

The Effect of Multi-Species Herbivory on Shoot Growth in Gorse, *Ulex europaeus*

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Several foliage-feeding herbivores are being considered for the classical biological control of gorse, *Ulex europaeus*, an introduced weed in New Zealand. Little information is available on the impact of these herbivore species, either singly or in combination, on the growth of gorse in its native range. In this paper, the number and combination of species of herbivores were experimentally manipulated in sleeves on gorse shoots, and subsequent shoot growth measured over 3-5 wks. Growth of gorse seedlings was reduced in the presence of *Sericothrips staphylinus* but unaffected by *Dictyonota strichnocera* or by artificial clipping. In contrast, growth of shoots on gorse bushes was reduced by *D. strichnocera* and *Tetranychus lintearius* but unaffected by *S. staphylinus* or artificial clipping, at the intensities of attack we used. When species were used together, the interaction terms revealed that *D. strichnocera* and *T. lintearius* combine additively to reduce shoot growth in gorse bushes. Artificial clipping appeared to have an erratic effect on the growth of gorse shoots, possibly even causing growth increases in some treatments.

Introduction

Gorse, *Ulex europaeus* L. (Fabaceae), is a spiny leguminous shrub that has become a serious weed in several areas of the world after introduction from its native range in Europe (Hill 1986). In Europe it is not normally regarded as a weed and is attacked by a range of herbivores (Hill 1982). Several of these herbivorous insects or mites have been considered for use as biological control agents against gorse in New Zealand. However, little is known about the impact of these herbivore species on gorse either acting singly or in combination. In general, although plants are often affected by a number of herbivore species simultaneously, the way that these effects combine has received far less attention than the impact of single species of herbivores. Evidence from weed biological control indicates that most programmes have relied on several agents (Harris 1981). Ideally, these agents are selected to attack different plant parts, plants of different ages or in different seasons, on the assumption that the impact of these agents will combine additively to stress the plant (Harris 1981). An alternative

hypothesis is that usually only 1 agent is necessary for successful weed biological control but that, because our abilities to predict successful agents are so poor, we have to introduce a number of agents as a form of lottery (Myers 1985). Several studies of the impact of potential or actual weed biological control agents have recently been conducted or are underway (e.g., Forsyth and Watson 1985, McEvoy *et al.* 1990, Muller *et al.* 1988, Pecora and Dunn 1990) and should provide further evidence to assess these alternative hypotheses.

However, perennial plants such as gorse, that can live for over 20 yrs, require equally long-term experiments to assess the real impact of herbivores on the population dynamics of the plant. Given constraints of time and funding, such very long-term studies will seldom form part of biological control programmes. In this study, we deliberately looked at the effect of single and multi-species herbivory on short-term shoot growth in gorse seedlings and bushes. With gorse bushes, we used a large number of shoots on each gorse bush on the assumption that the responses of these shoots would be

independent. Given the modular nature of plant growth and the short term nature of this experiment we regard this assumption as reasonable. Whether short-term effects by herbivores on growth of gorse shoots are likely to influence longer-term success of the plant is an issue to which we return in the Discussion.

The current gorse biological control programme has investigated a range of possible agents. These have included mesophyll feeders such as the gorse mite, *Tetranychus lintearius* Dufour (Acari: Tetranychidae), the gorse lace bug, *Dictyonota strichnocera* Fieb. (Hemiptera: Tingidae), and the gorse thrips, *Sericothrips staphylinus* Haliday (Thysanoptera: Thripidae) as well as several species of external feeding Lepidoptera (Hill 1986). All 3 mesophyll feeders were available from the field or from stock cultures, but larvae of the lepidopteran species are not normally abundant on gorse. Attack by lepidopteran larvae was therefore simulated by clipping gorse foliage. The gorse herbivore fauna around Silwood Park was studied extensively for 3 yrs by Hill (1982) who found that the peak levels of abundance for foliage feeding herbivores were normally low, perhaps because of the unusually low protein content of the foliage. Hence, we chose to limit our manipulations to relatively low numbers. All these herbivore species can be found simultaneously on gorse in the UK so the combinations of species used in this study are not unusual. In the first experiment, using seedlings, we varied the intensity of attack using single species of herbivores or artificial damage. In the second experiment, with gorse bushes, we used only 1 level of attack/species but exposed the shoots to factorial combinations of attack from up to 3 herbivore species and artificial damage.

