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# Cleaning Methods in Planted Scots Pine Stands in Southern Finland: 4-year Results on Survival, Growth and Whipping Damage of Pines

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The effects of four cleaning treatments on the survival, growth of, and whipping damage to Scots pine (*Pinus sylvestris* L.) main stems were studied in young planted pine stands in southern Finland. Treatments were: no cleaning, point-cleaning of broadleaves (mainly birch, *Betula pendula* Roth and *B. pubescens* Ehrh.) within a radius of 1 m from the pine, topping of competing broadleaves, and total cleaning of broadleaves. A randomised complete block design with three replicates was established in five sapling stands: the mean height of the pines was 1.5 m in the three younger stands (6 or 7 years old), and 3 m in the two older stands (9 years old). Measurements taken four growing seasons later showed that in the younger stands, all cleaning treatments significantly ($P < 0.05$) decreased the mortality and increased the diameter increment of the pines. The height increment of the pines on point-cleaned and topped plots was significantly greater than on totally cleaned plots. In the older stands, the effects of cleaning treatments on the mortality and increment of pines were non-significant. In the younger and older stands, point-cleaning and total cleaning significantly reduced the whipping damage to pines, whereas the topping of competing broadleaves did not. The preliminary results support the use of point-cleaning in planted Scots pine stands when the mean height of the pines is about 1.5 m.

**Keywords** birch, competition, *Pinus sylvestris*, tending of sapling stand
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# 1 Introduction

The recommended initial density of planted Scots pine (*Pinus sylvestris* L.) stands in Finland is 2000 seedlings per ha. According to inventories of three-year-old planted pine stands, the actual density of conifer seedlings (i.e. planted and natural pines and natural Norway spruces (*Picea abies* (L.) Karst.)) adds up to an average level of 1500–2500 stems per ha (Saksa et al. 2002). This kind of stand density in the sapling stage is too low for the production of high-quality wood (e.g. Persson 1977, Varmola 1996). According to Varmola (1980, 1996), it is not economical to increase planting density to establish dense enough pine stands. This means that the high density of seedling and sapling stands, i.e. > 4000 stems per ha (Varmola 1996), must be achieved in other ways.

Only after good seed years there may be high numbers of naturally regenerated coniferous seedlings to fill up planted pine stands, particularly on drier site types. Unfortunately, these naturally regenerated seedlings will not be able to grow at the same speed as biologically older seedlings planted some years earlier. In addition, the large variation in pine seed crops (Hokkanen 2000) hinders the use of natural regeneration to increase the density of planted pine stands.

The most evident solution to the problem of increasing the density of planted pine stands is to use naturally regenerated broadleaf saplings as supplementary stems. Birch (*Betula pendula* Roth and *B. pubescens* Ehrh.), since it is the commercially most valuable species, is the best alternative. In regeneration areas prepared e.g. by disc trenching, there is usually a variable number of birch seedlings, on average 3000–5000 seedlings per ha (Saksa 1992, Hämäläinen et al. 1995, Valkonen 2003). According to Kellomäki et al. (1992) the branches of 6–10 m high pines begin to die and fall off from the sixth whorl on (counted from the top of the trees). When the age of the whorl is 11–13 years, almost all branches are dead. Thus, the supplementary density of birch is needed until the pine stems are 7–8 m in height, when the branches of pine have died from the lowest part (4–5 m) of the pine stem.

The initial height growth rhythms of pine and birch are somewhat different, which may cause problems when growing pine and birch as a mixture. The damage caused by broadleaves is well known in planted pine stands through inventories of forest regeneration areas (e.g. Räsänen et al. 1985). There are, however, results that show that birch seedlings, when originated from seeds, can be used as supplementary trees in planted pine stands (Andersson 1993, Karlsson et al. 2002, Valkonen and Ruuska 2003). On the contrary, birch sprouts growing faster than seed-origin ones (e.g. Björkdahl 1983, Elfving and Nyström 1984) may suppress and whip pines.

