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Growth response of young Scots pines to artificial shoot breaking simulating moose damage

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TIIVISTELMÄ: HIRVIVIOITUSTA JÄLJITTELEVÄN VERSON KATKAISUN VAIKUTUS NUOREN MÄNNYN KEHITYKSEEN

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The main stem of young pine (*Pinus sylvestris*) trees was cut off halfway along the current leading shoot and the two previous years' leading shoots. Trees of the same size were chosen as controls before treatments. The experiment was inspected ten years after artificial stem breakage. Removing the current leading shoot and the second shoot did not essentially affect the height and diameter growth of the trees. Removal down to the third shoot reduced the height as well as diameter growth. The average loss in growth was equivalent to less than one year's growth. When the stem was cut off at the second or third shoot, stem crookedness and the presence of knots resulted in stem defects that will subsequently reduce the sawtimber quality. A high proportion of the stem defects will obviously still be visible at the first thinning cutting. Removing injured trees as pulpwood and pruning the remained parts of cut stems evidently improves the quality of pine stand with moose damage.

Männyntaimien (*Pinus sylvestris*) pääranka katkaistiin latvakasvaimen ja kahden edellisen vuoden kasvaimen keskeltä. Samanpituiset taimet valittiin vertailupuiksi ennen katkaisua. Koe tarkastettiin 10 vuoden kuluttua. Latvakasvaimen ja sitä 1 vuotta vanhemman kasvaimen katkaisu ei olennaisesti vaikuttanut pituus- eikä läpimitan kasvuun. Kahden vuoden ikäisen päärangan kasvaimen katkaisu vähensi sekä pituus- että läpimitan kasvua. Keskimääräinen kasvutappio oli vähemmän kuin yhden vuoden kasvu. Latvakasvaimen alapuolelta katkenneiden taimien mutkaisuuden ja haitallisten oksien arvioitiin alentavan sahatavaran laatua. Suuri osa vioista oli jäämässä rungon sisäisiksi. Sisäiset viat johtavat rungon sisäosasta saatavan sahatavaran laadun alenemiseen. Runkovikoja voidaan vähentää karsimalla katkenneiden päärankojen tyngät sekä poistamalla ne huonolaatuiset puut, joissa vielä ensiharvennusvaiheessa näkyy vikoja.

Keywords: *Pinus sylvestris,* stems, breakage, *Alces alces*, damage, growth, timbers, quality.
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1 Introduction

Moose (*Alces alces*) often break the main stems of young pine (*Pinus sylvestris*) trees while feeding in young stands. The proportion of main stem breakage out of the total number of trees browsed has been reported to be about 50 % (Löyttyniemi and Piisilä 1983, Peltonen 1986). The damage caused to the main stem later on leads to defects in timber quality, the severity of which depends on the location of the breakage point (Kangas 1937, 1949, 1962, 1963, Löyttyniemi 1983). Various types of quality defect reduce the technical properties of the stem, and the sawtimber that is eventually obtained (Uusvaara 1974, 1981, Kärkkäinen and Uusvaara 1982).

Evaluation of main stem damage is needed when decisions are made about whether to continue growing young stands seriously damaged by moose. It is especially important to know whether cutting off the main stem causes a permanent reduction in the quality of the stem. In the present study, the development of the trees with stem damage is investigated according to measurements made ten years after artificial stem breakage.

2 Material and methods

In 1977 an experiment was started in five young pine stands in order to study the effect of main stem cutting, performed at different heights, on the future development of the trees. The five stands located at Parkano (62°00'–62°15'N, 22°30'–23°00'E) and Muhos (64°45'N–65°00'N, 26°00'–26°30'E) were examined in 1987.

In 1977, moose damage was simulated by cutting off the main stem of altogether 240 young trees at three different heights, halfway along three consecutive years' annual shoots (top shoot, second shoot and third shoot). An equal-sized tree growing nearby was chosen as control for each damaged tree before treatments. The average height of the trees was 1.5–2 m, which conforms with the normal height browsed by the moose (Tables 1 and 2). Artificial breakage was done in late winter and in late autumn and the cut stem was removed from the main stem.

