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Original article

Effects of field vegetation control on pine weevil (*Hylobius abietis*) damage to newly planted Norway spruce seedlings

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Abstract – We investigated interactions between field vegetation and seedling damage caused by a major insect pest, the pine weevil *Hylobius abietis* (L.), in an experiment established on a clear-cut area in southern Sweden. Scarification was performed on three occasions (May and August 1998, May 1999) and Norway spruce seedlings were planted on three occasions (August 1998, May and August 1999). To keep the mineral soil open, field vegetation and mosses were removed using herbicides. In total, seven different soil treatments including planting in untreated soil were included. Damage to seedlings by the pine weevil and vegetation around each seedling was monitored 1–2 months after each planting. Fresh scarification significantly reduced pine weevil damage and increased seedling survival. However, the open mineral soil was gradually colonised by hairy grass (*Deschampsia flexuosa)* and the damage-suppressing effect of scarification was reduced with time. Herbicide treatment removed field vegetation and reduced pine weevil damage significantly, especially when there was a long period between scarification and planting. We conclude that vegetation in-growth was the main factor decreasing the effect of scarification on weevil damage.

***Hylobius abietis* / *Picea abies* / seedling damage / scarification / field vegetation**

Résumé – Effets du contrôle de la végétation basse sur l'importance des dégâts dus à *Hylobius abietis* sur des plants d'épicéa commun venant d'être plantés. Nous avons étudié les interactions entre végétation basse et dégâts aux jeunes plants provoqués par l'important insecte ravageur *Hylobius abietis* dans une expérience installée sur une coupe à blanc située en Suède méridionale. On a procédé à une scarification à trois dates différentes (mai et août 1998, mai 1999), de même pour l'installation des plants d'épicéa commun (août 1998, mai et août 1999). Pour garder le sol propre, on a utilisé des herbicides pour détruire la végétation basse et les mousses. Il en a résulté au total sept traitements différents y compris un témoin, c'est-à-dire plantation sans autre intervention. On a observé les dégâts d'hylobe et la végétation autour de chaque plant, 1 à 2 mois après plantation. Une scarification récente réduit de manière significative les dégâts d'hylobe et améliore le taux de survie. Cependant, le sol nu a été progressivement colonisé par *Dechampsia flexuosa*, et l'action bénéfique de la scarification s'est progressivement atténuée. Le traitement herbicide a détruit la végétation basse et diminué les dégâts d'hylobe de manière significative, en particulier lorsque scarification et plantation sont très espacées dans le temps. Nous en concluons que la repousse de la végétation est le facteur principal expliquant la baisse de l'effet de la scarification sur les dégâts de bostriche.

***Hylobius abietis* / *Picea abies* / dégâts sur les plants / scarification / végétation basse**

1. INTRODUCTION

The performance of planted tree seedlings can be adversely affected by other vegetation, not only through competition for resources, but also through a range of indirect effects [7]. For example, there appear to be interactions between field vegetation and seedling damage caused by a major insect pest in Europe, the pine weevil (*Hylobius abietis* (L.) [12].

Adult pine weevils feed on the stem bark of coniferous seedlings, causing high mortality and, thus, great economic losses [2]. Damage by the pine weevil is the most serious obstacle to successful regeneration in large parts of boreal forests in northern Europe. Mortality often reaches 60–80% if seedlings are planted without protection and previous scarification [11]. The insect is favoured by clear-cutting because large amounts of breeding material (roots of fresh coniferous stumps) are created each year, and the harvested areas can usually be readily reached by the pine weevils, which can disperse over long distances.

Insecticide protection of the seedling usually keeps damage at an acceptable level. However, the use of insecticides for this purpose is questioned today, and the insecticide generally used in Sweden (permethrin) will be prohibited in the European Union at the end of 2003. Weevil abundance is highest and attacks on seedlings are most serious in the first 3–4 years following cutting [10, 11]. Delaying planting is therefore an effective way of reducing pine weevil damage [4, 11, 14].

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However, delaying planting usually results in severe competition from ground vegetation [6].

