SEASONAL VARIATION IN SEEDLING GORSE SUSCEPTIBILITY TO FOUR HERBICIDES

DAVID PREEST

Forest Research Institute, Rotorua

Summary

Hexazinone, glyphosate and terbutylazine-plus-terbutylazine-plus-amitrole ('TTA') killed seedling gorse (*Ulex europaeus*) best in December (germination largely complete); 2,4,5-T killed best in January, and provided the most cost-effective control (January-March). In December only hexazinone achieved 100% mortality at all rates, and, together with the highest rate of 'TTA', inhibited any further germination. An autumn-winter mortality rise from hexazinone, glyphosate and 'TTA' correlated well with increasing root:shoot ratio. Mortality pattern differences between 2,4,5-T and glyphosate may be related to differences in herbicide formulation and seasonal changes in epicuticular wax thickness and cuticle development.

INTRODUCTION

Translocation of foliar-applied 2,4,5-T and other phenoxy herbicides in gorse is often regarded as poor. High rates of 2,4,5-T esters (6-10 kg/ha), thorough coverage (Matthews 1975) and even repeat treatments (Moffat 1965) are usually required to kill mature plants. However, excellent kills are achieved at certain times from lower rates (2-4 kg/ha) (Meeklah 1967), single treatments, and/or incomplete coverage, suggesting much better uptake or translocation, or both, at these times. This enhanced susceptibility to 2,4,5-T usually coincides with periods of active foliar growth, typically in November-January (Foreman 1964; Leonard 1965; Thompson 1973). Since the foliage is likely to be a more active metabolic sink at this time than the roots and, therefore, basipetal translocation weak, the improvement is probably due to greater uptake because of characteristics of the immature cuticle.

Thompson (1975) found that low pre-treatment soil moisture levels caused a highly significant reduction in growth-regulator herbicide efficiency in 2-year-old gorse. He suggested that this may result from low gorse growth activity, rather than the high plant moisture stress as such. Matthews (1975) stated that cotyledonary gorse seedlings are quite resistant to 2,4,5-T, but they become more susceptible after this stage, remaining so until 0.9-1.3 m high. (This ignores the seasonal variation in gorse susceptibility).

A number of other herbicides (including hexazinone, glyphosate, amitrole, and a mixture of terbutylazine and terbutylazine) have from time to time been reported to show a useful degree of activity against gorse. However, no firm information as to the seasonal variation in susceptibility of young seedlings to these herbicides has been reported.

This experiment investigated the susceptibility patterns of seedling gorse to two foliage-absorbed and two primarily root-absorbed herbicides, and attempted to relate these patterns to the observed patterns of root and shoot growth.

METHOD

The experiment was conducted on a bare, cultivated site in the Forest Research Institute nursery, Rotorua. It was a small-plot trial with experimental units consisting of 2 x 2 m plots. Gorse seed was collected from the duff layer beneath a mature gorse

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stand in the Rotorua basin and cleaned by sieving and winnowing. It was hot-water-treated (Zabkiewicz and Gaskin 1978) immediately before sowing. The seed was sown early in October 1977 in four lines spaced at 30 cm in the central 1 x 1 m area of each unit. Equal quantities of seed by volume were sown in each line. After germination the number of seedlings was thinned to 15-20 per line.

TABLE 1: Herbicide treatments and costs

Herbicide	Rate (kg/ha)	Herbicide cost (\$)
2,4,5-T	0.5	5.80
	1	11.61
	2	23.22
2,4,5-T + diesel oil (20 litres/ha)	0.5	
	1	
	2	
glyphosate	1	48.19
	2	96.39
	4	192.78
'TTA' (terbuthylazine + terbumeton + amitrole)	0.5 + 0.5 + 0.25	15.65
	1 + 1 + 0.5	31.30
	2 + 2 + 1	62.60
hexazinone	1	39.44
	2	78.89
	4	157.78

The four herbicides and rates of application are given in Table 1. The first two are foliage-absorbed, and the latter two primarily root-absorbed, though there is some foliage uptake. The dates of application and condition of the seedling gorse at each treatment stage are detailed in Table 2.

Each treatment was applied as a simulated aerial spray by precision boom sprayer using Spraying Systems 730077 Tee Jet flat fan nozzles spaced at 35 cm and operated at 275 kPa. The applications, which were made within an aluminium spraying cabinet to confine drift, were made in two passes at the rate of 150 litres/ha each. Boom height was 45-50 cm above the tops of the gorse plants. The weather on all the treatment dates was fine and all treatments were followed by at least 12 hours without rain.

TABLE 2: Herbicide application dates, and size and condition of gorse seedlings at each date

Application date	Height (cm)	Stage and condition of foliage
5.12.77	0-1.5	Cotyledonary through to first six true leaves. Soft. Some germination still occurring.
4.1.78	1.5-4.0	4-12 true leaf stage. Soft. A few seed still germinating
14.2.78	4-14	Majority of seedlings have well-developed spines which are generally still soft but starting to harden off.
31.3.78	6-15	Plants spiny and hardened off generally except for top 2-3 cm. Many with well-developed lateral branches.
26.5.78	6-22	All seedlings hardened off except for shoot tips (½-1 cm) which are still soft.

There were three replications and the design was randomised block. It was basically a (4 herbicides) x (3 rates) x (5 application dates) x (3 replications) factorial experiment.

Fig. 1 Gorse seedling mortality response to four herbicides applied at five different times (A-E) during the first six months of seedling development.