The forest site types of medium and low fertility were typical for Scots pine (Kujala 1979). The plantations had been established by sowing or by natural regeneration. As sub-dry site of mineral soil, *Vaccinium* site type represent better soil fertility than pine peat-moore type and as dry site, *Calluna* site type is relatively poor in fertility. Excluding the stands at Muhos, the experimental trees had also been examined five years after artificial breakage (Löyttyniemi 1983).

The height (cm), stem diameter (mm) at the cutting point and the diameter of the thickest side branch (mm) on the whorl below the cut were measured in 1987. The severity of the crookedness caused by cutting was determined according to three degrees of intensity (Löyttyniemi 1983). In the first class crookedness was noticeable but partly recovered. The second class consisted of trees with moderate crookedness, where the inner side of the stem did not, however, exceed the longitudinal axis of the stem at the crooked point. Severe crookedness (class 3) was where the inner side exceeded the longitudinal axis of the stem. Branching was considered to be strong when the diameter of the thickest side branch below the cutting point was over 50 % of that of the new main stem.

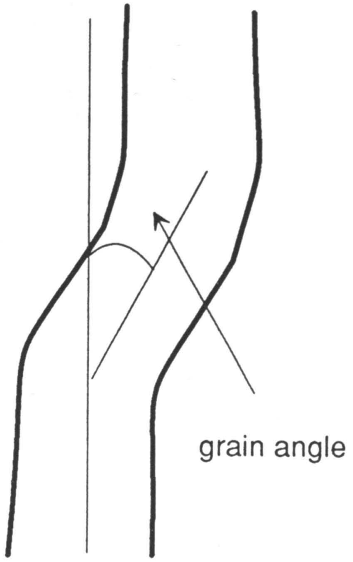

Fig. 1. Grain angle caused by crookedness.

Table 1. Site and tree characteristics in experimental stands at the start of the experiment.

Locality and site type	Trees at the start of the experiment			
	No. of trees (controls)	Age, years	Height, cm $\bar{x}$ ± S.E.	D.B.H., mm $\bar{x}$ ± S.E.
Parkano I *Calluna* site type Density 2240/ha	60(60)	24	200 ± 2	19 ± 0.5
Parkano II *Vaccinium* site type (paludified) Density 3280/ha	60(60)	13	181 ± 2	15 ± 0.4
Muhos I *Vaccinium* site type Density 2240/ha	74(74)	12	152 ± 3	12 ± 0.3
Muhos II Pine peat-moor with many undershrubs Density 2280/ha	46(46)	15	157 ± 4	11 ± 0.4
Muhos III *Vaccinium* site type Density 2560/ha	30(30)	14	172 ± 3	12 ± 0.4

The grain deviation due to the crookedness is one of the growth related defects in wood (Panshin and de Zeeuw 1980). The grain angle, measured as the deviation of the grain direction from the main axis, is considered to lower the quality of saw timber (Vientisahatavaran lajitteluohjeet 1979). Fifteen trees were chosen systematically (every fifth tree) from one stand at Muhos in order to study the grain angle in the crooked part of the main stem. The grain angle was measured as the deviation from the main axis at the point of the most crooked part of the stem (Fig. 1).

Side branches only were cut off in one stand (Muhos III) as follows: 1) All side shoots on the most recent branch whorl, 2) in addition, the one-year-old branch whorl was removed, excluding one branch, where only one one-year-old side shoot was cut off, 3) in addition to treatment 1, the one-year-old branch whorl was removed. Statistical analyses were made using the Student t-test.

Table 2. Initial diameter of the stem at cutting points.