Scarification reduces damage to seedlings by pine weevils significantly compared to planting in undisturbed humus [5, 11, 13]. This reduction in damage is usually most evident in the first year after planting [11]. The reduction in feeding is strongest if the seedling is surrounded by pure mineral soil [1] and less pronounced if the mineral soil is mixed with pieces of the humus layer [12].

Pine weevils move faster on mineral soil than on humus and thus spend less time on areas with mineral soil [3]. The weevils may avoid staying on bare mineral soil because of the risk of overheating due to sudden exposure to solar radiation [1] and/or because of the greater risks of predation on this substrate. Therefore, it is likely that the benefits of scarification will be lost if the scarified areas are invaded by vegetation [9]. Örlander and Nilsson [11] found that even for mounds prepared on fresh clear-cuttings this "ageing effect" was evident, although there were only small amounts of vegetation on these sites. Observed changes over time on scarified patches or mounds, besides the establishment of field vegetation, include the accumulation of litter, and compaction of the soil surface. Örlander and Nilsson [11] concluded that it is unclear how vegetation near the seedling affects pine weevil damage, and the processes involved should be investigated further.

Usually, clear-cuts in southern Sweden are invaded by hairy grass (*Deschampsia flexuosa*) but it often takes some years before they are fully colonised with the grass [6]. Scarified areas are colonised by hairy grass too, but also with several other types of field vegetation. In addition, mosses commonly colonise the mineral soil.

This study concentrates on the relationship between seedling damage and the establishment of vegetation cover close to the seedling. The following questions were addressed. Does field vegetation (especially hairy grass) reduce the protective effect of scarification against pine weevil damage? If so, is this reduction proportional to the vegetation cover? Do mosses reduce the protective effect to the same extent as grass, if the coverage is the same? Finally, does the damage-suppressing effect of scarification disappear so rapidly with time that it is essential to plant immediately after scarification?

Different levels of vegetation cover around the seedlings were obtained by varying the time between site preparation and planting, and by including herbicide treatments.

2. MATERIALS AND METHODS

2.1. Description of the sites

The experiment was established in 1998-1999 on a clear-felled area harvested in winter 1996/97 at Asa experimental forest (57° 10' N, 14° 47' E) in the south-central part of Sweden. The previous forest was a 105-year-old mixed stand of Norway spruce and Scots pine. The soil was classified as podzolic, sandy till and the soil moisture class was mesic.

2.2. Treatments

Scarification was done by hand in patches of 50 × 50 cm on three different occasions. The experiment was laid out in randomised blocks, with seven different soil treatments and 51 replications per treatment. The soil treatments were:

(1) Untreated humus, not scarified;
(2) Mineral soil, scarified in May 1998;
(3) Mineral soil, scarified in May 1998, treated with Roundup;
(4) Mineral soil, scarified in May 1998, treated with $FeSO_4$;
(5) Mineral soil, scarified in May 1998, treated with Roundup + $FeSO_4$;
(6) Mineral soil, scarified in August 1998;
(7) Mineral soil, scarified in May 1999.

In treatments 3 and 5 the field vegetation was removed by applying a herbicide (Roundup, 3% solution, 50 ml per patch). Mosses were removed (treatments 4 and 5) using Weibulls MossVäck (consisting of 96% $FeSO_4$), at a dose of 0.6%, 250 ml per patch. The chemical treatments were applied whenever necessary to keep the patches free from vegetation. Thus, the Roundup treatment was applied on five occasions (August and September 1998; March, April and June 1999). Planting/replanting was done on three occasions (August 20, 1998, May 10, 1999 and August 10, 1999). Containerised Norway spruce seedlings (provenance Vitebsk) were used. The average (± SD) height and diameter of the seedlings planted in August 1998 was 25.9 ± 4.1 cm and 3.9 ± 0.6 mm, respectively. Corresponding values for seedling planted in May 1999 was 25.3 ± 4.3 cm and 3.8 ± 0.8 mm, and in Aug. 1999 18.7 ± 3.1 cm and 3.3 ± 0.6 mm. When replanting, all old seedlings (both dead and living ones) were removed and new ones were planted in the same spot. Two seedlings were planted in the central part of each patch.

