0.001
Rate	3	<0.001	<0.001
Surfactant	1	0.444 NS	0.059 NS
Ester × rate	3	0.167 NS	<0.001
Ester × surfactant	1	0.387 NS	0.059 NS
Rate × surfactant	3	0.970 NS	0.789 NS
Ester × rate × surfactant	3	0.935 NS	0.996 NS
Error	32		

NS = not significant at the 0.05 probability level
d.f. = degrees of freedom

TABLE 3—Main effects of ester, 2,4,5-T rate and surfactant on seedling gorse survival and total shoot fresh weight

Factor	Level	Survival (%)	Total shoot fresh weight (g)
Ester	iso-octyl	30.3	482
	butyl	50.0	1250
Rate	0.5	83.7	2656
	1.0	50.8	623
	2.0	24.4	146
	3.0	7.1	41
Surfactant	0	41.6	966
	0.5	38.3	766

Tree Responses

Tree mortality was negligible. The few deaths which did occur were not attributable to the treatments.

Although the main effects of *ester, rate* and *surfactant* on foliage brown-off were significant or highly significant statistically (Table 1); none had a significant effect on the number of terminal leaders produced; *rate* and *surfactant* significantly affected height increment, but only *rate* had a significant effect on shoot fresh weight. Except, perhaps, for the effect of rate on shoot fresh weight none of the statistically significant effects would be of great practical significance (Figs. 1-3).

FIG. 1.

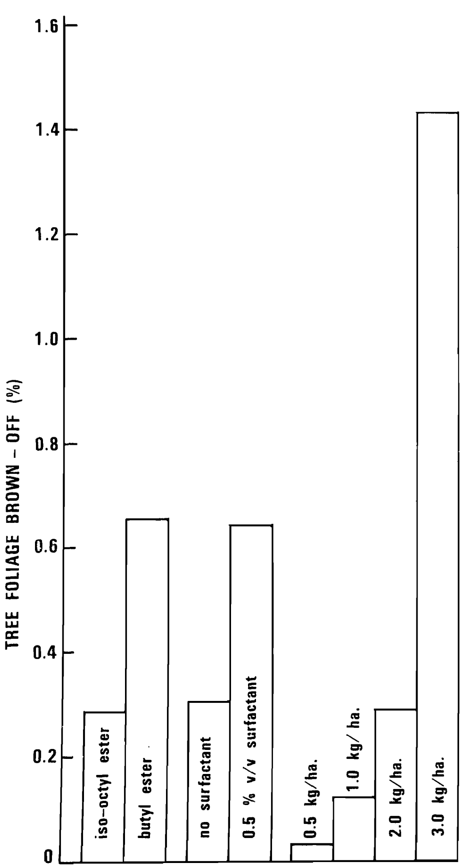


FIG. 2.

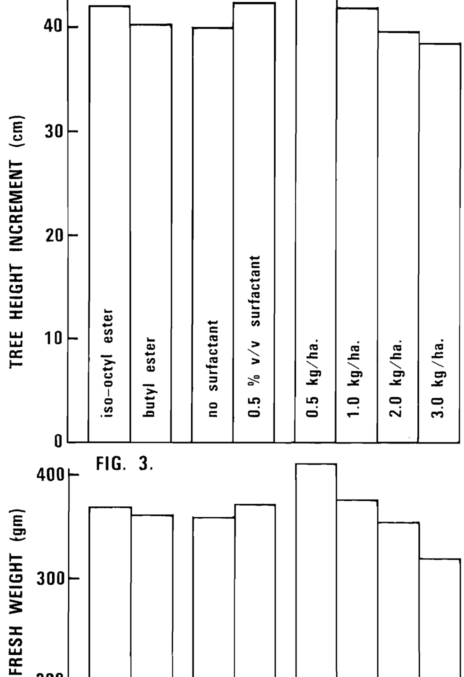


FIG. 3.

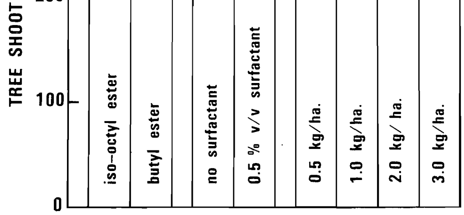


FIG. 1—Main effects of ester formulation, surfactant and rate of 2,4,5-T on radiata pine foliage brown-off eight weeks after treatment.