Methods

Experiment I: Gorse Seedlings

Sixty gorse seedlings, grown in pots for 1 yr from the same seed stock and with similar growth forms and appearance, were selected. Total shoot length was measured and the plants transferred on 20 May 1990 to individual vented plant propagators, in a controlled environment

room at 18°C and 70 % RH with an 18 h daylength. Five levels of each of 3 treatments were applied at random to the seedlings with 4 replicates at each level. The treatments were: 1.) addition of *S. staphylinus* adults; 2.) addition of 3-4 instar nymphs of *D. strichnocera*; and 3.) clipping to simulate damage by lepidopteran larvae. For each treatment, levels of 0, 1, 5, 10 or 20 herbivores or clippings were applied/seedling. Each clip removed 1 spine and the clippings were spread evenly over the shoots. Insects were collected from field sites near Silwood Park and maintained on potted gorse plants until required. The required numbers of insects were collected into gelatin capsules using a brush or minipooter. The capsules were then opened and placed on a seedling, allowing transfer of the herbivores with minimum disturbance. The seedlings were maintained for 20 d after which shoot lengths were again measured, allowing total shoot extension to be calculated.

Experiment II: Gorse Bushes

Three similar gorse bushes were used, each 1-1.5 m high and 4-5 yrs old. The plants originated as potted gorse plants from the same stock at Silwood Park and were planted outside in 1989. Actively growing shoots, or groups of adjacent shoots, that could be independently sleeved, were selected on each plant and labelled on 15 June 1990. Existing shoot growth was measured. Shoot length was then re-measured after 20 d to give a pre-treatment level of shoot growth immediately before the experiment. The 4 treatments comprised the addition of 3 species of herbivores or application of artificial clipping to simulate lepidopteran damage. The treatments were applied at 1 level consisting of 8 individual herbivores or clipped spines. The experimental design was factorial so that each gorse bush received 1 replicate of each possible combination of treatments (Table 1). The combinations were randomly allocated to the sleeved growing points. Two sleeves/bush were left empty to serve as controls. Herbivore transfer and clipping was carried out in an identical manner to the seedling experiment. The experiment was terminated after 34 d and total shoot growth

measured. The number of herbivores remaining on the shoots was recorded.

Results and Discussion

Experiment I: Gorse Seedlings

The shoot extensions achieved by seedlings while subjected to the treatments were expressed as a percentage of the total previous shoot length of each seedling are shown in Fig. 1. Only the addition of thrips appeared to influence seedling growth, causing a reduction in overall shoot extension that approached statistical significance (Fig. 1a, $0.05 < P < 0.1$).

Whether reduction in growth over this short time period is likely to influence the long-term growth or success of gorse seedlings is uncertain. Reduction in growth, even in the short term, may be significant if gorse seedlings are competing with other plants. We do not know whether the attack levels used in this study are likely to be maintained over long time periods or whether seedlings are capable of compensatory growth responses to herbivory. Indeed, we do not even know if the levels of attack used here are likely to be achieved on seedlings in the field in the UK. Furthermore, we cannot predict the possible attack levels that herbivores may reach when released as biological control agents. However, the results of this experiment do at least suggest that *S. staphylinus* can influence the growth of gorse seedlings even if the insect does not build up to the high densities that can be observed damaging or killing gorse plants in stock cultures. Although only 1 of the herbivore species used in the seedling experiment

appeared to have any effect on seedling growth, we do not know if combinations of the herbivore species could be more effective. Possible interaction was investigated using shoots on gorse bushes in Experiment II.

Experiment II: Gorse Bushes

Shoot growth was clearly reduced in the presence of herbivores and this reduction increased broadly with increased numbers of herbivore species (Fig. 2).

To distinguish between the effects from the different treatments and to examine the way that the treatments interact, we used an ANOVA on total shoot extension with 2 covariates (existing current year's growth and growth in the 20 d before treatment). The means of treatments and treatment combinations from the ANOVA are given in Table 2.

The ANOVA showed that the addition of *D. strichnocera* or *T. lintearius* significantly reduced the growth of gorse shoots in contrast to the lack of effect these 2 species appeared to have on seedlings. The lack of significant interaction terms when *D. strichnocera* and *T. lintearius* were combined, with or without further treatments, indicates that the reductions in growth on gorse bushes caused by these herbivores combine additively. The result suggests that, even at relatively low densities such as used in this experiment, simultaneous attack from these 2 species of mesophyll-feeders may be desirable in a gorse biological control programme. If very high densities are achieved, observations from stock colonies indicate that the dense webbing of *T. lintearius* will exclude most other herbivores.

Table 1. The combinations of impact treatments used on gorse bushes. Each of the 15 combinations was used once on each of 3 bushes, with 2 additional shoots/bush as untreated controls.