2.3. Measurements

Height and diameter at stem base were recorded on October 5, 1998, June 6, 1999 and October 12, 1999. Pine weevil damage was recorded using a 6-level scale where 0 = undamaged, 1 = slightly damaged, ..., 4 = severely damaged and 5 = dead. Feeding by pine weevils was also recorded by estimating the amount of bark on each seedling consumed (in 0.1 cm^2 units). The field vegetation and moss cover were recorded in each patch or in a 50 × 50 cm area around the control seedlings. At the same time the dominating species in each patch was recorded. Field vegetation was also recorded on August 20 before the first planting.

After the first experimental period (August–October 1998) the mean height and diameter of the seedlings were 25.9 ± 4.1 (SD) cm and 3.9 ± 0.6 mm, respectively. The corresponding values after the second period (May–June 1999) were 25.3 ± 4.3 cm and 3.8 ± 0.8 mm, and those for the third period (August–October 1999) were 18.7 ± 3.3 cm and 3.1 ± 0.6 mm.

2.4. Calculations and statistical analysis

The mean cover (± standard error) of field vegetation and mosses were calculated for all treatments and experiments. The effect of vegetation cover on pine weevil feeding was then analysed. The analysis was done separately for controls and the scarification treatments where Roundup was not used (treatments 2, 4, 6 and 7). Data were grouped in five classes depending on the vegetation cover (0–20%, 21–40%, 41–60%, 61–80%, 81–100%), and only presented if the number of observations was ≥ 8.

The patches were colonised to a very limited extent by mosses. In October 1999 the mean moss cover was 5.2% for patches that were not treated with $FeSO_4$. Therefore, in the analyses of the effect of field vegetation on pine weevil damage, treatment 4 (moss treatment) was analysed together with the non-herbicide treatments.

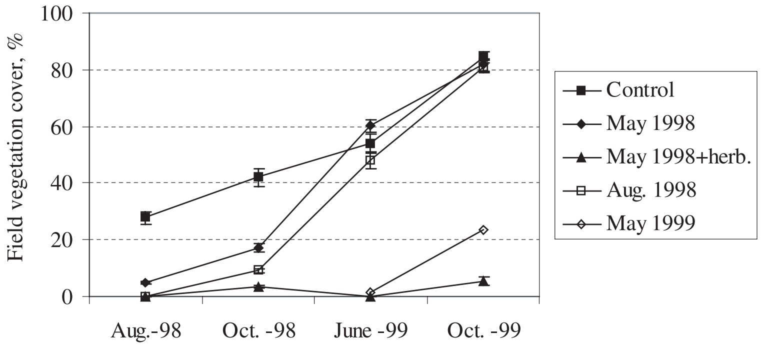

Figure 1. Development of mean field vegetation cover (%), mainly hairy grass, for control areas and patches scarified at different dates. Patches scarified in May 1998 were also treated with herbicide. Vertical bars represent ± SE.

Table I. Cover (%) of field vegetation in patches following different soil treatments and date of scarification. Measurements were taken at the end of each experimental period (cf. Tab. II). Means with SE in parentheses.

Treatment	Scarification date	Herbicide	Moss treatm.	Aug.–Oct. 1998	May–June 1999	Aug.–Oct. 1999
Control		No	No	42.0 (3.2)	54.1 (3.2)	84.3 (2.1)
Scarified	May 1998	No	No	17.0 (1.4)	60.2 (2.3)	81.7 (2.1)
Scarified	May 1998	Yes	No	3.4 (0.3)	0.1 (0.0)	5.4 (1.5)
Scarified	May 1998	No	Yes	17.4 (1.5)	48.2 (2.5)	80.7 (2.2)
Scarified	May 1998	Yes	Yes	3.6 (0.5)	1.8 (1.2)	3.3 (0.4)
Scarified	Aug. 1998	No	No	9.1 (0.8)	48.0 (2.7)	81.1 (2.3)
Scarified	May 1999	No	No		1.7 (1.0)	23.5 (1.8)

Significance tests were performed using analysis of variance. Prior to the test, frequencies or means of all the measured variables were calculated for each plot ($n = 51$). The following model was used:

$$Y_{ij} = \mu + A_i + B_j + e_{ij}.$$

Here, Y_{ij} = observed value for treatment i (i = 1, 2, …, 7) for block j (j = 1, 2, …, 51), where μ = general mean, A_i = effect of treatment, B_j = effect of block, and e_{ij} = random variation. Differences were considered significant when $p < 0.05$.