Andersson (1993) studied the effect of competition of birch on pine seedlings. In the first 10 years, serious whipping damage to the top of the pine stems was caused by birches that were taller than the pine and closer to them than 1 m. Smaller birches and birches growing further than 1 m from pine did not negatively affect the height growth of the pine. According to the models developed by Valkonen and Ruuska (2003), the number of competing birch did not affect the height development of pine but, rather, the increased competition had a positive effect on the quality of pine stems in sapling stands at the height of 2–8 m. Stands with serious damage caused by birch were not included.

Karlsson et al. (2002) studied the development of Scots pine stands that were treated when the pines were about 2 m high. In the subsequent 13 years after total cleaning pines survived and maintained their dominant position better than after point-cleaning or topping. On the other hand, the quality of the pine stems was poorer after total cleaning than after point-cleaning or topping. Karlsson et al. (2002) also concluded that point-cleaning has to be followed by precommercial thinning.

In Lapland, Ikäheimo and Norokorpi (1986) recommended that selective thinning (i.e. removing only broadleaves higher than pines) could be used in planted pine stands to improve timber production and the technical quality of the wood.

The results above support the observation that point-cleaning, where broadleaves taller than and closer than 1 m to pine are removed (see Andersson 1984), is a successful tool in the management of young planted pine stands in Fennoscandia. So far, the optimal timing of both point-clean-

**Table 1.** The main characteristics of young planted Scots pine stands at the beginning of the cleaning experiments in 1998.

| Site | Disc trenching / planting year | Location N | Location E | Altitude m | Mean (± SD) number of stems ($ha^{-1}$)[a] Scots pine | broadleaves | Mean (± SD) height (cm)[a] Scots pine | broadleaves |
|---|---|---|---|---|---|---|---|---|
| *Younger stands* | | | | | | | | |
| A. Nynäs I | 1991 / 1992 | 61°9' | 26°3' | 120 | 1431 ± 419 | 7247 ± 1782 | 172 ± 22 | 142 ± 18 |
| A. Nynäs II | 1991 / 1992 | 61°9' | 26°3' | 120 | 1671 ± 244 | 8773 ± 2442 | 153 ± 18 | 129 ± 13 |
| A. Kasper | 1992 / 1993 | 61°9' | 26°47' | 85 | 2051 ± 465 | 8611 ± 2598 | 156 ± 13 | 157 ± 9 |
| *Older stands* | | | | | | | | |
| B. Halla-Sippola | 1989 / 1990 | 60°50' | 27°3' | 75 | 2383 ± 376 | 4606 ± 1258 | 293 ± 13 | 256 ± 17 |
| B. Rantala | 1990 / 1990 | 61°10' | 26°47' | 110 | 1911 ± 728 | 11506 ± 2061 | 302 ± 30 | 286 ± 29 |

[a] Minimum heights of saplings of younger (A) and older (B) stands measured in 1998 were 60 cm and 150 cm, respectively.

ing and the following precommercial thinning are not known. Neither it is known how much point-cleaning increases the total costs of precommercial stand treatments and enhances the timber quality (cf. Fällman 2005).

The aim of this study was to analyse the effect of point-cleaning, compared to no cleaning, total cleaning and topping on the survival as well as height and diameter increment of pines, and whipping damage to pines caused by broadleaves in planted Scots pine stands. The results were based on re-measurements conducted four years after the establishment of the cleaning experiments.

## 2 Material and Methods

Two experiments on the tending of sapling stands were conducted in planted Scots pine stands that were as homogeneous as (not tested) possible in terms of sapling density, tree species composition and site characteristics; one experiment (A) was made in younger stands planted in 1992/93 and one (B) in older stands planted in 1990. The quantity of birch (*Betula pendula* and *B. pubescens*; species not distinguished in this study) had to be sufficiently high to constitute a significant supplement to stand density (i.e. > 4000 trees per ha). A total of five stands were selected from among planted pine stands owned by the UPM-Kymmene Forest Corp. in southern Finland (Table 1). In Finland, Scots pine is regenerated using planting mainly on relatively fertile growing sites of pine, where fast growing deciduous species and the quality of pine wood are perceived to be a problem. Thus, all stands of this study were growing on forest soil of medium fertility classified as *Myrtillus* site type in the Finnish system of forest site type classification (Cajander 1949).

