# Weed Control Trials with Fibre Mulch, Glyphosate and Terbuthylazine in Scots Pine Plantations

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The following treatments were compared in three Scots pine (*Pinus sylvestris* L.) reforestation areas on a scarified moist mineral-soil site in southern Finland, planted with 1+1 bareroot stock in spring 1987: (a) no weed control treatment; (b) mulching with a fibre slurry produced by mixing wastepaper with water and applied 1 cm deep to an area 60 cm in diameter around the seedling soon after planting; (c) glyphosate (at 2 kg $ha^{-1}$ a.i.) sprayed on a 1 $m^2$ spot around the seedling in early August 1987; (d) terbuthylazine (at 10 kg $ha^{-1}$ a.i.) applied as (c). Monitoring of the trials over a 4-year period between 1987–90 showed that none of the treatments reduced surface vegetation to an extent that would have benefited pine. The percentage cover development of the vegetation, dominated by *Agrostis capillaris, Calamagrostis arundinacea, Deschampsia flexuosa, Festuca ovina, Epilobium angustifolium* and *Pteridium aquilinum*, followed much the same pattern in all treatments, with (c) slightly favouring forbs. Survival of pine at the end of the study period was about 90 %, with non-significant differences between treatments. Mulching and terbuthylazine treatment slightly reduced seedling height growth in the second year. Growth was better in glyphosate treatment than in terbuthylazine treatment in the lowest (<30 %) and the highest (>60 %) pre-treatment weed cover classes and in the latter also better than in untreated control. Mulching gave variable results; at its best it provided good control of weeds for several years, without, however, improving the initial development of pine in these trials.

**Keywords** weed control, mulches, herbicides, glyphosate, terbuthylazine, *Pinus sylvestris*.
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# 1 Introduction

Traditionally vegetation has been controlled in Finnish forest plantations either mechanically, by cutting or trampling, or chemically with herbicides. The herbicides most commonly used today are glyphosate (Roundup) and terbuthylazine (Gardoprim) (Hynninen and Blomqvist 1992). There is, however, little information on the effect of these chemicals on the success of plantation establishment. Kolström (1991), in his sowing and planting trials with Norway spruce, used terbuthylazine and mechanical methods for grass control. Aro (1991) compared various mulch materials and two herbicides (glyphosate and terbuthylazine) in Scots pine plantations both in the forest and on abandoned agricultural land. Generally, the use of mulches for vegetation control in Finnish forestry has so far been limited to a few trials (Kokkonen 1963, Aro 1991)

The purpose of mulching is to ensure the initial development of the seedlings by suppressing competing vegetation, conserving soil moisture, and reducing soil erosion. Paper and various plant residues are well known mulching materials in horticulture and nurseries (Jacks et al. 1955, Rölin 1987, Ögren 1990). Commercial cellulose and recycled fibre products are in common use in forest tree nurseries in the US and Canada. There is a considerable number of test results concerning the effect of these materials on seed germination and seedling development (e.g. Clifford and Masello 1965, Rowan 1982, Landis et al. 1984, Racey and Raitanen 1983, 1985).

Little research has been done on the use of paper mulches in forest plantation establishment. Hunt (1963) compared various mulching materials and mechanical soil treatment in conifer plantations in Oregon. In his trials, the most durable mulches were black plastic, sawdust and newspaper. The least durable was clear plastic. All the mulches tested improved the initial survival of seedlings, whereas cultivation alone failed to do so. Frochot and Levy (1986) compared newspaper mulches and black plastic in growing wild cherry (*Prunus avium* L.). The best growth was obtained with the most durable mulches, which were black plastic and wax-coated newspaper buried in the soil. Height growth was three times and diameter growth 1.6 times that of the seedlings where weeds were controlled mechanically. Kokkonen (1963) tested three paper mulches (kraft, bitumen, and aluminium-coated paper) in Scots pine and Norway spruce plantations on forest and old-field sites in eastern Finland. The weather conditions were unusual; the seedlings suffered from drought, and mulching resulted in reduced growth. Haugberg (1971) also suspected that mulch increased the drying risk of Norway spruce seedlings. Problems with anchoring the mulch to the soil became obvious in Kokkonen's (1963) and Aro's (1991) trials.