FIG. 2—Main effects of ester formulation, surfactant and rate of 2,4,5-T on radiata pine height increment.

FIG. 3—Main effects of ester formulation, surfactant and rate of 2,4,5-T on radiata pine shoot fresh weight.

Several interactions were statistically significant, but could not on the whole be meaningfully interpreted. There were significant *ester* × *rate* interactive effects on foliage brown-off, height increment and fresh weight (Figs. 4-6). The first appeared to be due to the passing of some form of threshold between the 2 and 3 kg/ha rates in tree response to the butyl ester (Fig. 4). This interaction could not be interpreted for height increment or fresh weight (Figs. 5, 6). The *surfactant* × *rate* effects on shoot fresh weight (Fig. 7) suggested that the surfactant increased the damaging effect of the lowest rate of 2,4,5-T but protected the trees to some extent at the other three rates.

On the whole the trees were affected slightly less by the iso-octyl ester than the butyl ester, and, surprisingly, responded more favourably to the presence of surfactant than its absence. Although the presence of surfactant significantly increased foliage brown-off (Table 1; Fig. 1) it appeared to ameliorate the growth depressive effects of the herbicides (Figs. 2, 3), especially of the iso-octyl ester (Fig. 8). In view of the lack of competition

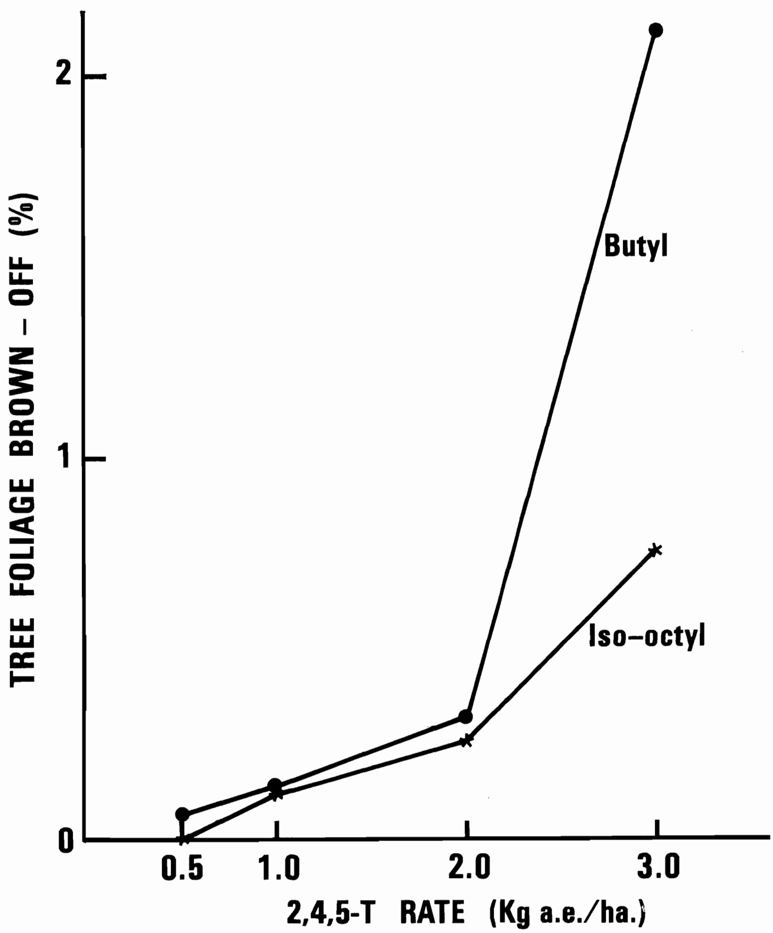


FIG. 4—Effect of ester formulation on radiata pine foliage brown-off response to 2,4,5-T eight weeks after treatment.

FIG. 5.

