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Vegetation management in changing landscapes

Use of herbicides to control weeds and promote the natural regeneration of *Fagus sylvatica*

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Summary

An experiment was established to investigate the effect of different herbicide treatments on the growth of naturally regenerating *Fagus sylvatica* seedlings and weed vegetation. Initially all of the herbicides used produced some damage to the vegetation in the ground flora of the beech wood, but effects were short lived and no significant differences between treatments in the cover of plant species were found. Triclopyr appeared to be the most effective herbicide for controlling *Rubus fruticosus*, but it may have resulted in the proliferation of *Carex remota*. Herbicide treatments containing paraquat caused tip die-back and delayed emergence of *Fagus sylvatica* seedlings which showed a smaller height increment than in other treatments. Stem diameter increment and the decline in seedling numbers were not related to treatment. Herbicides may have the potential to control weeds during the process of natural regeneration but more observations are required.

Key words: Beech, bramble, natural regeneration, herbicides, triclopyr, paraquat, glyphosate

Introduction

In the United Kingdom natural regeneration has recently become a popular method for restocking broadleaved woodlands but it is a process beset with problems which can be difficult to overcome. Increased light levels produced by thinning during the process of regeneration to promote established seedling survival and growth (Harmer *et al.*, 1997), can have the side effect of promoting the growth of the ground flora already present in many woodlands. This can proliferate to such an extent that it hinders or prevents satisfactory restocking. This is often the case in oak and beech woods where an initially sparse cover of bramble (*Rubus fruticosus*) can expand rapidly, colonising the whole site and suppressing any tree seedlings present which generally grow rather slowly.

In woodlands where litter accumulates on the forest floor to form a thick organic horizon, it is often necessary to manipulate the site using ground preparation to expose the mineral soil, providing a substrate into which seedlings can root (Evans, 1988). The importance of this procedure for the regeneration of beech growing on clay soils in the Chilterns is well-known, and has been applied in the shelterwood system used at the site where the following experiments took place. Although ground preparation is necessary to provide a rooting medium and protect seed from predation, the disturbance to the soil stimulates the germination of weed seeds present in the seed bank increasing the quantity and variety of weed species present, but this ground flora typically degenerates to one dominated by bramble. The following experiment was designed to investigate whether simple herbicide treatments could be used to promote growth of beech seedlings by reducing competition from bramble and other weeds.

Materials and Methods

The experiment took place in a mature Chiltern beech wood near Stokenchurch, Oxfordshire, UK (grid ref SU775954) which is being restocked by natural regeneration using a uniform shelterwood system (Pakenham, 1996). In autumn 1997 eighteen 1 × 5 m plots were established in an area with young beech seedlings that had germinated following the 1995 mast. The following six treatments were applied at random to the plots; there were three replicates of each treatment arranged in a fully randomised design.

(a) Tric = triclopyr, as Timbrel (480 g l^{-1} triclopyr, Dow AgroSciences, UK), at 2 l ha^{-1} (0.96 kg ai ha^{-1}), December 1997.

(b) Gly = glyphosate, as Roundup ProBiactive (360 g l -1 glyphosate, Monsanto, UK), at 1.5 l ha^{-1} (0.54 kg ai ha^{-1}), December 1997.

(c) Para = paraquat, as Gramoxone 100 (200 g l^{-1} paraquat, Zeneca, UK), at 5.5 l ha^{-1} (1.1 kg ai ha^{-1}), December 1997.

(d) PI = paraquat at 5.5 l ha^{-1}, December 1997, followed by isoxaben, as Flexidor 125 (125 g l^{-1} isoxaben, , Dow AgroSciences, UK), at 2.0 l ha^{-1} (0.25 kg ai ha^{-1}), March 1998.

(e) PAC = paraquat at 5.5 l ha^{-1}, December 1997, followed by tank mix of atrazine, as Atlas Atrazine (500 g l^{-1} atrazine, Atlas Crop Protection, UK), at 5 l ha^{-1} (2.5 kg ai ha^{-1}) with cyanazine, as Fortrol (500 g l^{-1} cyanazine, Cyamamid, UK) at 4 l ha^{-1} (2 kg ai ha^{-1}), March 1998.

