

Factors affecting the healing-over of pruned Scots pine knots

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SELOSTE: PYSTYKARSITUN MÄNNYN OKSIEN KYLJESTYMINEN

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The material of the study consisted of 21 pine trees that had been pruned in the 1930's and 1940's. The butt log of the pruned stems was peeled into veneer from which the length and shape of the resin taps were determined. The length of the resin tap was affected in the first place by the knot diameter and the height of the knot along the stem. The length of the resin tap was about 1.5-fold that of the knot diameter. With an increase in the height above the ground of a knot, its length decreased. The resin taps were particularly long on poor sites and in the butt end of stems; however, the variation in tap length was large both within and between individual tree stands. The shape of the resin taps is presented in this study by diameter classes. The resin taps studied in this work were longer than those measured in other works. This may be due to the fact that the knots were uncovered by peeling instead of sawing.

Tutkimusaineiston muodosti 21 1930- ja -40-luvulla pystykarsittua mäntyä seitsemästä eri metsiköstä. Karsittu tyvitukki sorvattiin viiluksi, josta määritettiin pihkatappien pituus ja muoto. Pihkatapin pituuteen vaikuttivat eniten karsitun oksan koko ja oksan korkeusasema. Pihkatapin pituus oli noin 1,5 kertaa oksan läpimitta. Pihkatappi lyheni oksan korkeusaseman kasvaessa. Pihkatapit olivat erikoisen pitkiä heikoilla kasvupaikoilla ja runkojen tyvillä, mutta pituuden vaihtelu oli suurta sekä metsikön eri puiden että metsiköiden välillä. Pihkatappien muoto on esitetty kuvin läpimittaluokittain jaoteltuna. Tässä tutkimuksessa mitatut pihkatapit olivat pidempiä kuin aiemmissa tutkimuksissa. Syynä saattoi olla oksien ottaminen esiin sorvaamalla sahaamisen sijasta.

Keywords: *Pinus sylvestris*, pruning, healing-over, resin tap length.
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1. Introduction

11. A brief history of pruning

The oldest pruning trials were carried out in Central Europe as early as in the 16th century. During the course of the following centuries pruning became more common, but it was not until the later half of the 19th century that the techniques of pruning and the tree species suitable for pruning were finally established.

In Germany (Central Europe), according to Mayer-Wegelin (1936), pruning experienced three culmination periods. The first of these periods took place in the 18th century, the next one began in the end of the 19th century and the third, in the 1920's. During these periods the study of pruning was increased, too.

In Finland, too, pruning has experienced three culmination periods. At least this is so if we draw our conclusions from the numbers of papers written on this matter during various periods of time. On the basis of Saranpää's (1984) list of references we may conclude that the first peak period occurred around the past turn of century and the next one in the 1930's and 1940's, whereas the third one began in the middle of the 1970's.

12. Physiology of the healing process

As a living branch is cut off from a tree, the cells that become injured will die and dry up. The cell tissue underlying this layer of damaged cells will be impregnated by various agents that will protect the tree and increase its power of resistance against diseases. Healing of the wound begins in such a way that the cambium along the edges of the wound is transformed into wound cambium, which has short cells and which is capable of dividing over a long period of time during the growing season. The radial growth of the stem is normal to the very end of the knot. Overgrowing of the cut proper begins as soon as the cambium adjacent to the knot has grown to the level

of the knot end. Now the wound cambium is able to grow over the cut in the knot end because there is no obstacle to check growth in this direction. The pressure on the cambium caused by the growth of wood and bark ceases when the branch is cut off, and this still stimulates cambium growth along the surface of the cut.

After *dèbranching* there is a decrease in the growth pressure, which is greatest in the bark ring around the stem in which the wound is located. The bark mantle above and under the wound remains intact. For this reason cambium growth is fastest on both sides of the wound.

Because the flow of fluid and nutrients from the needles better hits the upper than the lower edge of the wound, overgrowing is faster at the former. The only direct connection between the stem cambium and the branch cambium is in the lower side of the branch and this may be one reason why upper and side edges overgrow faster, because the stem cambium is not hurt there (Mayer-Wegelin 1952, Shigo 1985).

There is no organic connection between the dead cell tissue of the wound and the cells produced in the process of healing. In healing-over the new tissue just grows over the wound (Mayer-Wegelin 1952).

After pruning coniferous trees secrete resin for protection against rot fungi. In some species secretion is so ample that the resin also penetrates into the wood surrounding the wound (Bredenkamp and van Vuuren 1987).

13. Factors affecting the time of healing-over

The length of the time of healing-over depends on several different factors such as the tree species, the diameter of the branch, the length of the branch stub, the growth rate of the tree, the site, the condition of the tree, the time of the year when pruning is carried out and whether the branches pruned are dead or alive (Mayer-Wegelin

1936, Sairanen 1985, Huuri and Huuri 1988). In this section the time of healing-over is defined as the time needed for complete occlusion of a wound caused by pruning.

131. Influence of the tree species

Generally speaking, healing over is faster in hardwoods than in softwoods. According to one of Mayer-Wegelin's (1936) sources, the time required for healing-over of a branch with a diameter of 3 cm is thirteen years in Scots pine, seven years in birch and five years in oak. Ash, elm and beech heal over at about the same rate as oak.

In the softwoods Douglas fir and larch show the fastest rates of healing-over, whereas results concerning Norway spruce and Scots pine are contradictory.

According to Mayer-Wegelin (1936) and Sairanen (1985), Norway spruce heals over faster than Scots pine. On the other hand, according to source of Huuri and Huuri (1988), the time of healing-over is ten years in spruce, eight years in pine and six years in larch.

According to Krigul (1961), at similar branch diameter, the time required for overgrowing is 1...2 years shorter in pine than in spruce. The average healing time is about seven years in pine. However, the spruce branches studied in that connection were somewhat thinner than those of pine, and so the average time of healing-over was the same in both species. According to Romell (1941), the time of healing-over is of more or less similar length if the branch diameter and the growth rate trees are of similar magnitude. In his material, however, spruce was faster in healing-over than pine because the branches that had been cut off were smaller in the former.

132. Influence of the knot diameter

The length of time required for overgrowing increases with increasing knot diameter. This is so because the cambium tissue growing over the wound is expanding at a more or less constant rate, which even might grow slower as the wound

becomes older. In Mayer-Wegelin's (1936) study, for example, the time of overgrowing increased from eight to thirteen years when the knot diameter increased by one centimeter. Romell's (1941) material showed a difference of similar magnitude. In pine the time of overgrowing varied from three to twenty-two years when the diameter increased from six to forty millimeter and the growth rate was constant. Andersson (1967) presents similar results. According to Heiskanen and Taipale (1963), as 19-23 years had elapsed since pruning, the percentage overgrown knots shows a clear decrease with increasing knot diameter.

133. Influence of the length of the branch stub

With an increase in the length of the branch stub, the time of healing-over increases, too. This is because the cambium of the stem prior to the start of overgrowing has to reach the level of the stub end. The delay in the start of overgrowing approximately corresponds to the quotient obtained by dividing the stub length by the annual radial growth. In any case, pruned pine trees will need time for overgrowing their stubs because living pine branches must not be cut very close to the stem as there is meristematic tissue which must not be injured (Rommel 1941, Heiskanen and Taipale 1963).