Locality	Position of cut		
	Top shoot	Second shoot	Third shoot
		Diameter, mm	
	$\bar{x}$ ± S.E.	$\bar{x}$ ± S.E.	$\bar{x}$ ± S.E.
Parkano I	8 ± 0.3	11 ± 0.5	12 ± 0.6
Parkano II	8 ± 0.2	12 ± 0.6	13 ± 0.7
Muhos I	7 ± 0.2	10 ± 0.4	11 ± 0.5
Muhos II	6 ± 0.3	9 ± 0.5	10 ± 0.6

3 Results

3.1 Tree development

Height. Cutting off the main stem at the midpoint of the current leader shoot had no statistically significant effect on height growth (Fig. 2). None of the cutting treatments caused significant differences in height growth in Parkano I and Muhos II stands. Trees cut off at the midpoint of the second shoot were significantly shorter (on average 0.5 m) than the control trees in one stand (Muhos I). Trees cut off at the third shoot were 1.0 m shorter in Parkano II and 0.8 m in Muhos I than the control trees. The height loss as percentage of the height of undamaged trees averaged –5.8 % for top shoot, –3.9 % for second shoot and –13.3 % for third shoot cuttings, only the last proportion being significant (df = 78, $p > 0.05$). The average loss in height was 0.6 ± 0.1 m (df = 78, $p < 0.05$) for the most severe treatment compared with the untreated trees. This was equivalent to a yearly height loss of 6 cm. All the damaged trees survived.

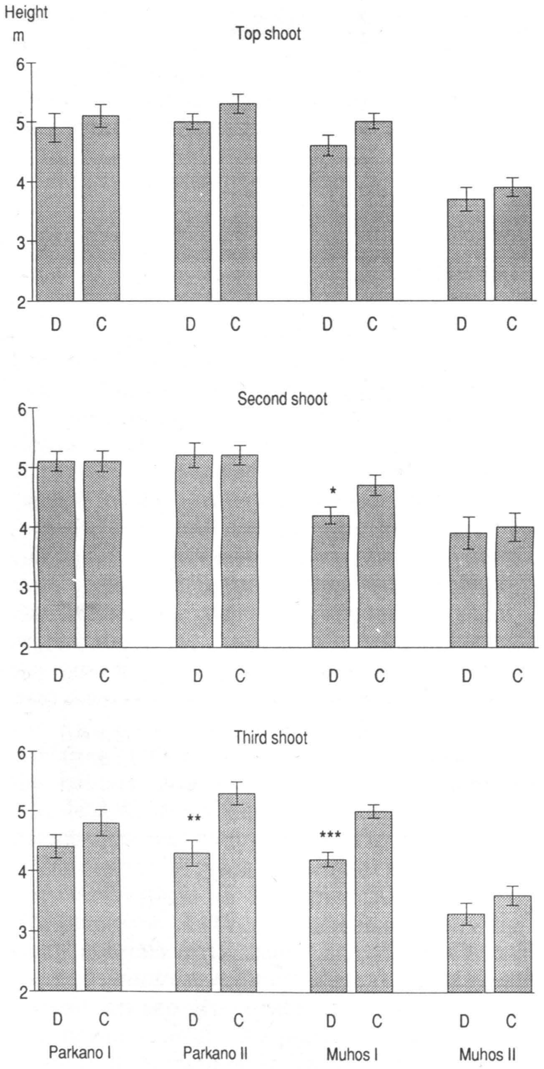

Fig. 2. Height (± S.E.) of the damaged and control trees 10 years after damage. D = damaged trees (n = 240), C = control trees (n = 240). T-test significance: * = $p > 0.05$, ** = $p > 0.01$, *** = $p > 0.001$.