3. RESULTS

The field vegetation around control seedlings was dominated by hairy grass (*Deschampsia flexuosa*). This was the dominant species in 90% of the planting spots in October 1999. Hairy grass also dominated in the scarified patches, the corresponding values being 83% for patches scarified in May1998, 94% for patches scarified in Aug. 1998, and 56% for patches scarified in May 1999.

The field vegetation cover increased with time from 28% in August 1998 to 40% in the autumn of the same year. When the clear-cut was two years old the mean cover was more than 80% (Fig. 1 and Tab. I). Scarification removed vegetation effectively, but relatively soon new vegetation was established. In June 1999 the mean vegetation cover of patches that had been scarified in May or August the year before was 48% and 60%, respectively, whereas almost no vegetation was established in patches that had been scarified in the same year (Fig. 1 and Tab. I). Cover was efficiently removed, and almost no vegetation was present in patches treated with the herbicide (Fig. 1 and Tab. I).

The damage measured on the three different occasions showed the same general trends in the effects of scarification on damage caused by pine weevils (Tab. II). A general finding was that fresh scarification reduced pine weevil damage significantly. However, the effect of scarification was greatly reduced within two years following treatment. For instance, when measured in June 1999, the debarked area of seedlings planted in patches scarified in May of the year before planting was significantly higher (2.5 cm^2) than the corresponding area (0.5 cm^2) for seedlings in patches prepared the same year as planting (Tab. II).

When field vegetation was removed from the scarified patches pine weevil damage was significantly reduced. Damage on herbicide-treated patches was about the same (no significant difference) as on freshly scarified patches (Tab. II).

The mortality caused by the pine weevil followed the same general pattern as the amount of feeding. Thus, survival was generally low for seedlings planted without scarification. For example, in June 1999 the mortality was 62% for control seedlings, 18–26% for seedlings planted in scarified patches with vegetation, and only ca 5% in patches that were free from vegetation.

There was no clear correlation between cover of vegetation and weevil damage for control seedlings, even though there tended to be more attacks where vegetation cover was high (Fig. 2). For seedlings planted in scarified patches there was a strong positive correlation between vegetation cover and weevil damage (Fig. 2).