The experiments were established in 1998, when the mean height of the pines was about 1.5 m in the younger stands and about 3 m in the older ones. The number of the pines was, on average, lower in the younger stands than in the older ones and the mean number of broadleaves was almost the same in all three younger stands, but varied in the older stands (Table 1). The proportion of birch in relation to the total number of all broadleaves was 75% in the younger stands and 90% in the older stands. In each stand, the mean height of the broadleaves was slightly lower than that of the pines.

Based on a preliminary inventory, each stand was divided into three blocks (replicates) so that one block included as small variation in stand characteristics as possible. All of the treatments were included in each block (i.e. randomised complete block design). The area of the squared treatment plots was 25×25 m, 30×30 m or 35 ×35 m, depending on the area and shape of the block.

In the younger stands (A), the following treatments were randomly distributed among the six treatment plots in each block:

1) no cleaning;
2) point-cleaning when the mean height of the pines is about 1.5 m;
3) point-cleaning when the mean height of the pines is about 2.5 m;
4) point-cleaning when the mean height of the pines is about 3.5 m (results are not presented);
5) total cleaning when the mean height of the pines

is about 1.5 m; and
6) topping of broadleaves when the mean height of the pines is about 1.5 m.

The experiment was established and the treatment options 2, 5 and 6 were performed in 1998. The point-cleaning of treatment options 3 and 4 was performed in 2000 and 2002, respectively.

In the older stands (B), the treatment options no cleaning, point-cleaning, total cleaning and topping of broadleaves were included. All of these treatments were conducted in 1998 when the mean height of the pines was about 3 m.

In the case of the point-cleaning, all of the trees closer than 1 m to the main pine stems were removed, whereas in the case of total cleaning all broadleaves were removed except those at stand openings. In topping, all broadleaves closer than 1 m to the pine were cut at a height of approximately 1.3 m. The treatments were carried out in late summer, after the end of the growing season.

On each squared treatment plot three circular sample plots of 100 $m^2$ in area were systematically located in a triangle. All planted pines and all naturally regenerated saplings on the sample plots that were more than 0.5 times the mean height of the planted pines were mapped and measured according to tree species, height (cm) and breast height diameter ($d_{1.3}$, mm). Main pine stems were selected so that they were assumed to be retained in the precommercial thinning. In addition to the planted pines, supplementary natural pines were also included in the main stems. The damage caused to the main pine stems by the whipping of broadleaves was classified as follows:

0) no contact in the upper crown,
1) slight contact on the branches in the upper crown,
2) strong contact on the branches in the upper crown,
3) contact with the main stem in the upper crown, and
4) stem defect already exists.

All sample plots were measured at the time of their establishment in 1998 and re-measured in 2002. The plots, which were point-cleaned at a mean height of 2.5 m in 2000, were measured before the treatment.

The effects of the treatments on the survival and whipping damage of main pine stems and also on the development of mean height and diameter of the ten tallest main pine stems (in 1998) were evaluated by means of analyses of variance using the SPSS Univariate GLM procedure (SPSS Inc. 2004). The ten tallest pines per sample plot represent the 1000 tallest pines per ha, which were assumed to be retained in the first commercial thinning. Measurements on three sample plots within a treatment plot are correlated, and thus the data from three sample plots were averaged.

The general linear model was as follows:

$$Y_{ijk} = \beta_0 + X_{ijk}\beta + ST_i + TR_k + ST_i \times TR_k + b_{ij} + e_{ijk} \quad (1)$$

where $Y$ is the response variable; $\beta_0$ is a intercept; $\beta$ is a coefficient of the covariate $X$; $ST$ and $TR$ are the fixed stand and treatment effect, respectively; $b$ is the random block effect; $e$ is the random error; and subscripts $i$, $j$ and $k$ refer to stand, block and treatment plot, respectively.

When modelling the response variable (the number of trees, height, diameter and whipping damage) in the year 2002, the corresponding response variable in 1998 was used as a covariate in the model. Whipping damage was a categorical variable which was summarised as proportions, i.e. proportions of main pine stems classified to the whipping classes 0–4. The proportion of damaged main pine stems was arcsine-root transformed prior to analysis. Based on the normal probability plots and the Kolmogorov-Smirnov statistics, the arcsine-root transformation resulted in a normal distribution of the residuals.