Single Treatments	Combinations of	
	2 Treatments	3 & 4 Treatments
1. Clipping (C)	5. C+D	11. C+D+S
2. <i>Dictyonota strichnocera</i> (D)	6. C+S	12. C+D+T
3. <i>Sericothrips staphylinus</i> (S)	7. C+T	13. C+S+T
4. <i>Tetranychus lintearius</i> (T)	8. D+S	14. D+S+T
	9. D+T	15. C+D+S+T
	10. S+T	

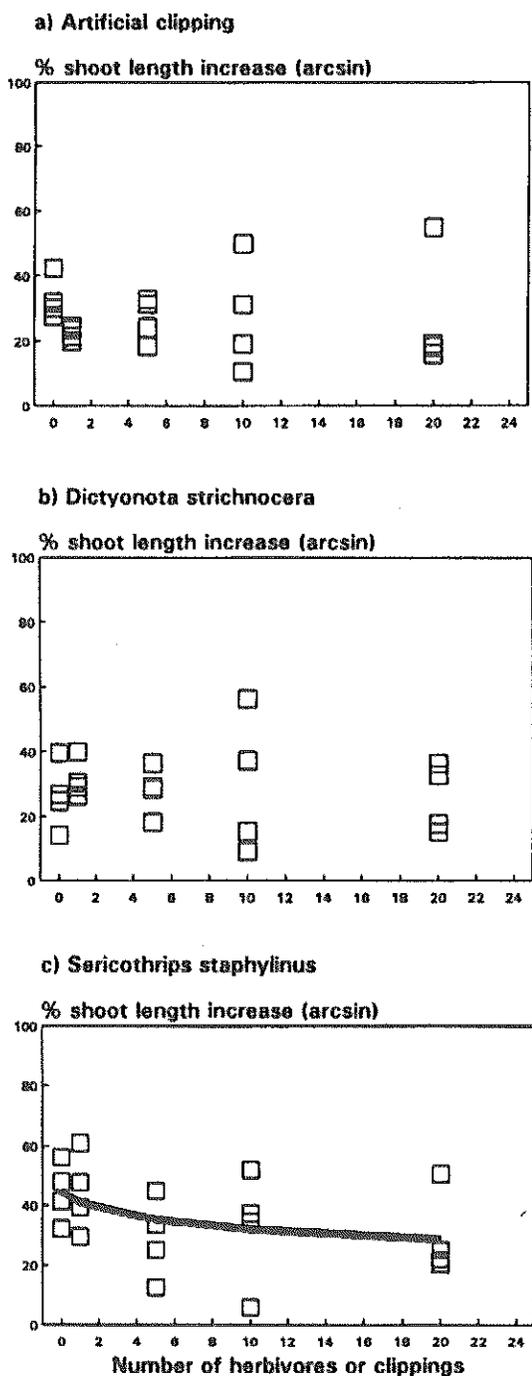


Figure 1. The reduction in growth of gorse seedlings over 20 d caused by variable numbers of 3 herbivore species (including artificial damage). (Only the application of *Sericothrips staphylinus* [c] caused any decrease in growth of the seedlings [$0.05 < P < 0.1$, $y = -11.9 \log x + 44.6$]).

Likewise, high levels of attack by *S. staphylinus* or *D. strichnocera* can severely damage gorse plants in laboratory conditions, making the plants unsuitable for other herbivores.

No significant main effects were revealed for either *S. staphylinus* or artificial clipping, although mean growth with *S. staphylinus* was reduced (Table 2). However, the presence of a significant interaction term for *S. staphylinus* and clipping complicates the interpretation of the effects of these treatments. Clipping appears to have a highly variable effect on shoot growth, in some cases apparently causing an increase. Clipping is likely to be a poor simulation of attack from any particular lepidopteran. It would be premature, therefore, to suggest that the several species of foliage feeding Lepidoptera under consideration for biological control of gorse might be ineffective. The lack of any growth reduction attributable to *S. staphylinus*, either alone or in combination with other species, is an interesting contrast to the result from the seedling experiment. It is possible that this difference reflects a difference in the effectiveness of the thrips on gorse seedlings and bushes. However, it is hard to confine small mobile herbivores such as thrips in sleeves: an average of only 3 adult *S. staphylinus* were recovered from the sleeves of the original 8 that were introduced. In contrast, adult thrips seldom leave a seedling unless the plant is unhealthy.