In the tests reported here, the effect of mulching with slurries made from wastepaper on the early development of planted Scots pine (*Pinus sylvestris* L.) was compared with that of chemical weed control. Mulch durability was also observed.

# 2 Materials and Methods

The study site was in southern Finland, about 60 km northwest of Helsinki. The selected areas were three mechanically scarified reforestation areas on a moist mineral soil, where vegetation control was regarded as necessary. They were planted in spring 1987 with 1+1 bare-rooted Scots pine. The planting density was 2000 seedlings ha$^{-1}$. The plantations were on south-facing slopes with an average gradient of about 10 %. The soil had developed on a fine-sand glacial till.

Plantations 1, 2 and 3 (1.8, 2.4 and 0.6 ha respectively) were divided into 25 m × 25 m plots, on which the treatments were randomised. The four treatments were: Control – no mulch or herbicide; Mulch – weed control with a fibre (wastepaper slurry) mulch; Glyphosate (Roundup); and Terbuthylazine (Gardoprim 80). In the control and mulch treatments there were 4, 8 and 2 replicates and in each of the herbicide treatments there were 2, 4 and 1 replicates at plantation 1, 2 and 3 respectively. In total, the study material comprised 829 seedlings.

The mulch was prepared by mixing wastepaper with water. For plantations 2 and 3 the paper sheets were shredded mechanically before mixing, thus producing a fine-textured mulch. For plantation 1 the paper was mixed with water without pretreatment.





The fibre slurry was applied about 1 cm deep to an area of 60 cm in diameter around the seedling in two weeks after planting. Application was made manually with shovels and buckets. The herbicides, glyphosate (2 kg ha$^{-1}$ a.i.) and terbuthylazine (10 kg ha$^{-1}$ a.i.) were sprayed on a 1 m$^2$ circular spot around the seedling with knapsack sprayer, in solutions of 400 l of water ha$^{-1}$ as total area spraying. For glyphosate treatment the seedlings were covered with conical shield (∅ = 15 cm) during spraying. The herbicide applications were made in early August in the year of planting, 1987. The weather was favourable for chemical application.

The trial was evaluated for the first time in July 1987 just before herbicide application. The measurements were made in a 100 m$^2$ circular plot (∅ = 11.3 m) marked out in the centre of each 25 × 25 m trial plot. The seedlings were mapped and labelled. Weed cover was analysed by species on a 0.25 m$^2$ circular plot (∅ = 56.4 cm) around each seedling. Repeat measurements were made in July 1988 and 1990. In 1990, weed cover was recorded only as the total percentage. Seedling vigour was scored visually on a 5-point scale. The two main causal agents of damage were recorded. Seedling height was determined at the time of planting and before the herbicide application. In 1990, annual height growth over the 1987–1990 period was also measured by measuring the internodes. Mulch durability was assessed visually.

Weather conditions during the study period ranged from a cool (1070 d.d. °C) and rainy (430 mm) growing season in 1987 to the next year's warm (1570 d.d. °C) growing season with normal precipitation (360 mm). In 1989 and 1990, the temperature sums were slightly above the long-term average (1280 d.d. °C) and the precipitation was normal.

The data were analysed using the BMDP package (BMDP... 1988). Treatments were compared by an analysis of variance, using a plantation as a block. Paired comparisons were made by Tukey's studentized range test. Dead seedlings and those with a missing shoot (e.g. damaged by voles) were excluded from height and height-growth comparisons. Percentage weed cover was computed for plant groups (grasses, forbs, dwarf shrubs). These values and seedling survival rates were tested following arc sine transformations using ANOVA. It was assumed that there was no block × treatment interaction.