The pairwise multiple comparisons between the treatments were performed using the Least Significant Difference (LSD) test after the F-test rejected the null hypothesis that treatments do not differ. If the level of significance of a statistical analysis was less than 0.05, the difference was called significant. The treatment effects were evaluated separately in the younger (A) and older (B) stands.

**Table 2.** Mean (± SD) number of main pine stems and broadleaves per ha on the treatment plots in younger (A) and older (B) stands. The post-treatment number of broadleaves per ha is in italics.

| Year | Minimum height (cm) | No cleaning | Point-cleaning in 1998 | Point-cleaning in 2000 | Total cleaning in 1998 | Topping in 1998 | Effect of treatment[1)] F-test | *P*-value |
|---|---|---|---|---|---|---|---|---|
| *A. Younger stands* (N = 9) | | | | | | | | |
| Scots pines | | | | | | | | |
| 1998 | 60 | 1826 ± 643 | 1670 ± 326 | 1833 ± 580 | 1526 ± 319 | 1733 ± 353 | 1.70 | 0.179 |
| 2000 | 60 | – | – | 1819 ± 579 | – | – | – | – |
| 2002 | 150 | 1696 ± 571[a] | 1674 ± 332[b] | 1737 ± 517[a] | 1533 ± 314[b] | 1741 ± 356[b] | 5.46 | 0.002 |
| Broadleaves | | | | | | | | |
| 1998 | 60 | 8330 ± 2233 | 8270 ± 2264 | 7770 ± 2245 | 8700 ± 3334 | 7981 ± 1897 | 0.18 | 0.948 |
| 1998 | 60 | – | *6585 ± 1893* | – | *1100 ± 871* | *6400 ± 1527*[2)] | – | – |
| 2000 | 60 | – | – | 8407 ± 2245 | – | – | – | – |
| 2000 | 60 | – | – | *3889 ± 1287* | – | – | – | – |
| 2002 | 150 | 4815 ± 1689[a] | 4252 ± 1477[a] | 4422 ± 1321[a] | 3000 ± 2211[b] | 4900 ± 1945[a] | 5.87 | 0.002 |
| *B. Older stands* (N = 6) | | | | | | | | |
| Scots pines | | | | | | | | |
| 1998 | 150 | 1939 ± 607 | 2178 ± 530 | – | 2433 ± 643 | 2039 ± 717 | 0.71 | 0.561 |
| 2002 | 200 | 1817 ± 588 | 2083 ± 451 | – | 2372 ± 592 | 2022 ± 728 | 1.67 | 0.223 |
| Broadleaves | | | | | | | | |
| 1998 | 150 | 8272 ± 4725 | 8350 ± 4725 | – | 7983 ± 3590 | 7617 ± 3469 | 0.27 | 0.848 |
| 1998 | 150 | – | *5100 ± 3247* | – | *250 ± 250* | *6394 ± 3683*[2)] | – | – |
| 2002 | 200 | 5611 ± 2982[a] | 3578 ± 2237[b] | – | 1706 ± 1785[c] | 5517 ± 2492[a] | 64.45 | 0.000 |

[1)] *P*-values are based on the F-test with df = (4,28) and (3,14) in the younger and older stands, respectively. Number of stems per ha in 1998 was used as a covariate for the corresponding variable in 2002; then df = (4,27) and (3,13) in the younger and older stands, respectively. Data not marked with the same letter are significantly different ($P < 0.05$).
[2)] Broadleaves without topping.

# 3 Results

## 3.1 Survival

At the beginning of the cleaning experiments in 1998, the number of main pine stems and broadleaves did not differ ($P > 0.05$) between treatments (Table 2). On the untreated plots of the younger stands, the average number of main pine stems decreased by 7% during the 4-year period. The corresponding mortality of main pine stems in the older stands was 6%. The number of broadleaves on the untreated plots decreased by 30–40%. At the end of the study period, the average density of broadleaves (taller than 1.5 m in the younger stands and taller than 2.0 m in the older stands) was about 5000 trees per ha, of which the proportion of broadleaves other than birch was only 3–9%.