Conclusions

All 3 herbivore species used in this study can damage gorse plants at high levels of attack and this is 1 of the reasons why these species are regarded as promising biological control agents. The present study shows that these 3 species can reduce growth of gorse shoots even when present in much lower numbers. Given the normally very low protein content of gorse foliage (Hill 1982), low levels of attack by most foliage feeding agents may be an unavoidable feature of attempts to control gorse biologically. The results demonstrate reductions in growth over only a short time period, which cannot be

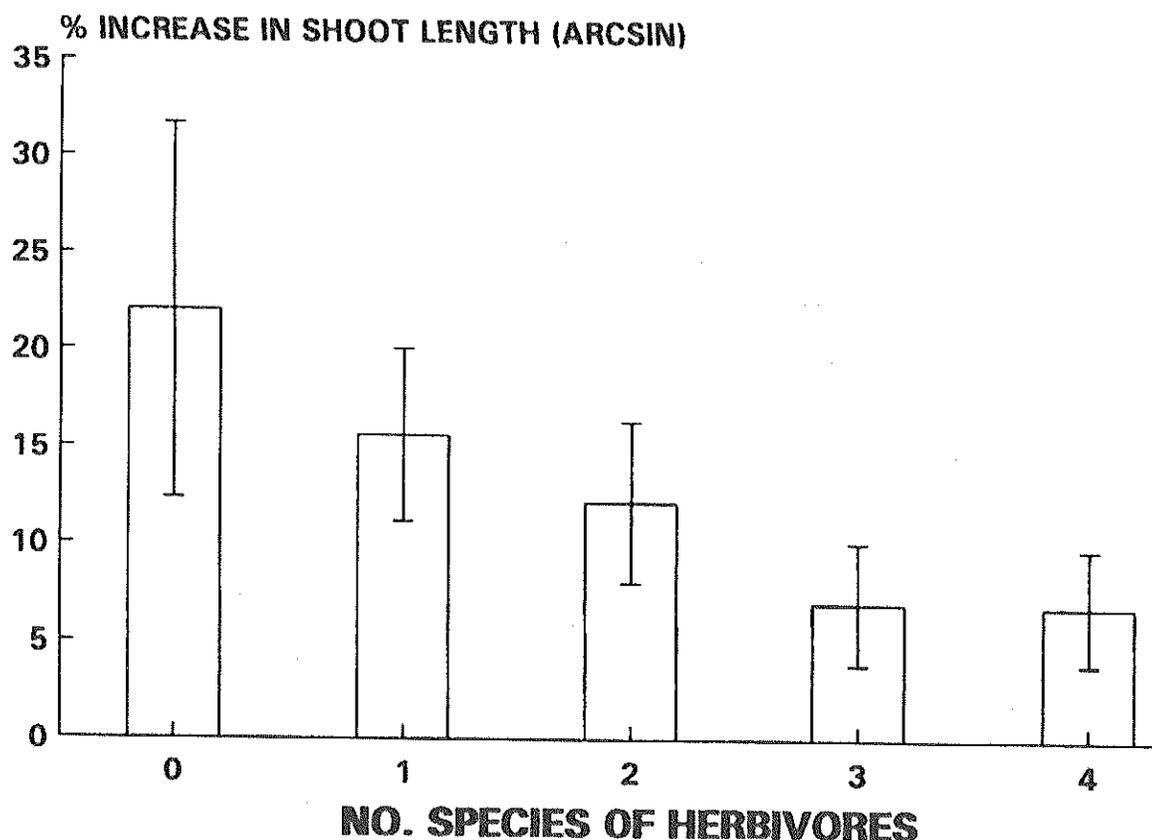


Figure 2. The reduction in shoot growth in gorse bushes over 34 d caused by combinations of up to four herbivore species (including artificial damage), each at 1 level of intensity. (Shoot extension is expressed as a percentage of existing shoot growth in 1990; error bars are 95% confidence limits; further details in the text.)

used to predict reliably any longer term effects on plant performance (Myers *et al.* 1990). Long-term effects on performance in a long-lived plant would require long-term experiments and even then may not allow extrapolation to effects on the population dynamics of the plant (Crawley 1989). Despite these problems, the current results do provide some evidence that all 3 agents considered here would be useful for gorse biological control, either to attack different stages of the plant or to combine in simultaneous attack on mature gorse bushes.

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Table 2. Mean shoot growth (cm) of growing points of gorse bushes with herbivores and artificial clipping applied as in Table 1.

Treatment Combination	Mean Growth	
	Without Treatment Combination	With Treatment Combination
Main effects		
Clipping (C)	16.75	16.46
<i>Dictyonota strichnocera</i> (D)	25.92	7.29 ¹
<i>Sericothrips staphylinus</i> (S)	20.88	12.33
<i>Tetranychus lintearius</i> (T)	22.25	10.96 ¹
2-way interactions		
C+D	25.00	6.08
C+S	26.33	17.50 ²
C+T	19.58	8.00
D+S	32.67	5.50
D+T	34.42	4.50
S+T	26.42	6.58
3-way interactions		
C+D+S	19.08	6.00
C+D+T	19.21	4.00
C+S+T	18.94	8.33
D+S+T	19.17	4.67
4-way interaction		
C+D+S+T	18.31	4.33

¹ $p < 0.01$, ² $p < 0.05$

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