134. Influence of the growth rate of the tree

The growth rate of the tree, the site and the condition of the tree influence the rate of healing-over in relation to each other. According to several authors, if the time of overgrowing is measured in terms of years, well-growing trees heal their wounds over at a faster rate than poorly growing trees (Mayer-Wegelin 1936, Krigul 1961, Andersson 1967). This decrease in the time of healing-over is a consequence of the fact that a fast-growing tree produces the wood mantle required for overgrowing the wounds much faster than a poorly growing tree.

14. Length of the resin tap and the factors affecting it

There are only few papers dealing with the factors affecting the length of the resin tap. We are in almost complete lack of information concerning the changes in resin tap length if we vary one factor of influence and keep the other ones constant. For example, are the resin taps of well-growing trees shorter than those of poorly growing trees at constant branch diameters?

The length of the resin tap produced in connection with the healing-over of wounds caused to pine through pruning and the factors influencing it have been dealt with at least by Romell (1941), Krigul (1961), Heiskanen and Taipale (1963) and Andersson (1967).

According to Romell (1941), there is no difference in the length of the resin tap produced in the end of dry- or greenpruned knots. In his opinion the length of the resin tap is dependent on the diameter of the branch and the growth rate of the tree during the period of healing-over. The length of the resin tap increases with increasing branch diameter. On the basis of data obtained from a material in which 90 per cent of the knots produced by pruning had already become overgrown, the length of the resin taps increased from 6 to 18 mm with an increase in branch diameter from 6 to 25 mm. According to Romell (1941), an increase in the annual radial growth produces an increase in resin tap length when the branch diameter is constant. In his material, when the average annual radial growth increased from 0.6 mm to 1.4 mm, resin tap length increased by 4–6 mm. However, Romell states that there is a very large variation in resin tap length even between branches of similar size that have been cut from the same trees. He, nevertheless, gives no explanation to this variation.

Krigul (1961) presents a formula according to which the time required for healing-over (in terms of years) depends on the knot diameter and the rate of diameter growth of the tree at breast height. The formula gives emphasis to the importance of the knot diameter, and the resin tap length is linearly dependent on knot diameter.

According to Heiskanen and Taipale (1963), too, the length of the resin tap in the first place is dependent on the knot diameter, and to some extent, on the fact whether the branch was cut off dead or alive. The resin tap forming in the end of a green-pruned knot is somewhat shorter than that forming in the end of a dry-pruned knot if branch diameter remains constant. According to formulae derived by these authors, resin tap length is linearly dependent on the knot diameter. The resin tap lengths obtained by means of these formulae are slightly smaller than those presented by Romell (1941). These authors also state that the diameter of resin taps of small knots is smaller than that of knots with a larger diameter. In their work the average tap length was 11.4 mm for green-pruned and 10.6 mm for dry-pruned knots. However, the authors state that the difference was due to the fact that the green-pruned branches were considerably thicker than the dry-pruned ones.

From the data presented by Andersson (1967) it is not possible directly to determine resin tap length by calculation. This is because he presents the extension of the overgrowing as the difference between two diameters: the stem diameter at knot height prior to pruning and after healing-over. He makes the presupposition that the length of the knot stub is always the same. According to Andersson, the stem diameter at the time of pruning, the annual radial growth prior to pruning and the branch diameter influence the length of the resin tap. In his formula he stresses the importance of the dependence of the resin tap length on the knot diameter and states that it is linear. Compared with the studies mentioned above, his resin taps were shorter.

Each one of the sources mentioned above emphasize the great importance of the knot diameter to the length of the resin tap. Moreover, the diameter growth of the tree is of importance: according to Romell and Andersson, by lengthening the resin tap, and according to Krigul, by shortening it.

Park (1982) studied pruned *Pinus radiata* in New Zealand. He presents a formula on the basis of which it is possible to determine by calculation the maximum extension of the overgrown zone (the length of

the resin tap) if the diameter of the tree prior to and after pruning are known. On the basis of his formula the maximum resin tap length is about 30 mm. He gives no information concerning the material from which the formula was derived. Differences in the length figures were due to the fact that the diameters of green-pruned branches were noticeably larger than those of dry-pruned branches.

McKinnel (1974), on the basis of a source of his, states that a stem of *Pinus radiata* that is pruned when its stem diameter at breast height is 10 cm must increase its breast height diameter by 8 cm until formation of knot-free wood is started.

The Rumanian Gava (1973) determined the length of the resin tap of pruned Norway spruce at 1.5–2.0 cm. However, he gives no information about the knot diameters.

15. Aim of the study

The present study was carried out to obtain information about the healing of wounds caused to Scots pine (*Pinus sylvestris* (L.)) by pruning and about the factors influencing the healing process. The study is an effort to find out how much radial growth is needed until the knots produced

by pruning are completely overgrown and to establish the amount of time that is needed for the process of healing-over. Moreover, the study deals with the length and shape of the resin tap forming in the end of the knots remaining after pruning as well as the factors influencing them.

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2. Material and methods of the study

21. Tree stands

The material of this study was obtained from seven stands which had been pruned in the 1930's and 1940's. Six of the stands were located in Finland and one in Sweden.

In each stand the site type and stand density were determined. When possible, the method of reproduction was established. Table 1 gives information about the tree stands of the sample plots.

In each one of the sample plots three pine trees were picked out as sample trees. The first one was selected subjectively to

make sure that it represented the normal pruned trees in the tree crop concerned. It was not allowed to grow at the edge of an opening or to be abnormal in growth for some other reason. After this decision the two pruned trees next to the first one were taken as sample trees. In some cases there was a possibility that a tree was overlooked because it was not possible in each case to see whether it was pruned or not. Generally speaking, it was not too difficult to discover the pruned trees even 40 years after pruning.

Table 1. Data on the tree stands in the sample plots.

Taulukko 1. Metsiköiden tiedot.

Stand no	Commune and owner	Forest site type	Density no. of stems/ha	Regeneration method	Year of pruning
Metsä no	Kunta ja omistaja	Metsätyyppi	Tiheys runkoa/ha	Uudistamis-menetelmä	Karsintavuosi
1.	Kapellskär, Sweden, Sveriges Lantbruksuniversitet	h100 = 28	550	planted <i>istutettu</i>	?
2.	Tammela Oy Finlayson Ab	VT	500	broadcast sowing in burned-over area <i>hajakylvö paloalueelle</i>	1948
3.	Tammela Oy Finlayson Ab	CIT	450	broadcast sowing in burned-over area <i>hajakylvö paloalueelle</i>	1948
4.	Janakkala Oy W. Rosenlew Ab	MT	550	?	in the 1930's <i>1930-luvulla</i>
5.	Tenhola Finn. For. Res. Inst.	MT	750	natural regeneration <i>luontainen uudistaminen</i>	?
6.	Tenhola Finn. For. Res. Inst.	VT	400	natural regeneration <i>luontainen uudistaminen</i>	in the 1930's <i>1930-luvulla</i>
7.	Elimäki, Mustiala Nils & Karl Tigerstedt	Pyt	500	?	in the 1930's <i>1930-luvulla</i>

22. Sample trees

In the case of each sample tree, the breast-height diameter was measured at an accuracy of one centimeter. The height of the tree as well as the height of the lowest living and dead branch were determined at an accuracy of one meter. The lowest dry branch was defined as the lowest one the thickness of which exceeded one centimeter. Table 2 shows the main characteristics of the trees.