In the younger stands there was no mortality in main pine stems on the plots that were point-cleaned, totally cleaned or topped in 1998 (i.e. at a mean height of 1.6–1.8 m). If the point-cleaning was delayed two years (up to a mean height of 2.5–3.0 m), the number of main stems decreased by 5%. In the older stands there was no significant difference in the mortality of the main pine stems; the number of main stems decreased by 6% in untreated plots and 1–4% in treated plots.

## 3.2 Development of Height and Diameter

The pre-treatment mean height of main pine stems in the younger and older stands was, respectively, 18 cm and 20 cm higher than the mean height of broadleaves (Fig. 1). However, the proportion of broadleaves taller than the medium height of the main pine stems varied from 30% to 40%, and the mean height of the ten tallest broadleaves was 0.2–1.8 m greater than the mean height of the ten tallest main pine stems in each stand. There was a slight within-stand variation in stand characteristics before the treatments. For example, the mean height of the ten tallest broadleaves was lower than that of the ten tallest

**Table 3.** Mean (± SD) height and diameter of the ten tallest main pine stems on the treatment plots in younger (A) and older (B) stands.

| | Year | No cleaning | Point-cleaning in 1998 | Point-cleaning in 2000 | Total cleaning in 1998 | Topping in 1998 | Effect of treatment[1)] F-test | *P*-value |
|---|---|---|---|---|---|---|---|---|
| *A. Younger stands* (N = 9) | | | | | | | | |
| Height (cm) | 1998 | $190 \pm 32$ | $180 \pm 18$ | $184 \pm 14$ | $169 \pm 30$ | $188 \pm 30$ | 0.90 | 0.479 |
| | 2002 | $392 \pm 50^{a}$ | $394 \pm 28^{b}$ | $393 \pm 23^{ab}$ | $363 \pm 55^{a}$ | $405 \pm 40^{b}$ | 2.96 | 0.038 |
| Diameter (mm) | 1998 | $22 \pm 3$ | $20 \pm 3$ | $21 \pm 3$ | $21 \pm 2$ | $21 \pm 4$ | 0.57 | 0.690 |
| | 2002 | $55 \pm 9^{a}$ | $62 \pm 7^{c}$ | $58 \pm 6^{ab}$ | $57 \pm 12^{bc}$ | $61 \pm 8^{bc}$ | 5.07 | 0.004 |
| *B. Older stands* (N = 6) | | | | | | | | |
| Height (cm) | 1998 | $312 \pm 17$ | $344 \pm 38$ | – | $362 \pm 35$ | $329 \pm 39$ | 2.43 | 0.109 |
| | 2002 | $529 \pm 41$ | $567 \pm 42$ | – | $572 \pm 30$ | $562 \pm 38$ | 1.80 | 0.196 |
| Diameter (mm) | 1998 | $41 \pm 8$ | $46 \pm 7$ | – | $47 \pm 4$ | $44 \pm 6$ | 2.73 | 0.084 |
| | 2002 | $73 \pm 16$ | $83 \pm 9$ | – | $87 \pm 3$ | $81 \pm 10$ | 1.26 | 0.327 |

[1)] *P*-values are based on the F-test with df = (4,28) and (3,14) in the younger and older stands, respectively. Mean height or diameter in 1998 was used as a covariate for the corresponding variable in 2002; then df = (4,27) and (3,13) in the younger and older stands, respectively. Data not marked with the same letter are significantly different ($P < 0.05$).