(f) Control.

Triclopyr is a foliar acting woody weed killer. It was chosen as Willoughby & Dewar (1995) suggest that at rates used for bramble control (0.96 kg ai ha^{-1}) established beech transplants may be tolerant (2.88 kg ai ha^{-1} required to kill beech). Glyphosate is a broad spectrum foliar acting herbicide which will control bramble at 1.08 kg ai ha^{-1} (Willoughby & Dewar, 1995), but has been shown to be safe to apply over dormant young transplants in some situations at up to 1.62 kg ai ha^{-1} (Willoughby, 1996). Paraquat had also been shown to be safe as a dormant season spray (Willoughby, unpub). It is a broad spectrum foliar acting herbicide but is not translocated – it was anticipated that it would offer the best tree tolerance of the foliar herbicides tested here in the dormant season, but with less control of the bramble. Isoxaben and atrazine plus cyanazine were added as residual herbicides that should prevent the re-seeding of bramble (Clay & Dixon, 1996 unpublished). Although there is a reasonable amount of information on the tolerance of transplanted tree seedlings to herbicides, there is little evidence on their effect on young naturally regenerated tree seedlings. All herbicides have full approval for use in forest situations (Willoughby and Clay, 1999).

Visible herbicide damage to the vegetation present in the plots was assessed on four occasions during spring and summer 1998, but no attempt was made to estimate the amount or severity of damage. Cover of individual species present in each plot was observed in June 1998 and July 1999. The number of seedlings present and the height of 20 randomly selected seedlings were recorded in winter 1997 and 1998. Damage assessments were analysed using Generalised Linear Modelling with a binomial distribution: vegetation cover, seedling number, height and stem diameter increments were investigated by analysis of variance using Genstat (Genstat 5 Committee, 1993).

Results

Vegetation cover

There were 10 species present on the plots at the end of March 1998. The number had increased to 17 by June 1998, but the mean cover of most was less than 1%. The species with mean percentage cover scores exceeding 5% on any plot are shown in Table 1. Two species, *Digitalis purpurea* and *Oxalis acetosella* had disappeared by summer 1999. Most species showed little change in cover between years but there were some exceptions (Table 1): *D. purpurea* declined markedly in Control plots – this is associated with its biennial habit; *Carex remota* declined by about half in Tric plots but there was large variation between plots; *Rubus fruticosus* increased in 1999 in all treatments, the relative increases being least in the control (60%) and greatest in the Tric (325%). Cover of *C. remota* was greater in Tric than other treatments in both 1998 and 1999. In contrast *R. fruticosus* cover in Tric plots was the lowest of all treatments in 1998 but by 1999 was similar. However, for both *C. remota* and *R. fruticosus* there was large variation between plots within treatments and despite the large differences in mean cover scores, there were no significant differences between treatments in both 1998 and 1999, (Table 1).

Table 1. *Mean percentage cover of the most abundant species present on the herbicide plots in summer 1998 and 1999*

		Control	Gly	Para	PAC	PI	Tric	Statistics
Remote sedge *(Carex remota)*	1998	4.3	1.5	2.3	2.8	8.3	21.3	NS p=0.13
	1999	3.8	1.6	3.5	3.8	8.8	11.8	* p=0.02, SED 5.8
Foxglove *(Digitalis purpurea)*	1998	19.6	0	0.2	0	0.3	1.6	+
	1999	0	0	0	0	0	0	
Bramble *(Rubus fruticosus)*	1998	25.8	17.9	9.3	18.0	13.7	7.8	NS p=0.64
	1999	43.2	37.2	31.1	43.1	46.7	33.8	NS p=0.86
Raspberry *(Rubus idaeus)*	1998	0.3	0.6	2.7	2.2	1.7	0.2	NS p=0.69
	1999	0.1	0.6	6.6	7.0	10.5	0.0	NS p=0.16
Beech *(Fagus sylvatica)*	1998	53.8	64.4	50.8	53.2	30.2	35.7	NS p= 0.36
	1999	56.0	68.8	62.8	52.2	33.2	35.9	NS p= 0.37

NS = no significant differences between means within rows at p value given; * significant at p value given; S.E.D. = Standard error of difference between means (for significant results only); + = too few plots with cover and no analyses carried out.