# 3 Results

## 3.1 Percentage Weed Cover

The arc-sine transformed weed cover percents were almost normally distributed. They were widely dispersed (CV > 1). No significant differences were found in total percentage weed cover between treatments (Fig. 1). In 1987 (just before herbicide application) and 1988, there was a marginally significant difference ($P < 0.10$) between treatments in the percentage cover of grasses. However, the changes from 1987 to 1988 followed much the same pattern regardless of treatment (Fig. 1). The percentage cover of forbs was 10 and 19 in 1987 and 1988 respectively, and that of dwarf shrubs was 3 in both years. In the glyphosate treatment, the increase in percentage cover of forbs was nearly double that of the other treatments. This was mainly due to a rapid increase in the percentage cover of *Epilobium angustifolium* L.

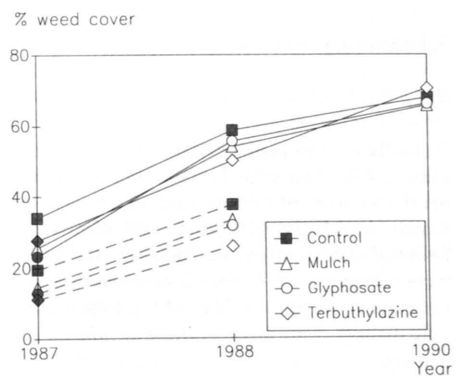


**Fig. 1.** Percentage weed cover at the time of herbicide treatment and after one and three growing seasons (—— all plants, – – – – grasses). Filled symbols indicate no weed control or situation just before herbicide application.

In plantation 1, where the mulch lasted for several years, the total weed cover on mulched plots was 51 % of that in the control (which had 38 % cover) after the first growing season (1987). The difference was statistically significant. In 1988 and 1990, the equivalent values were 83 % and 74 % respectively. The herbicide treatments also reduced vegetation cover in this plantation. Four years from planting, the weed cover on glyphosate treated plots was 69 % and on terbuthylazine treated plots 78 % of that in the control. In the second year after treatment (1988), the cover of grasses on terbuthylazine treated plots (7 %) differed significantly from that on control plots (36 %).

Of individual plant species, the most dominant among the grasses were *Agrostis capillaris* L., *Calamagrostis arundinacea* (L.) Roth., *Deschampsia flexuosa* (L.) Trin., *Festuca ovina* L. and *Luzula pilosa* (L.) Willd. and among the forbs, *Epilobium angustifolium* and *Pteridium aquilinum* (L.) Kuhn. The same species dominated in each treatment. However, the average percentage cover of *Pteridium* in plantation 1 was greater on terbuthylazine treated plots (30 % in 1987 and 35 % in 1988) than on the plots of the other treatments (8–15 % and 15–24 % for the corresponding years). In each treatment *Luzula pilosa* colonized bare mineral soil.

**Table 1.** Mean seedling heights (with standard deviations) after the first growing season (1987) and at the end of the study (three growing seasons after herbicide treatment and four growing seasons after mulch treatment).

| Treatment | Total seedling height, cm 1987 | 1990 | N |
|---|---|---|---|
| Control | 21.1 (2.6) | 85.2 (10.3) | 14 |
| Mulch | 21.0 (2.3) | 83.3 (10.2) | 14 |
| Glyphosate | 22.4 [1)] (2.3) | 89.1 (10.0) | 7 |
| Terbuthylazine | 21.0 [1)] (1.3) | 78.7 (7.6) | 7 |
| F-value | 0.83 | 2.30 | |
| Probability (P) | 0.48 | 0.094 * | |

* Marginally significant at the 0.10 level
[1)] Before herbicide application in 1987

## 3.2 Seedling Performance

### 3.2.1 Survival and Damage

Virtually all seedlings survived the first growing season. After four years (1990), the average survival rate was 89.1 % for control, 93.2 % for mulch, 91.4 % for glyphosate and 86.6 % for terbuthylazine. Differences between treatments were not significant. Fungal disease was the most common cause of mortality (34 %), followed by vole damage, pine weevil (*Hylobius abietis* L.) damage and plant competition (18 % each).