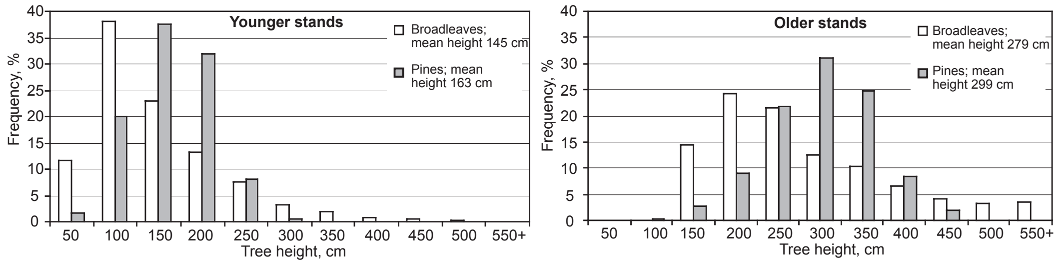


**Fig. 1.** Pre-treatment height distributions of main pine stems and broadleaves in the younger and older stands.

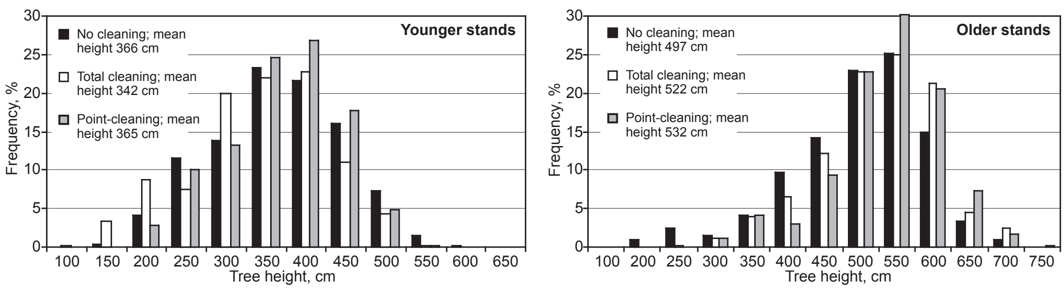


**Fig. 2.** Height distributions of main pine stems on untreated, totally cleaned and point-cleaned plots in the younger and older stands in the fourth year after establishment.

main pine stems on 5–20% of the sample plots of the stands.

Cleaning treatment had a significant effect on the mean height and diameter increment of the ten tallest main pine stems in the younger stands, but not in the older stands (Table 3, Fig 2). The height increment was greatest on the point-cleaned and topped plots, and lowest on the untreated or totally cleaned plots. Delaying the point-cleaning of the younger stands for two years reduced the height increment, but the decrease was not significant ($P$>0.05). The highest diameter increment was obtained on point-cleaned plots, whereas the lowest increment was obtained on untreated plots. Delaying the point-cleaning of the younger stands significantly reduced the diameter increment of the ten tallest main pine stems.

**Table 4.** Mean (± SD) proportion (%) of whipped main pine stems on the treatment plots in younger (A) and older (B) stands.

| Whipping class[1)] | Year | No cleaning | Point-cleaning in 1998 | Point-cleaning in 2000 | Total cleaning in 1998 | Topping in 1998 | Effect of treatment[2)] F-test | *P*-value |
|---|---|---|---|---|---|---|---|---|
| *A. Younger stands* (N = 9) | | | | | | | | |
| Slight (0, 1) | 1998 | 77 ± 11[a] | 93 ± 3[b] | 77 ± 9[a] | 94 ± 5[b] | 94 ± 3[b] | 20.06 | 0.000 |
| | 2000 | – | – | 66 ± 10 | – | – | – | – |
| | 2002 | 64 ± 13[a] | 89 ± 8[b] | 86 ± 5[b] | 93 ± 9[b] | 66 ± 17[a] | 13.37 | 0.000 |
| Strong (2) | 1998 | 16 ± 6[a] | 6 ± 2[b] | 15 ± 9[a] | 5 ± 5[b] | 4 ± 3[b] | 14.50 | 0.000 |
| | 2000 | – | – | 17 ± 6 | – | – | – | – |
| | 2002 | 23 ± 9[a] | 9 ± 6[b] | 10 ± 5[bc] | 7 ± 8[b] | 21 ± 12[a] | 8.09 | 0.000 |
| Serious (3, 4) | 1998 | 7 ± 6[a] | 1 ± 1[b] | 8 ± 4[a] | 1 ± 2[b] | 2 ± 3[b] | 7.27 | 0.000 |
| | 2000 | – | – | 17 ± 6 | – | – | – | – |
| | 2002 | 13 ± 8[a] | 2 ± 2[b] | 3 ± 2[b] | 1 ± 2[b] | 12 ± 8[a] | 13.85 | 0.000 |
| *B. Older stands* (N = 6) | | | | | | | | |
| Slight (0, 1) | 1998 | 58 ± 16 | 77 ± 13 | – | 73 ± 13 | 74 ± 12 | 2.41 | 0.110 |
| | 2002 | 51 ± 23[a] | 93 ± 7[b] | – | 98 ± 6[c] | 78 ± 14[d] | 30.05 | 0.000 |
| Strong (2) | 1998 | 30 ± 11[a] | 15 ± 11[b] | – | 17 ± 8[b] | 19 ± 11[b] | 3.81 | 0.035 |
| | 2002 | 20 ± 6[a] | 6 ± 7[b] | – | 1 ± 3[c] | 16 ± 9[a] | 16.40 | 0.000 |
| Serious (3, 4) | 1998 | 12 ± 8 | 9 ± 6 | – | 10 ± 8 | 8 ± 3 | 0.38 | 0.772 |
| | 2002 | 29 ± 20[a] | 0 ± 1[b] | – | 1 ± 2[b] | 6 ± 6[c] | 52.13 | 0.000 |