The radial growth of the sample trees was measured from discs that had been cut from the ends of bolts which, in turn, had been cut from the butt logs of the trees. Annual radial growth was determined by measuring the growth during five-year pe-

riods from the pith and dividing the values obtained by five.

23. Measuring the knot size

After felling the sample trees, the butt log, which had been pruned, was separated from the rest of each tree. The logs were cut into bolts about 70 cm in length. From between each bolt a disc about 5 cm in thickness was cut out for growth measurements, etc. In connection with felling the bolts and discs were marked in such a way that the point from which numbering of the knots was started came in the same direction along the stem in each bolt, and likewise, that the direction of growth mea-

surement from the pith was the same in each bolt.

To obtain detailed information about the knots, the bolts were peeled into veneer with a thickness of 1.5 mm. This made it possible to get data on the knots to be studied at intervals of one and a half millimeter. The diameter of the bolts to be peeled was measured both before and after rounding-off peeling, after which unbroken sheet of veneer was produced. The

diameter of the peeler core was 100 mm. The length of knot- and resin-free veneer from the outer mantle of the peeler block was measured, whereas the inner part of the block, which contained knots and resin, was dried to prevent molding and stored. To determine shrinkage, segments of lines on the veneer were measured before and after seasoning.

At the stage of measurement the veneer obtained from each bolt was used to rebuild

Table 2. Data on the sample trees.

Taulukko 2. Koepuiden ominaisuudet.

Stand no	Tree no	d.b.h.	Height	Lowest branch		Age	Average ring width at d.b.h	Length of butt log
				living	dead			
Metsikkö no	Puun no	Rinnan-korkeus-lpm.	Pituus	Alin oksa elävä	kuollut	Ikä	Keskim. luston leveys rinnan kork.	Tyvitukin pituus
		cm	m	m	m	y	mm	dm
1	1	31	23 ¹⁾	13 ¹⁾	5	67	2.1	45
	2	35	23 ¹⁾	13 ¹⁾	4	69	2.4	40
	3	27	23 ¹⁾	13 ¹⁾	5	68	2.6	42
2	1	27	26	20	5	64	2.1	42
	2	25	24	19	6	60	1.8	50
	3	27	26	14	6	66	1.9	56
3	1	22	20	13	5	63	1.6	49
	2	28	21	13	6	64	2.0	57
	3	26	21	12	5	64	1.8	49
4	1	28	21	8	6	80	1.6	50
	2	25	19	10	6	85	1.4	58
	3	22	19	9	5	104	1.5	49
5	1	21	19	11	5	53	1.8	49
	2	22	20	12	6	54	1.9	53
	3	28	23	13	6	57	2.2	54
6	1	27	19	11	5	82	1.5	48
	2	25	19	11	5	82	1.5	48
7	1	26	21	13	6	69	1.7	49
	2	24	22	15	6	64	1.7	55
	3	27	24	19	5	67	1.8	49
	4	28	25	18	7	68	1.8	56

¹⁾ Average in the stand
Metsikössä keskimäärin

a mantle around the peeling cores. Each knot was given a numerical symbol indicating the stand number (1...7), the number of the tree in each stand (1...4), the number indicating the order of the bolt from the butt end of each sample tree (1...9), the number indicating the order of the branch whorl from the butt end of each sample tree (1...14) and the number indicating the order of the knot concerned in each of the branch whorls (1...10). In addition, the distance of the point of measurement from the peeler core was indicated as the number of revolutions from the peeler core. In this way it was possible to identify each knot and to relocate each point of measurement. In the same way it was possible to identify each tree and each bolt, too. The symbol of the sample trees had two, and of each bolt, three digits.

On the basis of test measurements carried out in the very beginning of data collecting it was decided that each knot be measured at each odd revolution from the peeler core. This was done in order to speed up work and because the changes in the size and qualities of the knots were very small at 1.5 mm distances.

Each set of measurements consisted of determination of the quality of the knot concerned, its smallest and largest diameter and its distance from the lower edge of the sheet of veneer. In addition, in one case in each whorl, the distance along the sheet of veneer between two specimens of the same knot was measured. Knot quality was determined using the following criteria:

- 1) living knot the wood of which had grown completely together with the surrounding wood,
- 2) declining knot in which more than a half of the knot wood was attached to the surrounding stem wood,
- 3) dying knot in which less than a half of the knot wood was attached to the surrounding stem wood,
- 4) dead knot in the case of which the knot wood had become separated from the surrounding stem wood,
- 5) resin tap, in the case of which there was no wood in the knot hole. The resin tap was considered to continue as far as there was

something else than wood in the place of the knot.

The largest knot diameter was defined as the diameter of the knots in direction of the fibres of the stem wood, and the smallest, the knot diameter at right angles to the former.

By measuring the distance of the knots from the lower edge of the sheet of veneer it was possible to determine the curving of the knots. This distance was measured from the lower edge of the knot or the resin tap to the lower edge of the sheet of veneer.

If, in connection with pruning a knot had been cut obliquely, healing-over was considered as having started at the middle of the oblique surface. In some cases this shortened the resin tap to some extent, but taking the largeness of the study material into consideration the importance of this could not be but negligible.

The point of pruning of the knots was defined as the last revolution from the peeler core at which there was knot wood. This way of measuring led to systematic underestimation of the distance between the point of pruning and the pith, but the error was small, never exceeding 1.5 mm. Determination of the point of pruning made it possible to determine the length of the knots from the pith. This was obtained by multiplying the number of revolution of the point of pruning by thickness of the sheet of veneer, 1.5 mm, and adding 50 mm, i.e., half of the diameter of the peeler core, to the product obtained. The stem diameter at the height of a certain bolt at the time of pruning was obtained by subtracting from the length of the knot 10 mm as the average stub length remaining after pruning (Heiskanen and Taipale 1963). The length of the pruned branches had to be determined by calculation because the year of pruning was not known in all instances.

The radial growth of the bolts during the time of occlusion was determined by dividing the total radial growth of the bolts by the number of years covered by the period of healing-over. The radial growth was determined on the wood of a mantle that reached one centimeter from the pruning point toward the pith and a distance corresponding to the length of the resin tap

Table 3. Number of measured knots.

Taulukko 3. Mitattujen oksien lukumäärä.

Stand no. Metsikön no.	1			2			3			4			5			6		7			
Tree no. Puun no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	1	2	3	4
Number of measured Mitattu																					
- knots oksia	60	35	54	81	23	55	82	99	65	81	89	68	73	81	66	67	50	52	72	63	66
- knot whorls kiehkuroita	13	8	11	9	8	14	16	18	13	20	23	21	12	13	10	10	10	8	11	10	11
Knots/whorl Oksia/ kiehkura	4,7			5,1			5,2			3,7			6,3			5,9		6,3			

toward the bark.

The rest of the knots, which remained in the peeler core, was measured after splitting along the pith. On this part of the knots the diameter was measured at 10 mm intervals and the branching angle at a distance of 40 mm from the pith.

All in all the material of this study comprises measurements on twenty-one stems from seven tree stands. Data on the overgrowing of knots was obtained from 1375 knots. All the knots of the stems were not measured, and this was so partly because a part of them happened to come into the discs that were cut for growth measurement, and partly because knots that were not intact in the whole sheet of veneer were left unmeasured. Table 3 shows the knot material divided by plot and tree stand.