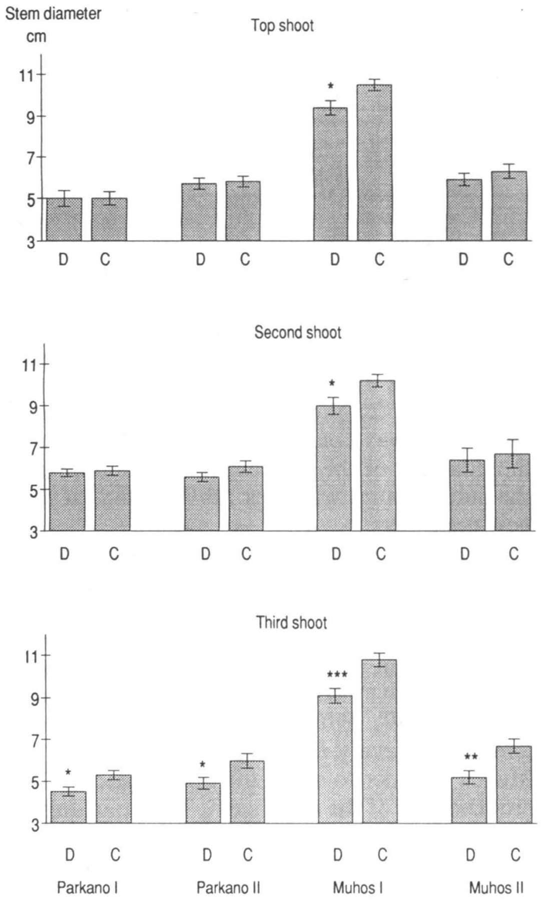

Fig. 3. Stem diameter of the damaged and control trees 10 years after damage. See further explanation in Fig. 2.

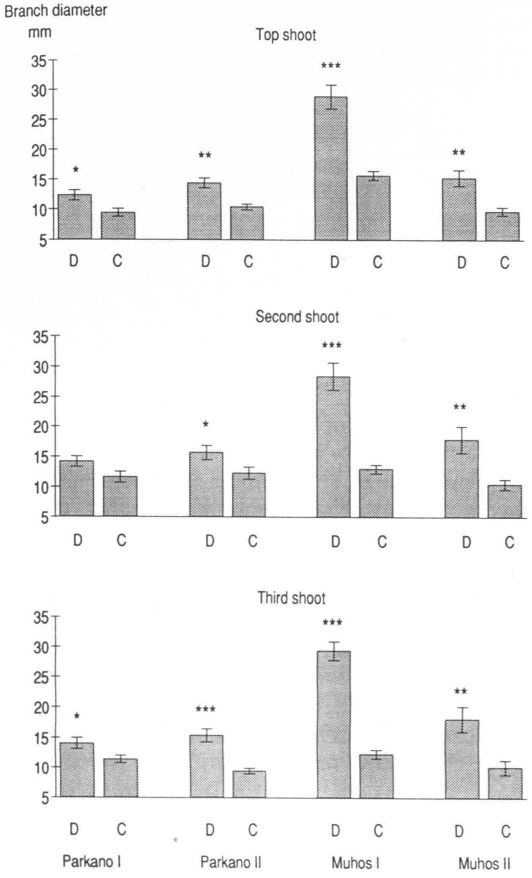

Fig. 4. Diameter of the thickest side branch under the cutting point on damaged and control trees 10 year after damage. See further explanation in Fig. 2.

The trees in Muhos II were shorter (< 4 m) than those in the other stands, where the height varied from 4.2 m to 5.3 m. The difference was evidently due to the varying fertility of the site types. Neither this nor the variation in stand density explained the recovery of the trees in different stands. When artificial stem breakage was done only once, there were no signs of excessive or bushy development of the tree crown.

Diameter. The diameter of the new main stem of trees cut off at the current or previous year's leader shoot did not differ significantly from the control trees, with the exception of Muhos I (Fig. 3). In this stand the trees cut at the top shoot were 1.0 cm and those cut at the second shoot 1.1 cm thinner than the control trees. The trees cut off at the third shoot in Muhos I were 1.7 cm and in the other stands 0.8–1.5 cm thinner than the control trees. The average difference in class C, compared with the control trees, was 1.2 ± 0.1 cm (df = 78, $p < 0.01$), which is equivalent to a yearly loss in diameter growth of 1.2 mm.