[1)] Whipping classes: 0 – No contact in the upper crown; 1 – Slight contact with the branches in the upper crown; 2 – Strong contact with the branches in the upper crown; 3 – Contact with the main stem in the upper crown; and 4 – Stem defect already exists.
[2)] *P*-values are based on the F-test with df = (4,28) and (3,14) in the younger and older stands, respectively. Proportion of the whipping class in 1998 was used as a covariate in the model (Eqn 1) for proportion of the corresponding whipping class in 2002; then df = (4,27) and (3,13) in the younger and older stands, respectively. All proportions were arcsine-root transformed prior to analysis. Data not marked with the same letter are significantly different ($P < 0.05$).

### 3.3 Damage by Whipping of Broadleaves

When the experiments in the younger stands were established, 7% of the main pine stems on the untreated plots were seriously damaged by whipping of the broadleaves i.e. the whipping class was 3 or 4 (Table 4). Four years later, 13% of the main pine stems on the untreated plots were seriously damaged by the broadleaves. In the older stands, the proportion of seriously damaged main pine stems on the untreated plots increased from 12% to 29% during the 4-year period, and only a half of the tops of the main pine stems had a free growing space (i.e. the whipping class was 0 or 1).

Compared to untreated plots, the proportion of seriously damaged main pine stems was significantly lower on all treated plots, except on topped plots in the younger stands (Table 4). Only 0–3% of the main pine stems on point- and totally cleaned plots were seriously damaged in 2002, whereas 6–12% of the main pine stems on topped plots were seriously damaged. On point- and totally cleaned plots, also the proportion of whipping class 2 (serious damage to the branches in the upper crown) was significantly lower than on untreated and topped plots.

The need of an early stand treatment in planted pine stands with a rich birch admixture is illustrated in Fig. 3. The number of undamaged main pine stems decreases as the mean height of the ten tallest broadleaves increases. If the early stand treatment occurs before the height of the broadleaves is above 2.5 m, more than 80% of main pine stems will be free of whipping damage.

# 4 Discussion

The cleaning experiments aimed at studying the competition effect, caused by broadleaves, mainly birches, to turn from positive to negative in planted Scots pine stands. The admixture of seed-origin birch is needed to increase the total stand density and thus to reduce the diameter growth of branches and stems, and hence to improve the wood quality of Scots pine main stems (e.g.