The proportion of healthy seedlings in 1990 was 54, 62, 62 and 50 % for control, mulch, glyphosate and terbuthylazine respectively. Also the remaining vigorous classes distributed evenly between treatments. In 1990 the average proportions of slightly damaged, weakened or stunted seedlings ranged between 17–23, 5–10 and 5–8 % respectively. Out of the seedlings examined, 43 % had been injured by pine weevils and 12 % by voles. The incidence and severity of damage were not significantly different between treatments.

### 3.2.2 Height and Height Growth

The mean heights at the time of planting in spring 1987 were 12.7, 12.0, 13.8 and 13.0 cm for control, mulch, glyphosate and terbuthylazine respectively. No significant difference was found between treatments either in initial heights or in heights at the time of herbicide application in 1987 (Table 1). At the end of the study period (1990), there was a marginally significant difference (P 0.10) between treatments; seedlings were tallest in the glyphosate treatment and shortest in the terbuthylazine treatment.

In the second year (1988), height growth of the seedlings differed at the 0.10 level between treatments (Table 2). Growth was 20 % poorer on terbuthylazine treated plots than on control plots. In plantation 1, mulching had reduced growth by 19 % compared with the control. Using initial height as a covariate had no effect on the results of ANOVA.





**Table 2.** Mean annual height growth (with standard deviations) of pine seedlings over four-year period 1987–1990.

| Treatment | Height growth, cm 1987 | 1988 | 1989 | 1990 | N |
|---|---|---|---|---|---|
| Control | 8.8 (1.6) | 12.1 (1.9) | 24.5 (4.0) | 28.0 (4.9) | 14 |
| Mulch | 8.7 (1.6) | 11.0 (2.9) | 24.4 (4.2) | 27.5 (3.0) | 14 |
| Glyphosate | 8.8 [1)] (2.0) | 11.1 (2.7) | 26.3 (4.0) | 29.7 (4.7) | 7 |
| Terbuthylazine | 8.2 [1)] (1.2) | 9.7 (2.3) | 22.7 (4.0) | 25.8 (2.5) | 7 |
| F-value | 0.50 | 2.43 | 1.29 | 1.71 | |
| Probability (P) | 0.69 | 0.081 * | 0.29 | 0.18 | |

* Marginally significant at the 0.10 level
[1)] Before herbicide application in 1987

To find out possible differences in the effect of the herbicides on the abundance of weed cover, the weed cover was classified into three classes, percent cover <30 %, 30–60 % and >60 % at the time of treatment. The cumulative height growths of seedlings was examined in these classes (Fig. 2). In both sparse and dense vegetation (percentage cover <30 and >60 respectively), the difference was significant between treatments, after one year (1988) at the 0.05 level and after three years (1990) at the 0.01 level. In sparse vegetation, seedling growth on terbuthylazine treated plots was less than that on control plots. The difference was significant in four years' cumulative height growth. In dense vegetation, glyphosate improved seedling growth compared with the controls. The number of observations were 113, 59 and 35 for control, 127, 35 and 16 for glyphosate, and 86, 33 and 16 for terbuthylazine, in ascending order of vegetation cover.

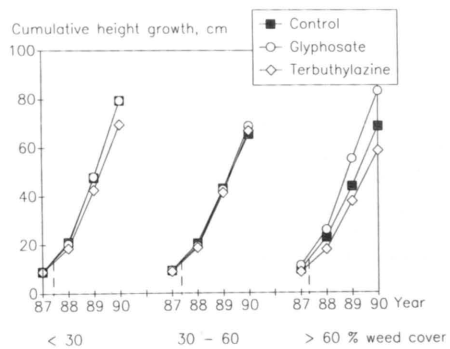


**Fig. 2.** Mean annual cumulative height growth of pine seedlings in control, glyphosate and terbuthylazine treatments by pre-treatment weed cover classes (1987). Broken vertical lines indicate the time of herbicide application after first growing season.

## 3.3 Mulch Durability

After two growing seasons, the mulch remained almost unchanged in 27 % and had disappeared completely in 62 % of the cases. In plantation 1, where the mulch was manually prepared and coarse-textured, it was still all there after two years, whereas in the other two plantations, where it was produced from mechanically shredded paper, it was still there in only 7 % of the cases. Four growing seasons after planting (1990), the mulch was still almost unchanged in 15 % and had almost totally disappeared in 77 % of all cases. Again the mulch was most durable in plantation 1.