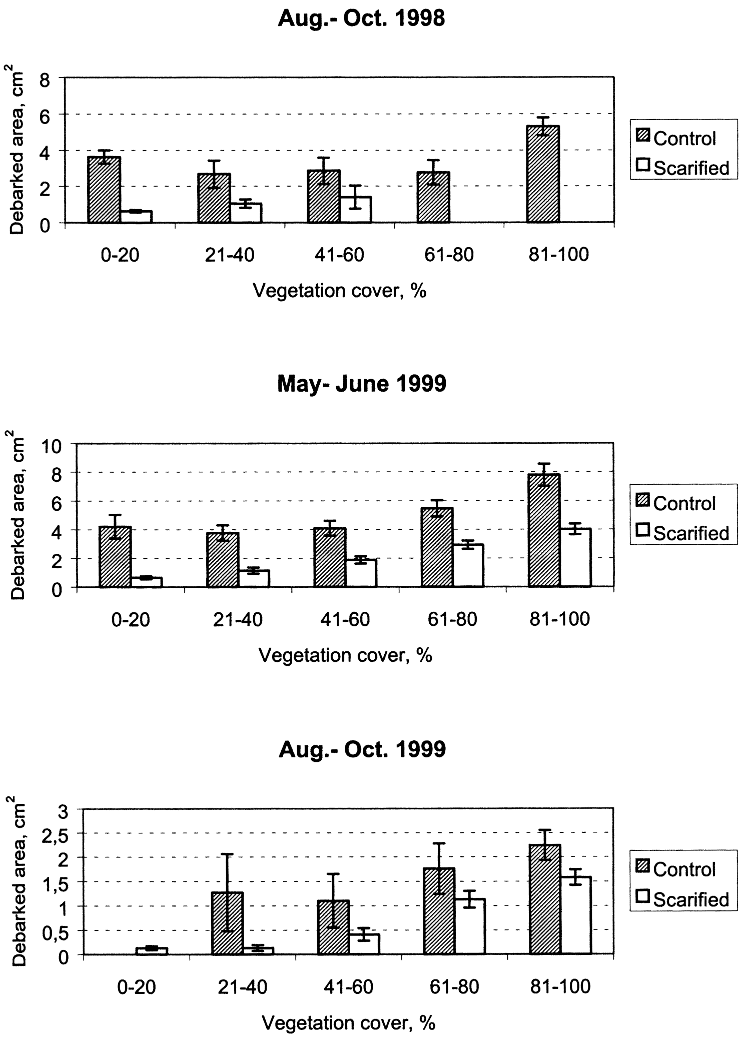

Figure 2. Effect of vegetation cover on pine weevil feeding for control seedlings and seedlings planted in scarified patches. Herbicide-treated plots were excluded from the analysis. The figures represent three different planting dates. Vertical bars represent ± SE.

Table II. Mean debarked area (cm^2) for seedlings planted following different soil treatments and dates of treatment. Planting was performed on three different dates: August 20, 1998, May 10, 1999 and August 10, 1999 and the debarked area was measured 1–2 months after planting. Results of treatments followed by the same letter are not significantly different.

Treatment	Scarification date	Herbicide	Moss treatm.	Aug.–Oct. 1998	May–June 1999	Aug.–Oct. 1999
Control		No	No	3.56 a	5.25 a	1.97 a
Scarified	May 1998	No	No	0.96 b	2.45 b	1.22 b
Scarified	May 1998	Yes	No	0.54 bc	0.67 c	0.38 c
Scarified	May 1998	No	Yes	0.91 bc	1.97 b	1.18 b
Scarified	May 1998	Yes	Yes	0.42 bc	0.73 c	0.27 c
Scarified	Aug. 1998	No	No	0.27 c	2.13 b	1.48 ab
Scarified	May 1999	No	No		0.49 c	0.13 c

4. DISCUSSION

As expected, the effect of scarification was greatly reduced within two years following treatment [11]. The present experiment showed clearly that the presence of vegetation reduces the damage-suppressing effect of mineral soil. Moreover, the density of vegetation seems to be a critical factor for pine weevil damage. The rate of establishment of field vegetation in both unscarified and scarified soil was similar to that reported from other clear-cuts in southern Sweden [6, 8, 9]. Thus, vegetation colonisation following scarification is an important factor to consider when attempting to reduce pine weevil damage.

The vegetation cover had only limited effects on weevil damage if the seedlings were planted without scarification. However, damage levels were always high, irrespective of vegetation cover, in the absence of scarification. This is in accordance with results presented by Örlander and Nilsson [11], who found no reduction in pine weevil feeding when the vegetation was controlled with herbicides on unscarified plots. In the cited study vegetation was dominated by hairy grass, as in this investigation.

Pine weevils may avoid open mineral soil areas because of the risk of overheating during sunny periods [1] or because of the higher risk of predation on such areas. In this study we found that feeding intensity by the weevil was approximately the same in control plots and scarified plots if they were covered with dense field vegetation. Thus, dense vegetation cover and undisturbed humus appear to affect the weevils in similar ways. The exact mechanism(s) involved remains to be elucidated, but we suggest that both the vegetation and humus provides shelter for the pine weevils, and that this increases the likelihood that they will remain in the area and feed on seedlings.

In the present study it was not possible to evaluate the effect of mosses in the scarified patches. It is likely that mosses also reduce the effect of scarification on pine weevil damage, but this remains to be proved.