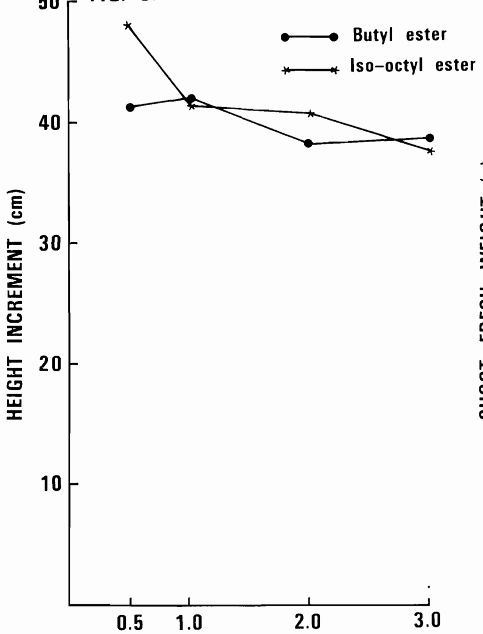


FIG. 6.

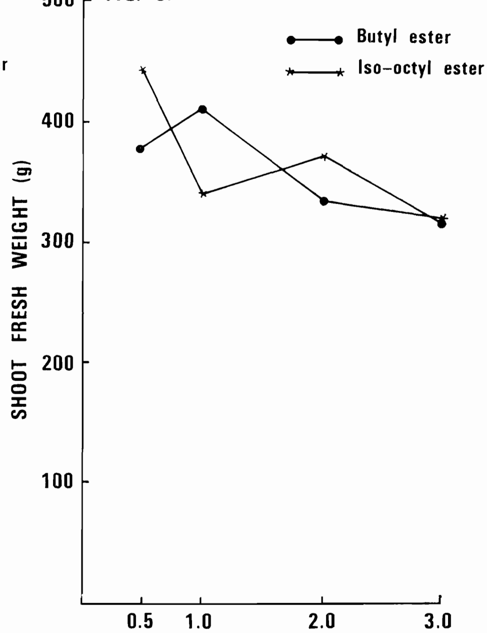


FIG. 7.

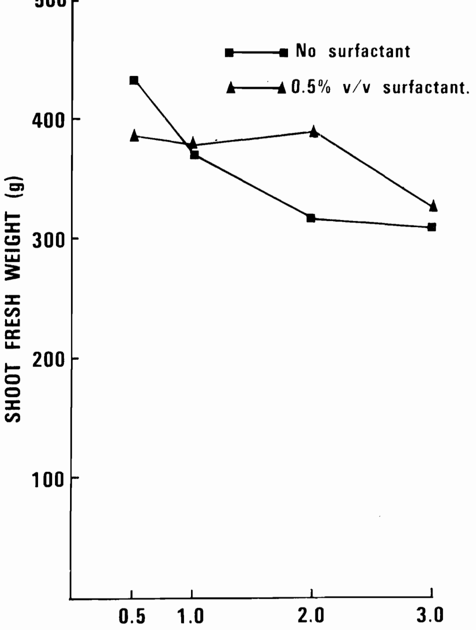
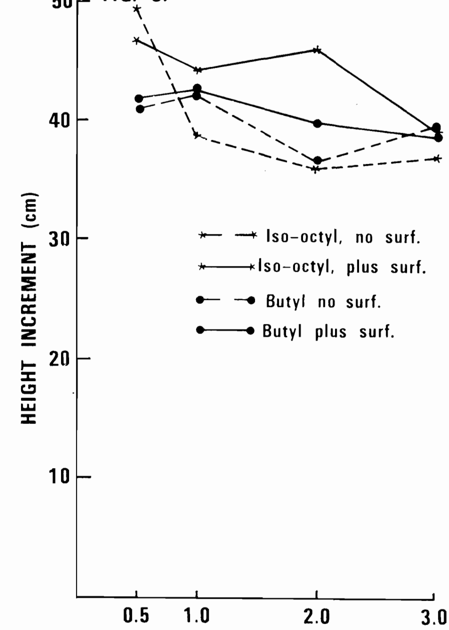


FIG. 8.



2,4,5 - T RATE (kg a.e./ha.)

FIG. 5—Effect of ester formulation on radiata pine average height increment response to 2,4,5-T.

FIG. 6—Effect of ester formulation on radiata pine shoot average fresh weight response to 2,4,5-T.

FIG. 7—Effect of surfactant on radiata pine shoot average fresh weight response to 2,4,5-T.

FIG. 8—Effect of surfactant on radiata pine shoot average height increment response to the iso-octyl and butyl esters of 2,4,5-T.