Herbicide damage

The presence of damage varied with time of recording, herbicide and species: analyses showed that the presence of any damage to any species differed significantly between treatments at all dates (Table 2).

In general, the frequency with which any damage occurred was greatest in the Para, PAC and PI treatments. The occurrence of visible damage declined during summer and by September was only obvious on *Fagus sylvatica* seedlings. There were too few data to investigate species herbicide interactions properly but the analyses indicated that all species were less frequently damaged by Tric than other herbicides. All treatments containing paraquat caused tip die back and delayed flushing of *F. sylvatica* seedlings on all plots. Some glyphosate damage was apparent on one plot in June and September. Similarly, damage which may have been caused by triclopyr was seen on only one plot at one date in summer.

Table 2. *Estimates (± standard error) of predicted occurrence of any damage caused by herbicides to any species at different dates in 1998*

	Control	Gly	Para	PAC	PI	Tric	Prob.
26 March	0.00	0.22 ±0.14	0.30 ±0.15	0.38 ±0.17	0.38 ±0.17	0.00	P<=0.05
13 May	0.00	0.29 ±0.11	0.50 ±0.14	0.73 ±0.13	0.55 ±0.15	0.20 ±0.10	P<=0.001
16 June	0.00	0.48 ±0.11	0.32 ±0.10	0.65 ±0.12	0.50 ±0.12	0.20 ±0.10	P<=0.001
September	0.00	0.10 ±0.06	0.19 ±0.10	0.19 ±0.10	0.36 ±0.13	0.00	P<=0.01

Fagus sylvatica *seedlings*

At the start of the experiment there were about 250 seedlings present in each plot but this number declined to about 180 during 1998. Although there were large differences between treatments in the numbers of seedlings initially present and at the end of 1998 they were not statistically significant (even when differences in vegetation cover was used as a covariate in the Anova). Initially seedlings were about 15 cm tall with stem diameters of 1.2 mm. During 1998 there was a negligible increase in stem diameter that did not differ between treatments (Table 3). In contrast there were significant differences in height increment between treatments, the greatest of about 6 cm occurring in the Control treatment with seedlings in the PI treatment showing no increment (Table 3).

Table 3. *Number of seedlings, and mean 1998 increment in height and stem diameter of* Fagus sylvatica *seedlings in plots receiving different herbicide treatments*

	Control	Gly	Para	PAC	PI	Tric	sig, p, **S.E.D.**
Number							
Start	281	254	302	255	178	207	NS, p=0.56, –,
1998	225	196	227	194	112	111	NS, p=0.35, –,
Increment							
Stem diameter	0.92	1.23	1.17	1.01	0.72	1.06	NS, p=0.39, –,
Height	5.8	4.2	1.2	2.3	0	3.6	*, p=0.04, **1.7**,

sig = level of significance of difference between means within row; NS = not significant; * = p<=0.05. S.E.D. = Standard error of difference between means, 12 degrees of freedom.

Discussion

The distribution of vegetation on the experimental site was heterogeneous and many of the species present occurred in fewer than half of the plots. Even some of the abundant species listed in Table 1 were absent from some plots. The mean cover of most species was less than 2%, but there was also considerable variability for the most abundant species. This heterogeneity in both distribution and cover across the site resulted in large within treatment variation and fewer statistically significant treatment effects than would be anticipated from the mean values presented in the tables. However, the quantitative differences between some of the means suggests that treatments had some effects that may become more obvious following further study.