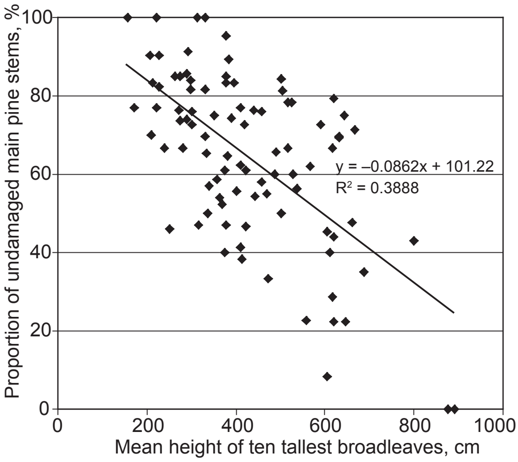


**Fig. 3.** The proportion of undamaged main pine stems (whipping class 0 or 1) as a function of the mean height of the ten tallest broadleaves on untreated sample plots at the time of re-measurement.

Valkonen and Ruuska 2003). However, nearby broadleaves, especially those taller than pine will whip the main pine stems, which may in turn lead to mechanical defects and poorer timber quality (Andersson 1993). In this study we attempted to discover the optimal compromise for the cleaning treatment and its timing, which would result in better wood quality and as little whipping damage as possible in the early developmental stage of planted Scots pines.

According to the height development curves presented by Björkdahl (1983), the birch sprouts will catch up with the pines, and the positive effect of the cleaning will last only a short time if the mean height of the pines is less than 1.2–1.3 m at the time of cleaning. Hence, in this study the cleaning treatments were established in 6- or 7-year-old pine stands with a mean height of 1.5 m. Four years after total cleaning the mean height of the sprouts was 2.1 m and the mean height of the main pine stems was already more than 3.5 m. In these particular stands, the cleaning performed 1–2 years earlier might therefore have been a contributing factor in the height development of the birch sprouts.

The effects of cleaning on the development of main pine stems were clear, especially in the younger stands. The results are, however, preliminary and based on permanent plots that have been observed only during the first four years after their cleaning treatments. In the untreated plots the number of main pine stems decreased by 1–2% each year, while the mean height of the main pine stems increased from 1.5 to 5.0 m. According to Karlsson et al. (2002), the average mortality of Scots pine main stems was even higher, i.e. 3–4% per year, when untreated plots were observed up to a mean height of 8 m. In addition to an increase in mortality, the proportion of serious whipping damage increased from 7% to 29% on the untreated plots observed in our experiments. The strong whipping of the upper crowns of pine will usually result in a change of leader shoot and, later on, in poorer timber quality.

Considering both mortality and serious whipping damage, the total loss of main pine stems was 19% and 33% at a mean height of 3.7 (younger stands) and 5 m (older stands), respectively if the cleaning of a saplings stand was not carried out in planted Scots pine stands with a high admixture of birch (5000–8000 stems per ha). According to Karlsson et al. (2002), only 30–40% of the initial main stems were retained at the mean height of 8 m. Thus, in pine stands with a rich birch admixture, early stand treatment is needed in order to maintain pine as the dominant tree species. According to our experiment, more than 80% of main pine stems will be free of whipping damage if the early stand treatment occurs when the height of the broadleaves is less than 2.5 m.

The results of this study support the use of point-cleaning as an early stand treatment when the mean height of the pines is about 1.5 m. On point- and totally cleaned plots, there were no differences in the mortality, diameter increment or whipping damage of main pine stems. After point-cleaning, the height increment was even greater than after total cleaning. Vestjordet (1977) has reported the same kind of reduction in height increment in the first 2–3 years after precommercial thinning in dense pine stands. If the early stand treatment (including point-cleaning) was delayed up to a mean height of 2.5–3.0 m, the mortality and increment of main pine stems did not increase but whipping damages decreased compared to untreated plots. In the younger stands, topping the competing broadleaves did not yield as good results as point-cleaning. Competing broadleaves that were topped at breast height continued their height growth from a living side branch and thus were able to catch up with in height with the main pine stems in both the younger and older stands.

The stands in this study will be re-measured at the precommercial thinning stage, when the dominant height will be about 8 m. Subsequently, it will be possible e.g. to analyse the long-term effects of the treatments, to calculate the total costs of tending, and to make recommendations concerning cleaning treatments for planted Scots pine. In addition, the effects of competing broadleaves on the characteristics of individual main pine stems (the diameter of the thickest branch, live crown height, diameter and height increment, whipping damage, etc.) will be analysed.

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