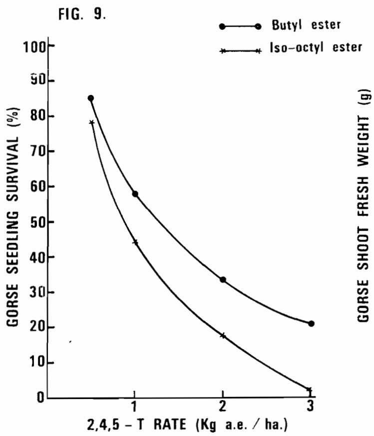


FIG. 9.
Butyl ester
Iso-octyl ester
GORSE SEEDLING SURVIVAL (%)
2,4,5 - T RATE (Kg a.e. / ha.)

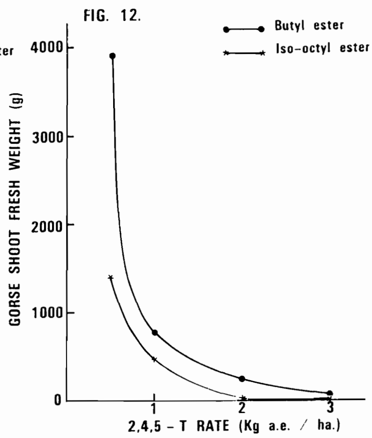


FIG. 12.
Butyl ester
Iso-octyl ester
GORSE SHOOT FRESH WEIGHT (g)
2,4,5 - T RATE (Kg a.e. / ha.)

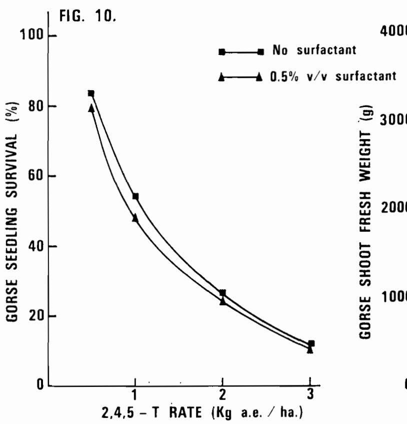


FIG. 10.
No surfactant
0.5% v/v surfactant
GORSE SEEDLING SURVIVAL (%)
2,4,5 - T RATE (Kg a.e. / ha.)

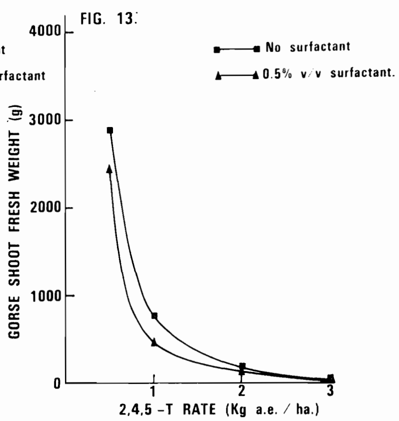


FIG. 13.
No surfactant
0.5% v/v surfactant.
GORSE SHOOT FRESH WEIGHT (g)
2,4,5 -T RATE (Kg a.e. / ha.)

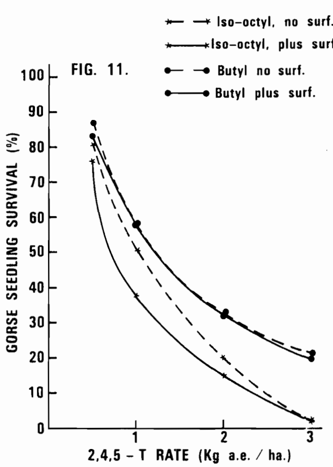


FIG. 11.
Iso-octyl, no surf.
Iso-octyl, plus surf.
Butyl no surf.
Butyl plus surf.
GORSE SEEDLING SURVIVAL (%)
2,4,5 - T RATE (Kg a.e. / ha.)