In the whole material a total of 189 measured knots were abandoned. In fifteen cases the wounds were not overgrown at all, and in 174 cases healing-over had begun at such an early time that the pruning point was in the peeler core. In stem no. 2, stand no. 2, healedover knots occurred only up to a height of 70 cm, so this stem was considered unhealed, too. In this case 80 knots

Table 4. Number of knots that were not measured.

Taulukko 4. Mittaamatta jääneiden oksien lukumäärä.

Stand Metsikkö	Healed Kyljestyneitä	Unhealed Kyljestyttömiä	Total Yhteensä
1	—	2	2
2	10	82	92
3	8	11	19
4	56	—	56
5	9	—	9
6	1	—	1
7	89	—	89

remained unmeasured. Table 4 shows the knots that were abandoned, divided by tree stand.

Knots that had healed over near the pith primarily occurred in stands 4 and 7, which were growing on the best sites. In these cases the branches also had been pruned at a smaller diameter than the average of the total material. The average diameter of unhealed knots was 19 mm and that of overgrown resin taps at the peeler core surface 7 mm.

24. Analysis of the data

The data obtained from measurements was analyzed using the BMDP program. Frequency distributions and correlations between various factors were determined.

The data was first grouped by tree stands and single trees, and for the groups thus obtained a number of different averages were calculated. At the next stage of the study the data was grouped according to the factors that were expected to be of importance for the length of the resin tap. Such factors are the branch diameter at time of pruning, the growth of the tree during the period of overgrowing and the height of the branch on the stem.

A number of analyses were performed using dummy variables, too. Thus it was possible to compare a part of the data with the rest of it in respect to a certain variable.

To improve the statistical reliability of the material efforts were made to group it so that each group would contain at least

100 observations. This, however, was not possible in all instances.

In the treatment of the material the concept knot size was used for the smallest, the horizontal diameter of the knots. Such a decision was made because in the case of the largest diameter there occurred a slight overestimation, which was caused by the branch angle and which could not be eliminated.

The height of the knots along the stem was determined by bolts as multiples of 70 cm. Thus all the knots of the same bolt were given the same value for the distance above the ground. The height of the knots was determined on the basis of the height of the bolts instead of the ordinal number of the branch whorls because it was observed during the course of the study that the properties of the knots were affected to a larger extent by their absolute height above the ground than the height determined by the ordinary number of the branch whorls.

3. Results of the study

31. Data grouping by sample plots and single trees

At the first stage of treating the material the measured knots that were included in the study were grouped by tree stands. Thus it could be assumed that growth conditions, stand treatment and pruning were similar in each group.

Table 5 shows the average horizontal diameters of the knots at the pruning point, the radial growth during the course of the time of occlusion and the length of the resin taps. The results are average for all knots.

The table in Appendix 1 shows the same data as averages for single trees. The tables do not contain information about knots that had not healed at all or the pruning point of which was in the peeler core less than five cm from the pith.

Table 6 shows the distribution of the knot diameter by stands. In most cases the

diameter of the knots was less than 25 mm. In respect to their average, the groups do not differ much from each other. In sample plot 1, which represents a good site, the diameter distribution of the knots was wider than in the other stands. Large knot diameters, which occurred in this site, were lacking in the sites representing Myrtillus site type. In the case of sample plot 2 it ought to be noticed that one tree was represented only by knots in the very butt end of the stem. In stand 4 the diameter of the knots was very small.

32. Effect of the knot diameter on the length of the resin tap

The average of the largest knot diameter at time of pruning was 11.8 mm and that of the smallest diameter 10.3 mm, whereas the average length of the resin taps was 16.5 mm. The ratio between the smallest knot

Table 5. Average knot diameter, tap length and growth by stands.

Taulukko 5. Karsittujen oksien keskimääräinen läpimitta, pihkatapin pituus ja puiden kasvu metsiköittäin.

Stand no.	Knot diameter, mm		Average Keskimääräinen Tap length, mm		Growth, mm/y		Ratio Tap length/knot diameter	
	Oksan lpm, mm		Pihkatapin pituus, mm		Kasvu, mm/vuosi		Pihkatapin pituus/ oksan läpimitta	
	\bar{x}	s	\bar{x}	s	\bar{x}	s	\bar{x}	s
1	16,7	11,5	16,5	8,9	2,2	0,4	1,4	1,5
2	9,8	5,1	20,0	12,3	2,1	0,6	2,7	3,8
3	8,8	4,7	11,9	5,5	2,1	0,4	1,5	1,1
4	7,2	3,5	10,7	5,4	1,3	0,3	1,7	1,8
5	10,7	6,1	13,1	6,4	1,6	0,3	1,3	1,0
6	10,9	6,3	15,3	10,5	1,7	0,4	1,7	2,1
7	9,6	5,0	11,7	5,4	1,9	0,2	1,4	1,1

Table 6. Distribution of the knot diameter by stands.

Taulukko 6. Oksien läpimitan prosentuaalinen jakautuminen läpimittaluokkiin metsiköittäin.

Knot diameter Oksan läpimitta mm	Plot number Metsikön numero							All Kaikki
	1	2	3	4	5	6	7	
	Percent of knots in diameter class Prosenttia oksista luokassa							
- 5	20	24	28	36	22	26	26	26
6-10	19	36	40	48	33	26	34	35
11-15	10	23	40	48	33	26	34	20
16-20	17	12	7	3	14	15	18	12
21-25	10	4	1	1	7	5	0	4
26-30	7	0	0	0	1	3	0	1
31-35	10	0	0	0	1	0	0	1
36-	7	0	0	0	0	0	0	1

diameter at time of pruning and the length of the resin taps was 1.6. i.e., the length of the resin tap was approximately 1½-fold the knot diameter at time of pruning. However, the variation was large.

The knot diameter, both in terms of absolute figures and relatively, greatly affects the length of the resin tap.

Table 7 shows the length of the resin taps, the radial growth during the period of healing-over and the height above the

ground of the knots grouped by the horizontal knot diameter.

The length of the resin tap shows an increase with increasing knot diameter. Likewise, the growth rate during the period of healing is fastest for large-sized knots. This is probably so because the biggest knots occur in the best-growing trees or parts of trees.

Examination of the data on the height of the knots above the ground shows that the

Table 7. The average tap length, radial growth and location above the ground grouped by the knot diameter.
Taulukko 7. Keskimääräinen pihkatapin pituus, sädekasvu ja oksan sijainti tukissa ryhmiteltynä oksan läpimitan perusteella.

Diameter Läpimitta mm	No. of knots Oksien lkm	Tap length, mm Pihkatapin pituus, mm		Growth, mm/y Kasvu, mm/y		Location above ground, m Etäisyys maahan, m	
		\bar{x}	s	\bar{x}	s	\bar{x}	s
-10	728	12,2	8,5	1,8	0,5	2,3	1,3
11-20	380	15,4	6,8	1,9	0,4	3,1	1,3
21-30	60	18,3	7,0	2,0	0,6	3,7	1,4
31-	26	25.5	7,8	2,3	0,4	3,2	1,1

smallest knots occur in the butt end of the stems. The largest knots, however, do not occur in the very topmost parts of the logs, but at a somewhat lower level. This reflects the shape of the tree crown at time of pruning; the largest branches occur at a height above the ground of about three meters.