Fig. 2 Seasonal response patterns of gorse seedling mortality to four herbicides (A-D), and corresponding changes in root:shoot ratio (E).

Root:shoot (R:S) ratios based on oven dry (o.d.) weight were determined by digging up a representative selection of between 26 and 63 gorse plants at each treatment date (Fig. 2,E). Seedlings from several spare plots were utilised for this purpose. The results of the treatments were assessed by survival count in December 1978 when it was assumed that further mortality due to treatment would not occur. Post-treatment germination was noted and used to correct the survival figures. The final results are expressed as percentage mortality for each treatment (Figs. 1 and 2)

RESULTS AND DISCUSSION

Fig. 1, A-E, shows the effects of the treatments at each date. Both hexazinone and 'TTA' achieved 100% or nearly 100% kills of existing seedlings at all rates at the first application date (no significant differences at $p = 0.05$ level); they had the important advantage over the foliage-absorbed 2,4,5-T and glyphosate that they inhibited most subsequent seed germination. Hexazinone prevented all subsequent germination even at the lowest rate of 1 kg/ha. While 2 and 4 kg/ha glyphosate gave 100% kills of existing seedlings, and 2 kg/ha 2,4,5-T gave a 99.4% kill, those achieved by lower rates were poor or inadequate. Glyphosate and 2,4,5-T at 1 kg/ha were both significantly different ($p < 0.05$) from hexazinone at 1 kg/ha. Neither 2,4,5-T nor glyphosate prevented early, post-treatment germination, with one to eight seedlings emerging on each plot.

By early January the relative performance of the herbicides had altered markedly. 2,4,5-T had displaced hexazinone as the most successful killer of existing seedlings and 'TTA' had become the least effective, a position which it retained for all the subsequent application dates. 2,4,5-T gave poor control of cotyledonary (December) as compared with post-cotyledonary (January) seedlings ($p < 0.05$ for 0.5 and 1.0 kg/ha rates). 2,4,5-T was more effective in controlling established seedlings in January, February and March at 1 and 2 kg/ha than any other chemical ($P < 0.05$ except for 2,4,5-T vs hexazinone at 2 kg/ha) at the same rates, and would undoubtedly have been even more effective at 4 kg/ha. A pronounced fall-off in the relative effectiveness of 2,4,5-T occurred between the March and May applications, which even the addition of diesel oil and emulsifier did not wholly rectify (Fig. 1,E).

Fig. 2,A-D shows that the activity of 2,4,5-T diminished continuously during the later summer and into the winter while, unexpectedly, that of the other chemicals, after an initial fall in effectiveness, tended to remain static (lower rates) or even increase (higher rates) as winter approached. Where increases occurred, the differences between the lowest and highest means were significant ($P < 0.05$) for glyphosate and 'TTA' but not for hexazinone. The patterns of glyphosate, 'TTA', and hexazinone activity may be related in part to the pattern of root and shoot growth as indicated by the R:S ratio (Fig. 2,E). The falling R:S ratio during the summer indicates a relative decline in root growth activity and a decline in the ability of the root metabolic sink to attract and accumulate photosynthate and, along with it, herbicides. The shape of the R:S ratio curve into the autumn and winter, however, suggests increasing root growth relative to shoot growth, indicating an active root sink into which herbicides would tend to be carried. While this may go some way towards explaining the late-season patterns of gorse susceptibility to glyphosate, hexazinone, and 'TTA' (all generally well correlated with the R:S ratio) it does not explain those of 2,4,5-T (poorly correlated with R:S ratio). Rainfall records for the 7 days prior to and following each application date were examined but no pattern was evident which would suggest a rainfall-related explanation of the response curves.

It is speculated that the differences in response to glyphosate and 2,4,5-T relate to changes in the amount of epicuticular wax and cuticle thickness. Zabkiewicz and Gaskin measured epicuticular wax and cuticle thickness in samples of seedlings drawn from the same trial at each treatment date. They found (pers com) that epicuticular wax tended to diminish as the season progressed, whereas cuticle thickness increased. The fairly heavy wax deposits and the absent or very thin cuticle of the earlier treatment dates would favour the entry of the lipophilic, non-ionic, 2,4,5-T ester formulation, but discriminate against the entry of the ionic, hydrophilic glyphosate. Later in the season,

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as the wax diminished and the cuticle thickness increased, the ionic pathway would tend to improve favouring the absorption of glyphosate but causing a fall-off in the uptake of 2,4,5-T ester.

CONCLUSIONS

- (1) Best control of seedling and germinating gorse by the two root-absorbed herbicides was given by hexazinone applied at or shortly after germination. In practice a rate of at least 2 kg/ha may be required.
- (2) Foliage-absorbed chemicals should not be applied until germination is complete and the plants have at least 4-12 true leaves. 2,4,5-T was more effective than glyphosate, and was most effective when applied to actively growing post-cotyledonary seedlings 1.5-4 cm tall.
- (3) 2 kg/ha 2,4,5-T was the most cost-effective treatment by a factor of two or more; 2-4 kg/ha would be required in practice (2,4,5-T has the added advantage of controlling stump regrowth).
- (4) Some characteristics of the seasonal response patterns of seedling gorse to the different herbicides appeared to be related to the growth patterns of the roots and shoots.
- (5) Differences between the gorse mortality response patterns to 2,4,5-T and glyphosate may result from an uptake interaction effect related to herbicide formulation and observed seasonal changes in the thickness of the epicuticular wax and the cuticle.

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