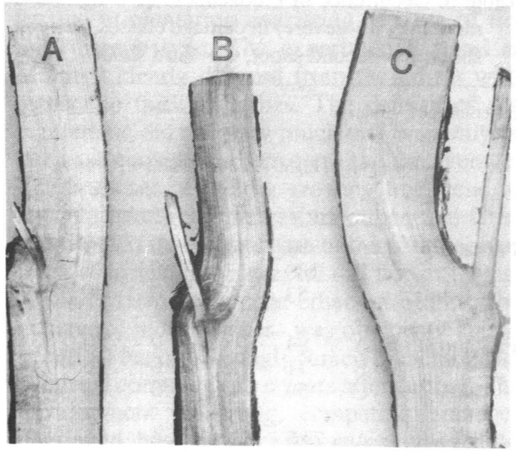

Fig. 5. Longitudinal section of stem cuttings. Position of cut: top shoot (A), second shoot (B), third shoot (C).

Branches. In addition to the formation of the new main stem from the branch whorl below the cutting point, the thickest branch of this whorl was clearly thicker than those on the control trees (Fig. 4). Thickening of the branches was greatest in Muhos I and least in Parkano I stand. Also branches of the control trees were slightly thicker in Muhos I stand compared to others.

The remaining section of the cut main stem usually remained attached, especially in trees cut off at the second or older leading shoot. The remaining section was not alive in any cases. Strong, forked branching of the top shoots occurred only in trees cut below the top shoot, and only in 6 % of the trees.

Development of crookedness. The crookedness resulting from cutting was the stronger, the lower the location of the cutting point (Table 3, Fig. 5). On an average, almost 90 % of the top shoot and 65 % of the second shoot removals resulted in only light crookedness. Over one

Table 3. Occurrence of crookedness (1 = light, 2 = moderate, 3 = severe) in damage classes (A = top shoot, B = second shoot, C = third shoot).

Experimental stand	Damage class	Class of crookedness Light	Moderate %	Severe	No. of trees
Parkano I	A	94	6	0	20
	B	100	0	0	20
	C	53	47	0	20
Parkano II	A	94	6	0	20
	B	71	29	0	20
	C	59	41	0	20
Muhos I	A	80	16	4	25
	B	44	40	16	25
	C	22	52	26	24
Muhos II	A	83	17	0	18
	B	62	31	8	13
	C	33	53	14	15
All sites	A	87	12	1	83
	B	66	27	8	78
	C	41	49	10	79

Table 4. Grain angle of crooked stem compared with normal stem in different damage classes (position of cut: A = top shoot, B = second shoot, C = third shoot).

Damage class	Grain angle Degrees	S.E.	N
A	26.2	3.2	5
B	39.0	3.7	5
C	40.0	14.8	5

half of the cuttings made at the third shoot resulted in moderate or severe crookedness. The crookedness that developed after removal at the second or older shoot was often severe enough to remain visible for a longer period in the stem. The persistance of crookedness as a factor lowering the quality of sawtimber depends, however, on the grain angle.

Grain angle. The grain angle caused by the crookedness was the greater, the lower the cutting point (Table 4). The difference between cuttings made at the top shoot and those at the second or third shoots was considerable. The difference between class A and class B was significant ($p < 0.05$, $t = 2.59$, $df = 8$). Values for the third shoot removal varied too much to permit definite conclusions to be drawn.

Side branch cutting. Removal of the side branches of the current and one-year-old branch whorl did not affect the height nor the diameter growth.

4 Discussion

Cutting off the main stem of young pines halfway along the current leader or second shoot did not seem to have any marked effect on the height and diameter growth. The growth loss during the study period was less than one year's growth. This result was to be expected, because the differences in growth were only small at the time of the first inspection five years after the start of the experiment (Löyttyniemi 1983). The ability of the trees to compensate for the loss of biomass at the top of the tree is obviously partly due to the improved illumination of the lower foliage. Långström (1980) and Ericsson et al. (1985) demonstrated that the reduction in the biomass of the top of young pines results in a relatively short-lived and small decrease in growth. Probably the loss in growth would be greater for smaller trees with less biomass available for recovery.