Fig. 1 shows the influence of the knot diameter on the length of the resin tap. The horizontal axis presents the largest knot diameter divided into 10 mm classes. The vertical axis on the right hand shows the length of the resin taps, and that on the left hand, the ratio between the knot diameter and the length of the resin taps. According to the straight line in the graph, which represents levelled averages, there is a positive correlation between the knot diameter and the length of the resin tap. On the other hand, the increase in the length of the resin tap grows smaller with increasing knot diameter, which is shown by the curve indicating the ratio between the knot diameter and the length of the resin tap, which taking the shape of a paraboloid goes down from 2 to 0.5 with an increase in the knot diameter from 5 to 45 mm. Thus, relatively speaking, the resin taps of small knots are longer than those of larger ones.

To illustrate the differences occurring between tree stands of different type the data was divided by sample plots and the linear regression of the length of the resin taps on the maximum diameter of the knots were drawn on the basis of calculation. The

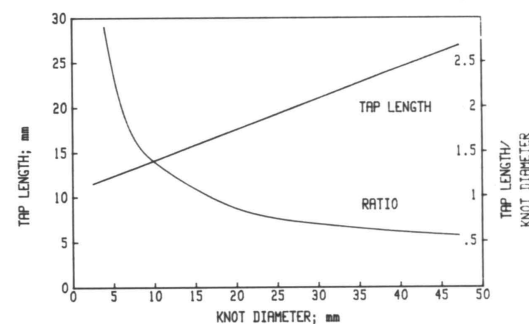


Fig. 1. Dependence of the length of the resin tap on the largest knot diameter, and the correlation between knot diameter and tap length.

Kuva 1. Pihkatapin pituuden (TAP LENGTH) riippuvuus oksan suurimmasta läpimitasta (KNOT DIAMETER) sekä oksan läpimitan ja pihkatapin pituuden välinen suhde (RATIO).

graph in Fig. 2 shows that there were great differences in the lengths of the resin taps corresponding to knots of similar size and that there was a variation in the dependence of the length of the resin tap on the diameter of knots. The poorest dependence was recorded for stands 2 and 6, and the closest dependence for stand 3 and 5.

Comparisons were made using dummy variables. Stand 1 was used as reference, and the changes in resin tap length in the other stands were compared with the tap length in this stand. The results were as follows:

Stand no.	1	2	3	4	5	6	7
Change in tap length	0	6.2	-1.6	-2.1	-1.2	1.0	-2.1

The differences are of a magnitude similar to that shown by Fig. 2. A difference in the average lengths shown by the table, and on the other hand, the figure, is probably caused by the fact that a right line in every case is not the best possible regression curve between knot diameter and resin tap length.

Examination of the dispersion of the length of the resin tap as presented in Table 5 shows that the dispersion was largest and really considerable in stands 2 and 6. A dispersion of corresponding kind could not be established for the knot diameter.

To get a more detailed idea of the dependence between the length of the resin tap and the knot diameter at time of pruning regression lines were drawn up for single trees (Fig. 3). The length of the resin tap is shown on the vertical axis and the minimum knot diameter and the growth during the period of healing-over on the horizontal axis. The lines of the graphs indicate the dependence of the resin tap length on the knot diameter and the radial growth during the period of healing. It was decided to describe this dependence by the use of straight lines because it was observed that linear correlation offers the best possibilities to level out the cluster of points. This can be seen in Fig. 1, for example. The poorest linear correlations were observed for stands 2 and 6, in the case of which the tap lengths were largely scattered.

In the case of stands 5 and 7 healing-over very well coped with the theory according to which the length of the resin tap is affected by the knot diameter and the radial growth of the tree during the course of the period of healing-over. The lines also run very close to each other, and this means that the differences between the single trees in the stands were very small. This also can be seen when studying the data presented in Appendix 1.

A different group is formed by plots 1, 3 and 4. In these cases there was a positive correlation between the length of the resin tap and the knot diameter. However the

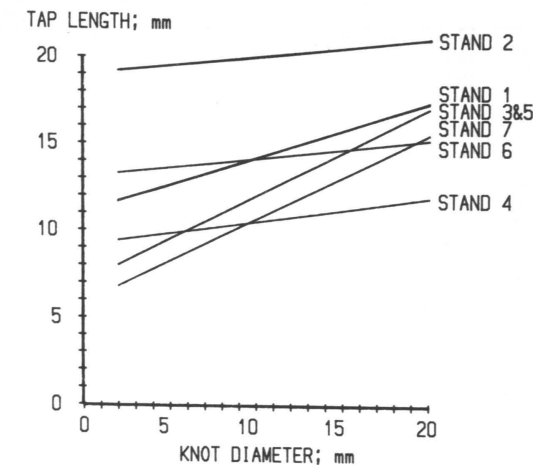


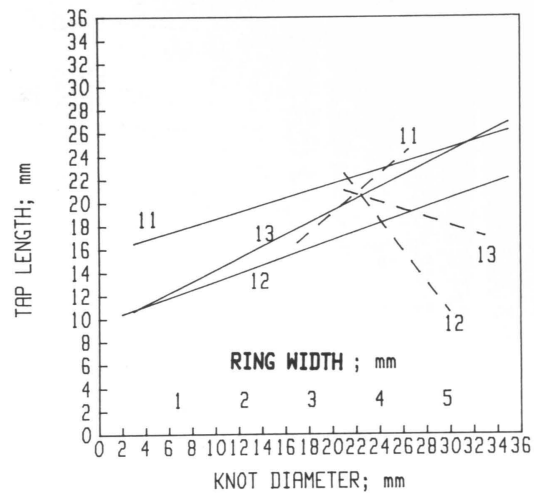
Fig. 2. Dependence of the length of the resin tap on the knot diameter by tree stands.

Kuva 2. Pihkatapin pituuden (TAP LENGTH) riippuvuus oksan läpimitasta (KNOT DIAMETER) metsiköittäin.

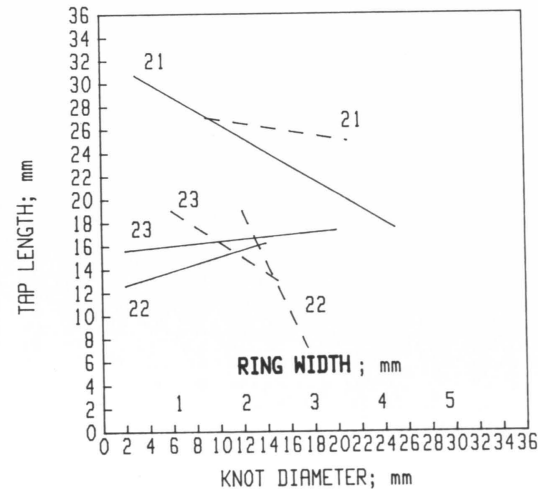
differences between single trees were larger than in the case of the first group. In this group there was at least one tree in each stand the growth of which was contradictory to theory, i.e., the length of the resin tap increased with increasing growth rate.

Another group was formed by sample plots 2 and 6. In this group there was a negative correlation between tree growth and resin tap length, and the correlation between tap length and knot diameter was of an unexpected nature.