# 4 Discussion

The analyses of variance indicated that differences between plantations (blocks) were greater than those between weed control treatments.

Treatment × block interaction was not significant and was ignored in the final analysis. It was, however, worth examining some of the results at plantation level, since the mulch lasted sufficiently well in only one plantation.

Weed control treatments failed to reduce vegetation cover to an extent that would have clearly benefited pine. In two plantations, the mulch disintegrated too soon to have any effect on the vegetation. Glyphosate slightly favoured forbs (especially *Epilobium angustifolium*) at the expense of grasses. This is characteristic of foliar herbicides, which, by reducing competition, create favourable conditions for seed germination (Torstensson 1985, Lund-Høie and Grønvold 1987). On the other hand, several species are somewhat resistant to glyphosate and they have shown a rapid recovery (Lund-Høie and Grønvold 1987).

Herbicide treatments earlier in the season might have given better results. In Sutton's trials in Canada (1984), glyphosate was more effective against deciduous trees, shrubs and lesser vegetation when applied in July, rather than in early September. Also, the new recommendations for use of terbuthylazine (Gardprim 500 FW) prefer application in early summer or in late autumn when soil moisture is high. In addition, if deep-rooted weeds (e.g. *Epilobium, Calamagrostis*) are present, terbuthylazine is recommended to be used in combination with other herbicides (e.g. Brække et. al. 1986). The dispersion of vegetation cover percents and the skewness of distributions are typical for vegetational material and are due to the patchiness of the vegetation (Kärenlampi 1968, Ferm and Pohtila 1977). Also errors in visual assessment contribute to dispersion (Tonteri 1990).

Growth reduction on mulched plots in 1988 may have been caused by the previous year's cool and rainy summer, the effect being aggravated by the mulch. The insulating effect of light-coloured paper mulch moderates temperature in the soil (e.g. Ballik 1970, Waggoner et al. 1960, Ögren 1990). Soil temperature, among other things, greatly affects root growth (e.g. Lippu and Puttonen 1990); it may have been poorer under the mulch than under the other treatments, leading to a reduction in shoot growth (Ballik 1970, Bassman 1989).

The reduction in height growth in the terbuthylazine treatments was probably due to the toxic effect of this soil-acting herbicide. This effect is indicated by the inferior height growth of seedlings in this treatment, compared with glyphosate and control, when the surface vegetation was sparse. The results were similar to those obtained by Bärring (1967) and Hynönen (1976) with soil-acting herbicides (atrazine and simazine). However, no signs of seedling injury were evident in this study. Glyphosate gave a positive growth response in the highest weed cover class (>60 %). The poor result of the terbuthylazine treatment in this class was due to the abundance of bracken (*Pteridium aquilinum*), which was resistant to this herbicide. On glyphosate-treated plots, *Agrostis* and *Calamagrostis* dominated the pre-treatment weed cover.

The longevity of the coarse-textured fibre mulch encourages further studies under more severe conditions of plant competition. The fine-textured mulch, when dry, usually sticks firmly to the soil surface. In this study, however, either the application rate was too low, or the slurry was washed off before drying. Preparing paper as a slurry means extra work. On the other hand, it eliminates anchoring problems and allows machine application. It is a well-known practice in nurseries (e.g. Landis et al. 1984). However, in this case time-consuming manual application was used.

More attention should be paid in future studies to the effect of mulches on soil conditions and microclimate. In unfavourable growing conditions these effects can either increase or reduce stresses on the seedlings (e.g. Kokkonen 1963, Haugberg 1971, Litzow and Pellet 1983, Davies 1985, 1988). Risks are greatest early and late in the growing season (e.g. Creech and Hawley 1960, Whitcomb 1980). Among the most serious risks with transparent materials are high temperatures under the mulch (e.g. Salisbury and Long 1959, Davies 1988), and with highly reflective materials, high temperatures above the mulch (Kokkonen 1963, Richards 1970).





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