The marked ability of Scots pine to recover is evident from the fact that those trees whose main stem was cut off at the third shoot even were significantly shorter than the control trees in only two stands. Compared with the situation five years after cutting (Löyttyniemi 1983), the difference in height at Parkano was significant in one stand only, compared with three stands in 1981. Permanent bushy development of the tree crown was not found, even though this phenomenon had occurred five years after cutting in 5–20 % of the trees, depending on the severity of damage. However, the diameter of the cut trees was in all of the most severe damage cases smaller than that of the untreated ones. This was probably due to the concentration of compensative growth on height development.

A high proportion of the trees that were cut off at the second or third main stem shoot evidently develop strong and persistent crookedness defects. Crookedness was on average clearly lighter than five years after cutting (Löyttyniemi 1983). Thus the reduction in the proportion of most severely damaged cases averaged 56 %. In the moderate and light damage classes the increase was 11 % and 45 %, respectively. However, a high proportion of these defects were still present within the stem. Some of the defects will reduce the quality of the butt logs. The hidden defects will become visible only when the logs are being converted into sawtimber. When the grain angle is taken as a measure of the severity of the defect (Vientisahatavaran lajitteluohjeet 1979), those trees that are broken off below the top shoots will produce timber of inferior quality. The effect of the defects on the quality of saw timber depends also on the practice of sawing. The unaffected parts outside the central section will produce timber of normal quality. On the other hand, even a slight deviation in the grain direction may be important e.g. when using the strenght-grading of timber (Panshin and de Zeeuw 1980).

The remaining section of the broken main stem usually remains attached for a long time, especially when the stem cutting is located below the current leading shoot. Furthermore, the number of harmful, dead knots will increase, reducing the suitability of the logs for saw timber (Heiskanen 1954, Panshin and de Zeeuw 1980). Shoots broken off by moose have an irregular surface, which may increase the risk of decay. The remaining section of the broken top can be removed, and the defective point will evidently occlude more rapidly. Pruning the living side branches also reduces the problem caused by thickening of the knots.

Thickening of the branch in the branch whorl below the cutting point also reduces the technical quality of the wood, because knottiness is considered to be an important quality criterion (Heiskanen 1954, Kellomäki et al. 1988). In the present study branch thickening was most intensive in plantation consisting of trees of the thick-branch type. The experimental stand at Muhos I clearly differed from the others with respect to thick branches. The density of the plantations did not vary much and was only in one case considerably greater than the average. The branches of rapidly growing trees tend to become relatively thick (Kärkkäinen and Uusvaara 1982). As the site type of the plantation of thick-branch type, however, did not differ essentially from that of the others at Muhos, the difference in branchiness was obviously due to genetical factors. Strongly forked branching had occurred commonly five years after cutting. The development of strong, competing branches continued, however, in a few cases only.

From the economic point of view, most important result is the uselessness of a great proportion of the lower part of the trunk for sawtimber of high quality, especially when the trees are broken off below the top shoot (cf. Kärkkäinen 1984). Growth loss is not important unless the trees are broken off below the second main stem shoot. Crookedness and branchiness may, however, reduce the yield of pulpwood obtained from such trees. Smaller saplings are reported to respond relatively strongly to stem cutting (Poikola 1987). Definite conclusions of the effects of cuttings can be drawn after experimental sawing of butt logs.

The trees that are broken off below the current leader shoot should be removed in thinnings as pulpwood. Although a great proportion of the stem defects will eventually be overgrown, they may be visible in the first thinning at least. In the present study only stem cutting occurred once was analysed. Repeated damage is, however, a common occurrence, because moose often browse on previously injured young trees (Löyttyniemi and Piisilä 1983, Bergström 1984, Heikkilä 1991). In young stands repeatedly damaged by moose over a period of several years the number of trees without any recovering ability increases. If the main stem is broken off at a point below the third main stem shoot, the trees do not usually recover (Löyttyniemi 1983).

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