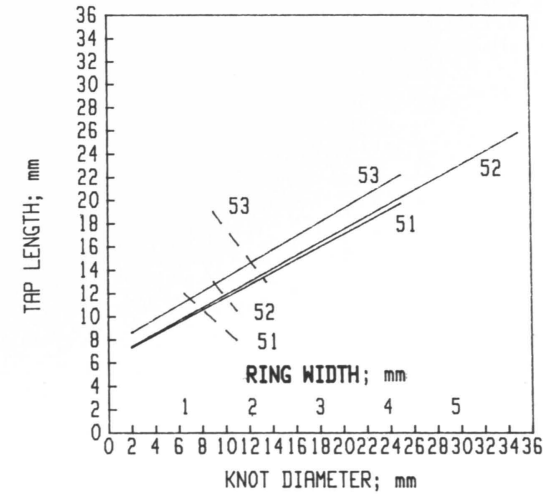
In tree no. 1, stand 2, there was a negative correlation between the length of the resin tap and the knot size, i.e., the resin tap was shorter the larger the knot diameter. The negative correlation was very clear. In the case of the other trees of the same stand the correlation was weakly positive. When examining the data obtained from this stand it also should be kept in mind that the knots of tree no. 2 did not heal at all, but that the resin taps were still visible at the time when the tree was peeled. The slowness of occlusion in stand no. 2 also becomes visible in the ratio between the length of the resin taps and the knot diameter, which was exceptionally large, 1.9...3.6.



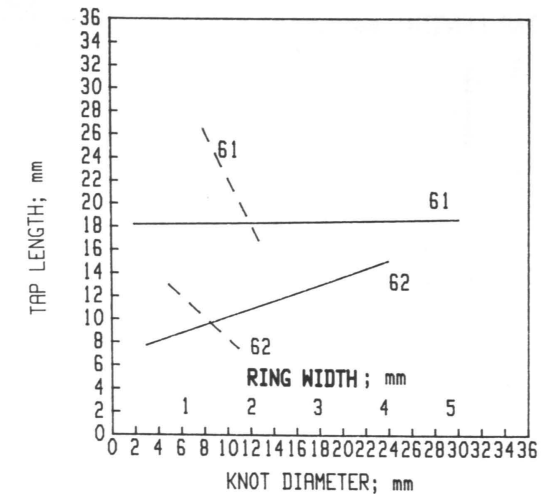
Sample stand 1.
Metsikkö 1.



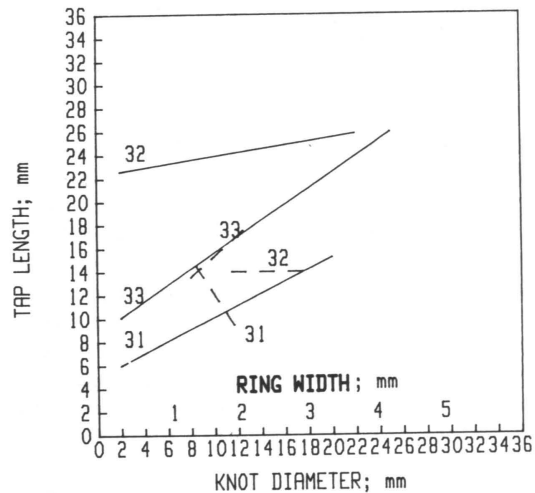
Sample stand 2.
Metsikkö 2.



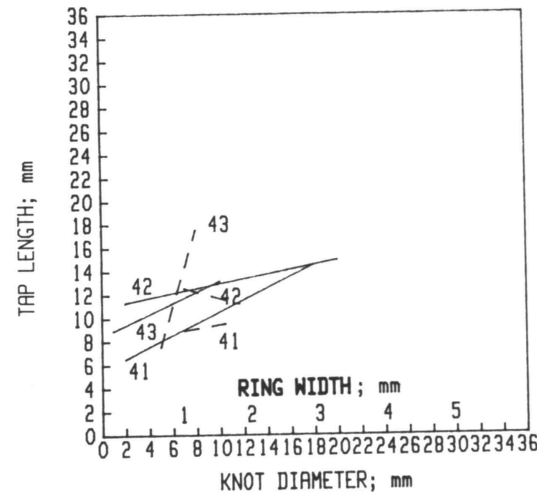
Sample stand 5.
Metsikkö 5.



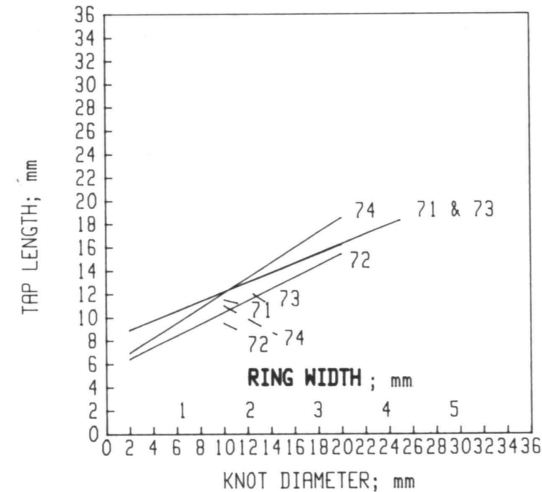
Sample stand 6.
Metsikkö 6.



Sample stand 3.
Metsikkö 3.



Sample stand 4.
Metsikkö 4.



Sample stand 7.
Metsikkö 7.

Fig. 3. Dependence of the length of the resin tap on the knot diameter and on the stem growth during the period of healing over and by tree stands. The dependence of the growth is indicated by a broken line and its scale is in upper x-axis. Knot diameter is in lower x-axis. The figures are numbers of the trees.

Kuva 3. Pihkatapin pituuden (TAP LENGTH) riippuvuus oksan läpimitasta (KNOT DIAMETER) ja vuotuisesta rungon läpimitan kasvusta (STEM GROWTH) kyljestymisaikana metsiköittäin. Riippuvuus kasvusta on piirretty katkoviivalla ja sen asteikko on ylemmällä x-akselilla. Luvut viittaavat rungon numeroihin.

In the case of tree no. 1, stand 6, there was no correlation between the length of the resin tap and the knot diameter; the knot diameter did not affect tap length at all. Likewise, in the case of tree no. 1, the ratio between the length of the resin tap and the knot diameter was large, 2.2. In tree no. 2 the correlation was positive.

The efforts to find a reason for the unexpected correlations in the case of trees no. 21 and 61 revealed that the resin taps in

both cases were exceptionally long in comparison with the other trees, and particularly, that the ratio between the length of the resin tap and the knot diameter was of a considerable magnitude. In tree no. 21 the average knot size was larger than in the other trees in the same stand. In stand no. 6 a difference of this kind did not occur. On the other hand, there was a considerable difference in the growth during the period of healing-over.

The main reason for the poor correlation in the case of these trees, however, seemed to be the fact that the thin knots in the butt end of the trees healed over at a very slow rate as compared with the other trees, and this led to a decline of the regression coefficient. In fact, no good explanation was found for the poor healing-over in the case of these knots.

Because of this situation, it was decided to exclude the data on trees 21 and 61 from

continued examination. Instead, the study was focused to other factors of influence on the length of the resin taps.

When the data concerning these two trees had been abandoned, the changes in resin tap length as calculated with the help of dummy variables in comparison with stand no. 1 was 1.7 mm in stand no. 2 and -4.6 in stand no. 6.