The growth habit of the species studied differs and complicates interpretation of treatment effects. All except *D. purpurea* are long-lived perennials: *C. remota* is a densely tufted sedge; *R. idaeus* spreads by rhizomes; and *R. fruticosus* produces long stolons that can grow by several metres in one year. Although no distinction was made between cover arising from plants rooted inside the plots and those outside, it was clear that most cover of *C. remota* and *R. idaeus* was from plants within the plots, but *R. fruticosus* arose from plants rooted both inside and outside. Herbicides may have had a marked effect on *R. fruticosus* within the plots but this was probably masked by production of shoots from plants rooted outside. Any effect of the residual herbicides on subsequent germination of bramble was also masked.

Herbicide Effects

All herbicides had some effect on the vegetation present: the frequency with which damage was caused, and the influence on vegetation cover varied, but observations were generally consistent with known effects of the herbicides used (Willoughby & Dewar, 1995): for example, relative to Control treatment, Tric had a large adverse effect on the cover of *R. fruticosus*, but conversely *C. remota* was unaffected and apparently increased in abundance. The differential effects of Tric on these species caused a shift in vegetation type to one dominated by a sedge which has been observed to have a severe effect on the survival of *F. sylvatica* seedlings (Pakenham, 1996); but the absence of a covariate effect for *C. remota* cover in the analysis of seedling numbers suggest that it did not have an important effect over the duration of this experiment. The visibility of herbicide damage generally declined as the growing season progressed, but the converse was true for *F. sylvatica* seedlings which were leafless when the treatments were applied. The obvious failure of the terminal bud, tip dieback, and delayed leaf and shoot emergence from living, more basal, buds in the Para, PAC and PI treatments, indicate that dormant season application of paraquat can damage small, naturally regenerating *F. sylvatica* seedlings. These observations are consistent with practical trials carried out elsewhere on the site (Pakenham, personal communication). This damage to *F. sylvatica* seedlings was unexpected as dormant tree seedlings are usually thought to be tolerant of paraquat : the reasons for the damage are unclear but may be related to the size, development and physiological state of small, naturally-regenerating, *F. sylvatica* seedlings growing beneath a woodland canopy.

Seedling Numbers and Growth

Although some treatments damaged *F. sylvatica* seedlings this had no significant effect on survival or stem increments. Mean seedling height increments in 1998 were influenced significantly by treatment. The smallest increments, which occurred in treatments containing paraquat, were the result of death of the terminal bud and dieback of the shoot tip. Although not statistically significant, seedling numbers fell by around 50% to the end of 1998 in the triclopyr treated plots. The experiment did not show that the subsequent invading vegetation had a significant effect, and there were few signs of herbicide damage. One possible explanation for this drop in numbers is that substantial seedling mortality resulted from the herbicide treatment, and as dead stems rotted they may not have been evident by the time of the March assessment. The absence of any large effects on the growth and survival of *F. sylvatica* seedlings in the year following treatment suggests that any effects of herbicide, either directly by causing damage, or indirectly by an influence on the growth of other vegetation, were small in comparison to other factors influencing establishment (e.g. shade from overstory trees and summer drought). However, initial cover of weed species was low and results may be different on sites with larger amounts of weed.

Conclusions

Results are only indicative but they suggest that Triclopyr can be used to control bramble amongst dormant, naturally regenerating *F. sylvatica* seedlings. However, any reduction of bramble will be short-lived unless large areas are treated. Beneficial effects on seedling growth may be small if spot weeding treatment is practised, as bramble rapidly reinvades from untreated areas. Repeated overall treatment for at least 2 years may be required to allow establishment of young seedlings. Further studies are required treating larger areas of more extensive bramble cover, treating different tree species and investigating the effect of repeat treatment of promising herbicides such as triclopyr with and without the confounding effects of subsequent alternative vegetation invasion. Additional experiments investigating physical pulling of the bramble, on a larger scale in an area adjacent to this experiment, appeared to give little control over bramble over the same period of time.

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