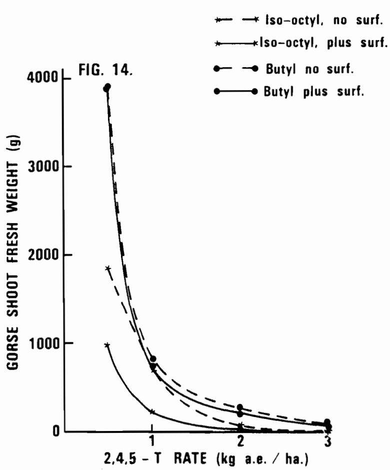


FIG. 14.
Iso-octyl, no surf.
Iso-octyl, plus surf.
Butyl no surf.
Butyl plus surf.
GORSE SHOOT FRESH WEIGHT (g)
2,4,5 - T RATE (kg a.e. / ha.)

offered the trees by the gorse plants on the plots, and the fact that tree growth was overall weakly, but positively, correlated with gorse survival and fresh weight, it seems unlikely that the ameliorating effect of added surfactant was due merely to a "releasing" effect resulting from better gorse control (see later and Figs. 11, 14). This apparent protective effect of the surfactant was contrary to expectations and cannot at this stage be explained.

Gorse Responses

Both *ester* and *rate* had highly significant effects on gorse seedling survival and fresh weight (Tables 2, 3). Fewer seedlings survived at all rates with the iso-octyl ester than with the butyl (Fig. 9); the higher the rate the greater the difference between the esters, although the interaction was not statistically significant. At the 3 kg/hr rate only 2% of the iso-octyl ester-treated seedlings survived compared with 20% of the butyl ester-treated seedlings. Similarly, there was a consistently larger reduction in total seedling fresh weight from the iso-octyl ester than from the butyl ester (Fig. 12). In this case the *ester* × *rate* interaction was highly significant, but this is almost certainly due to the large difference in response to the two esters at the 0.5 kg/ha rate.

Although the tabulated and graphed results indicated definite negative *surfactant* effects on gorse seedling survival and fresh weight (Table 3; Figs. 10, 13) the initial analyses showed them to be of a low or doubtful order of significance, statistically (Table 2). From Fig. 14 it was evident (as in the tree data) that the effect of surfactant was different for the two esters. Supplementary separate analyses of the iso-octyl ester and butyl ester subsets of the data showed that surfactant had a large, highly significant negative effect ($p < 0.001$) on gorse seedling fresh weight response to the iso-octyl ester, but only a small, non-significant ($p = 0.758$), negative effect on the response to the butyl ester. Surfactant enhancement of the iso-octyl ester resulted in reductions of 50% or more in fresh weight compared with the iso-octyl ester alone.

Although the supplementary ANOVAs did not indicate that the survival response to *surfactant* was statistically very significant ($p = 0.284$), Fig. 11 strongly sugests that a worthwhile enhancement of seedling mortality may be obtained when a surfactant is used with the iso-octyl ester but not with the butyl ester.

CONCLUSIONS

The iso-octyl ester of 2,4,5-T caused greater seedling gorse mortality and growth suppression than the butyl ester throughout the 0.5-3.0 kg a.e./ha range investigated. The addition of surfactant at 0.5% v/v increased gorse growth suppression and mortality

FIG. 9—Effect of ester formulation on gorse seedling survival response to 2,4,5-T.

FIG. 10—Effect of surfactant on gorse seedling survival response to 2,4,5-T.

FIG. 11—Effect of surfactant on gorse seedling survival response to the iso-octyl and butyl esters of 2,4,5-T.

FIG. 12—Effect of ester formulation on total gorse seedling shoot fresh weight response to 2,4,5-T.

FIG. 13—Effect of surfactant on total gorse seedling shoot fresh weight response to 2,4,5-T.

FIG. 14—Effect of surfactant on total gorse seedling shoot fresh weight response to the iso-octyl and butyl esters of 2,4,5-T.

by the iso-octyl ester but not by the butyl ester.

Use of the iso-octyl ester did not significantly affect tree height or fresh weight compared with the butyl ester. Surfactant significantly improved tree height response but not fresh weight. In general iso-octyl ester and surfactant treatments resulted in larger more robust trees than the butyl ester and surfactant-less treatments. Surfactant enhancement of the iso-octyl ester was limited to the rates below 3.0 kg/ha.

It would appear that in the iso-octyl ester-plus-surfactant combinations we have treatments which are significantly more active against seedling gorse than the butyl ester-plus-surfactant treatments, while at the same time being marginally less damaging toward the young radiata pine tree crop.

These results suggest that further work on the influence of ester formulation on 2,4,5-T activity against gorse and selectivity towards radiata pine could well yield worthwhile dividends in selective and non-selective gorse control in farming and forestry.

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