In order to establish the dependence between knot diameter and resin tap length

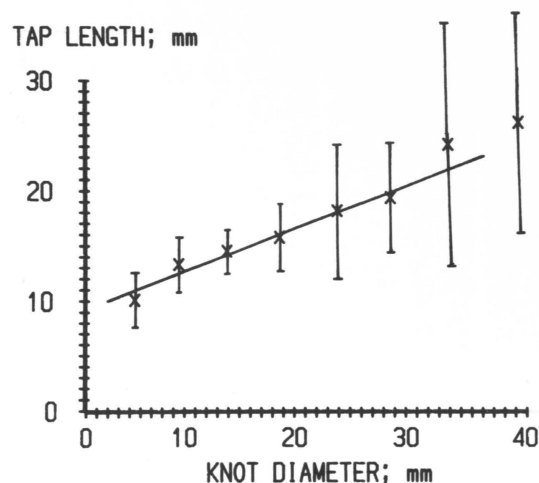


Fig. 4. Dependence of the length of the resin tap on the knot diameter by diameter class. The 95-% reliability interval is indicated for each diameter class.

Kuva 4. Pihkatapin pituuden riippuvuus oksan läpimitasta läpimittaluokittain. Kuvaan on piirretty 95 % luotettavuusväli kullekin läpimittaluokalle.

the tap lengths were first divided by diameter classes using 5 mm as class width. Fig. 4 shows the result. The figure also shows the reliability interval at 95 % level for each diameter class. The graph shows that the variation is smallest for knot diameters less than 20 mm. In the case of larger diameter values the reliability grows weaker because large knots are represented only by a small sample material. Nevertheless, Fig. 4 clearly shows that the length of the resin tap increases with increasing knot diameter. The length, however, grows at a slower rate than the diameter.

The dependence of knot diameter on the length of the resin taps was derived by regression analysis. On the basis of the average values for the classes presented in Fig. 4, for example, it was assumed the curve concerned would take the form $y = ax^3 + bx + c$. The value of a , as calculated on the basis of analysis, was extremely small (near 0), and thus the final result was a straight line the equation of which took the form

$$y = 9.5 + 0.41x, \text{ in which}$$

y = the length of the resin tap and

x = the horizontal diameter of the knot.

The explanation degree of the equation, being only 12 %, is not very good. The diameter, by the use of this model, explained only slightly more than 10 % of the variation in resin tap length.

In connection with the study of the fitness of this formula to explain the length of the resin tap it was observed that its explanation degree increased with increasing height of the knot above the ground. In the butt end of the stems, below 70 cm in height, the equation explained only 5 % of the variation, whereas, at heights exceeding 2.5 m, its explanation degree varied between 17 and 25 %. Nevertheless, in each case, irrespective of the height of the knots above the ground, the dependence was linear. As the variation in resin tap length was largest in the butt end of the stems, a regression line was drawn by excluding all knots below 70 cm in height above the ground. The equation thus obtained took the shape

$$y = 7.9 + 0.47x, \text{ in which}$$

y = resin tap length

x = horizontal knot diameter.

The explanation degree of this equation was 21 %.

The dependence between the length of the resin tap and the knot diameter was best explained in stands 1, 5 and 7. In the case of stands 3 and 4 the variation was larger, and as already mentioned in the foregoing context, there was almost no dependence in the case of stands 2 and 6.

All in all it can be established that the diameter of the knot at time of pruning explains only a small part of the resin tap length. There is a clear correlation in the case of good sites and vital trees. The importance of the height of the knot above the ground is indicated by the fact that the correlation was better in the higher parts of the stems than in the butt, where near the ground other factors seem to have a greater influence on the length of the resin taps.

Table 8. Average knot diameter, tap length and growth at different heights above the ground. Taulukko 8. Keskimääräinen oksan läpimitta, pihkatapin pituus ja kasvu eri korkeuksilla.

Location above ground Etäisyys maahan	Diameter, mm Läpimitta, mm		Tap length, mm Pihkatapin pituus, mm		Growth, mm/y Kasvu, mm/y	
	\bar{x}	s	\bar{x}	s	\bar{x}	s
- 70	7,1	4,4	18,0	12,1	1,8	0,3
70-140	8,3	5,7	12,4	8,0	1,8	0,4
140-210	10,1	6,6	14,0	8,1	1,7	0,5
210-280	10,8	7,1	13,4	7,0	1,7	0,6
280-350	12,0	7,1	13,6	6,7	1,9	0,4
350-420	12,6	8,1	13,0	6,2	1,9	0,4
420-490	12,3	6,5	11,7	5,7	1,9	0,7
490-	13,5	6,8	11,4	5,8	2,1	0,4

33. Effects of the height above the ground of knots on resin tap length

Table 8 shows the variation of the knot diameter, the rate of growth during the period of healing-over and the length of the resin tap at various heights along pruned stems.

The results presented in the table are averages by bolts. The higher along the stem the knot, the shorter was the resin tap. The dispersion, as the resin tap length, too, was largest in the butt end of the logs. The average knot diameter showed an increase at an even rate with increasing height of the knots above the ground. Fig. 5 shows the results obtained. According to the figure, the average resin tap length shows a slight decrease or remains nearly the same with increasing knot diameter. The growth of the trees during the period of healing seems to be the same at all heights along the stem, which means that the variation in growth cannot explain the variation in resin tap length or knot diameter.

The correlation between the knot diameter and the length of the resin tap seemed to be of the same type in all the stands covered by the study. All in all there is a clear positive correlation between the height of the knots above the ground and their diameter. In the case of knots of similar size, there was no clear correlation between the length of the resin tap and the height of the knot above the ground, but tap length was

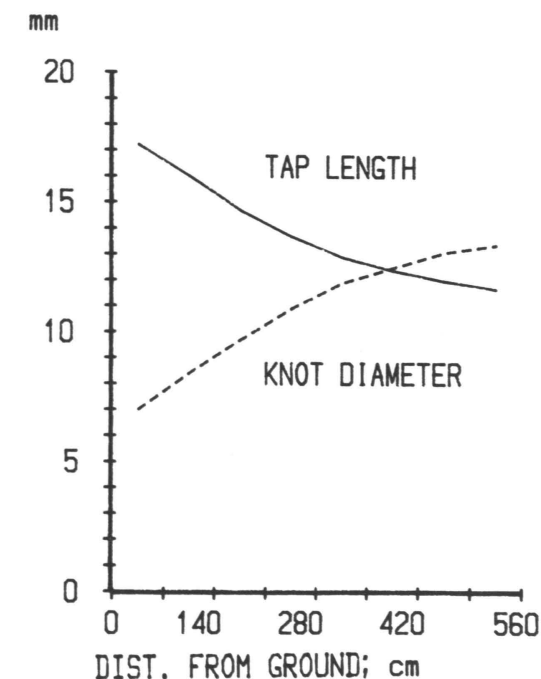


Fig. 5. Change in the average length of the resin taps and the knot diameter with increasing height above the ground.

Kuva 5. Pihkatapin keskimääräisen pituuden (TAP LENGTH) ja oksan keskiläpimitan (KNOT DIAMETER) riippuvuus oksan etäisyydestä maan pinnasta (DIST. FROM GROUND).

nearly the same at various heights along the stem. The ratio between the length of the resin tap and the knot diameter grows smaller with increasing height above the ground of the knots, and this means that resin taps in knots of similar size are longer in the butt than in the top end of logs.