Örlander and Nilsson [11] discussed the possibility that there might be an "ageing effect" of scarification, besides the vegetation-mediated effects, because mounds lost their damage-suppressing effect even on sites where there were only small amounts of vegetation. The present experiment shows that old vegetation-free scarified patches were as effective as fresh ones in protecting seedlings from the pine weevil. Thus, physical changes in the scarified patches, e.g. compaction of the surface layer, seem to be of minor importance for the pine weevil. There is often an accumulation of litter over time in scarified patches, which has also been shown to reduce the damage-suppressing effect of scarification [9]. In the present experiment litter was removed from the patches in order to isolate the effects of vegetation. Thus, in a practical situation it is likely that litter would be more important and contribute to the "ageing effect".

The results of this study have several practical implications for forest regeneration. The most obvious is that planting should be done as soon as possible after scarification in order to maximise the damage-reducing effect. Moreover, scarification methods leading to slower establishment of vegetation than patch scarification, e.g. mounding or inverting, should be preferred when avoidance of pine weevil damage is important.

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REFERENCES

[1] Björklund N., Nordlander G., Bylund H., Host-plant acceptance on mineral soil and humus by the pine weevil *Hylobius abietis* (L.), Agric. For. Entomol. 5 (2003) 61–65.

[2] Day K.R., Leather S.R., Threats to forestry by insect pests in Europé, in: Watt N.E., Hunter M.D. (Eds.), Forests and Insects, Chapman and Hall, London, 1997, pp. 177–205.

[3] Kindvall O., Nordlander G., Nordenhem H., Movement behaviour of pine weevil *Hylobius abietis* in relation to soil type: an arena experiment, Ent. Exp. Appl. 95 (2000) 53–61.

[4] Långström B., Abundance and seasonal activity of adult *Hylobius*-weevils in reforestation areas during first years following final felling, Comm. Inst. For. Fenn. 106 (1982) 1–23.

[5] Lindström A., Hellqvist C., Gyldberg B., Långström B, Mattson A., Field performance of a protective collar against damage by *Hylobius abietis*, Scand. J. For. Res. 1 (1986) 3–15.

[6] Nilsson U., Örlander G., Vegetation management on grass-dominated clear-cuts planted with Norway spruce in southern Sweden, Can. J. For. Res. 29 (1999) 1015–1026.

[7] Nilsson U., Örlander G., Response to newly planted Norway spruce seedling to fertilisation, irrigation and herbicide treatments, Ann. For. Sci. 60 (2003) 637–643.

[8] Nordborg F., Nilsson U., Growth damage and net nitrogen uptake in *Picea abies* (L.) Karst. seedlings, effects of site preparation and fertilisation, Ann. For. Sci. 60 (2003) 657–666.

[9] Nordlander G., Örlander G., Petersson M., Bylund H., Wallertz K., Nordenhem H., Långström B., Pine weevil control without insecticides – final report of a research program, Swedish University of Agricultural Science, Asa Forest Research Station, Rep. 1, 2000, pp. 1–77 (in Swedish with English summary).

[10] Örlander G., Nilsson U., Nordlander G., Pine weevil abundance on clearcuts of different ages: a 6-year study using pitfall traps, Scand. J. For. Res. 12 (1997) 225–240.

[11] Örlander G., Nilsson U., Effect of reforestation methods on pine weevil (*Hylobius abietis*) damage and seedling survival, Scand. J. For. Res. 14 (1999) 341–354.

[12] Petersson M., Örlander G., Effectiveness of combinations of shelterwood, scarification, and feeding barriers to reduce pine weevil damage, Can. J. For. Res. 33 (2003) 64–73.

[13] Söderström V., Bäcke J., Byfalk R., Jonsson C., Comparison between planting in mineral soil heaps and some other soil treatment methods, Swedish University of Agricultural Science, Department of silviculture, Rep. 11, 1978, pp. 1–177 (in Swedish with English summary).

[14] von Sydow F., Abundance of pine weevils (*Hylobius abietis*) and damage to conifer seedlings in relation to silvicultural practices, Scand. J. For. Res. 12 (1997) 157–167.