34. Effects of the length of the period of healing-over on resin tap length

In the present study the effects of the radial growth on occlusion was studied from two different viewpoints. One point of departure was to find out how the rate of growth affects the length of the resin tap, and another one, how the rate of growth affects the length of the period of healing-over in terms of years.

The concept growth in this connection refers to the average annual radial growth in millimeters per year during the period of healing-over. Table 9 shows the average resin tap lengths and minimum diameters as divided into four groups on the basis of the growth.

The concept period of healing-over in this connection does not include the time required for overgrowing of the branch stub remaining on the stem after pruning.

As can be seen from Table 9, radial growth does not directly affect the length of the resin tap, but it is more or less constant. This is at least partly so because there is a clear positive correlation between the growth during the period of healing-over and the total growth of trees. The better the

total growth of a tree, the larger is the branch diameter and the longer are the resin taps formed after pruning. Thicker branches that are required/produced by better growth tend to increase tap length. This is well described by the ratio between the tap length and the smallest knot diameter, which was 1.6 at growth values less than 1.5 mm/year and 1.1 at growth values exceeding 2.5 mm/year. These ratios are almost similar to those obtained when grouping the tap lengths according to the knot diameter. The time required for healing-over is 50 % shorter at an increase in growth of this magnitude.

The fact that the rate of growth does not influence tap length becomes visible as branch diameter is made constant. Table 10 shows the situation in the case of knots the diameter of which is 10...15 mm. Grouping was made according to the rate of growth. The table shows that the rate of growth does not affect tap length, but, as is quite logical, it does affect the time of healing-over. In other diameter classes, too, it could be seen that the rate of growth does not influence tap length.

Table 5, which deals with averages by stand, shows the negligible importance of the growth rate in explaining tap length. In the case of stands 1, 2, 3 and 7 the average growth rate of the trees are of similar magnitude, but the average tap length varies between 11 and 20 mm. In stands 2, 3, and 7 the knot diameter, too, is of similar magnitude, and this in turn means that the variation in knot diameter does not explain the variation in resin tap length either.

Table 9. Average knot diameter, tap length, and healing-over time by year when grouping is done by annual growth.

Taulukko 9. Keskimääräinen oksan läpimitta, pihkatapin pituus ja kyljestymisaika vuosina ryhmiteltynä vuotuisen kasvun perusteella.

Growth Kasvu mm/y	Knot diameter, mm Oksan läpimitta, mm		Tap length, mm pihkatapin pituus, mm		Time, year Aika, vuotta	
	\bar{x}	s	\bar{x}	s	\bar{x}	s
-1,5	8,7	7,5	13,1	7,5	10,5	6,0
1,6-2,0	9,8	5,6	14,3	9,9	8,0	5,2
2,1-2,5	11,6	8,2	13,7	7,0	6,1	3,1
2,6-	13,8	9,3	14,6	6,9	5,2	2,5

Table 10. Effect of growth on resin tap length and over-healing time, knot diameter 10...15 mm.

Taulukko 10. Kasvun vaikutus pihkatapin pituuteen ja kyljestymisaikaan karsitun oksan läpimitan ollessa 10...15 mm.

Growth Kasvu mm/y	Tap length, mm Pihkatapin pituus, mm		Time, year Aika, vuotta	
	\bar{x}	s	\bar{x}	s
-1,5	14,7	5,3	11,6	4,1
1,6-2,0	15,5	9,3	8,7	4,8
2,0-2,5	14,7	5,1	6,6	2,4
2,6-	15,0	3,7	5,4	1,4

35. Effects of other factors on resin tap length

The average density of the wood in the mantle formed by overgrowing wood tissue was 442 kg/m³ as measured from the total material of bolts. The variation in density from plot to plot was 414...483 kg/m³. From the butt to the top end of the logs there was a decrease in density from 455 to 422 kg/m³. There was a slight but positive correlation between the wood density and the resin tap length.

The differences in tap length between green and dry pruned knots were examined on knots with a diameter of 5...20 mm that had been growing at heights between 0.7 and 3.5 m above the ground. According to the results obtained, the resin taps of dry pruned knots on the average were one millimeter longer than those of green pruned knots when the knot diameter was the same.

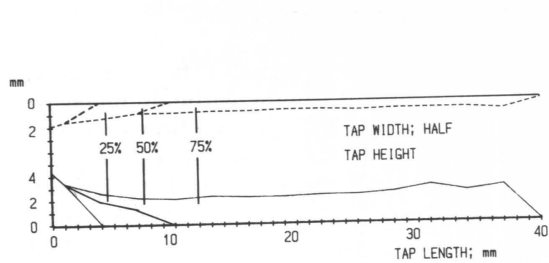
36. Shape of the resin taps

Fig. 6 shows the shape of the resin taps. The tap height is drawn as the diameter in a direction parallel to the fibres of the stemwood and the width of the resin taps as the diameter perpendicular to that. On the basis of the knot diameter at the point of pruning the material was divided into classes as follows: 0-5, 6-10, 11-20, 21-30 and 31 + mm. The tap length is also indicated when 25, 50 and 75 % of the knots had become overgrown.

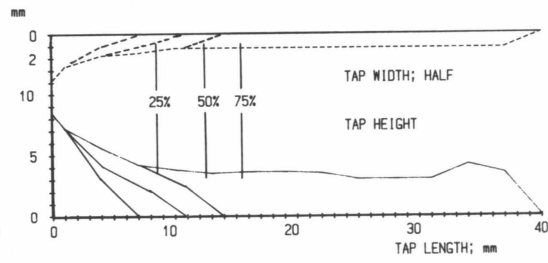
In the knot diameter class 6...20 mm the healing-over ratio in the lower part of the resin tap was 1:3. This means that the lower part of the resin taps was grown over by one millimeter as the distance from the pith increased by three millimeters. At knot diameters less than six millimeters the corresponding ratio was 1:6. This ratio has only a guiding importance because the rate of overgrowing varied very much in the lower part of the resin tap even in the case of similar knot diameters in the same whorls. Because of the large variation in the rate of healing in the lower parts of the resin taps, the overgrowing of the lower parts of the knots was excluded from the figures. The correct ratio would have been about 1:4.

The increase in tap height which is visible in the tap ends is due to the fact that in the cases concerned there are only less than five observations. In these instances healing-over was extremely slow, and poor healing-over usually becomes visible in the form of tap height, not tap width.

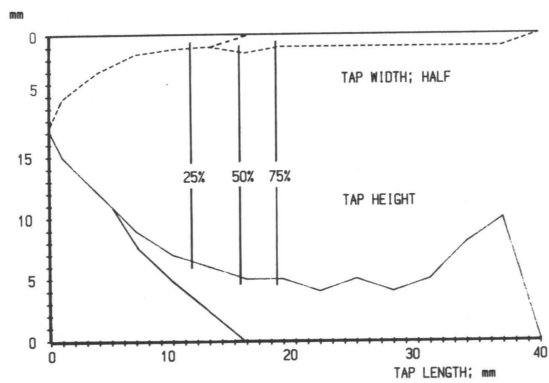
In the case of the groups of knots representing all diameters the average resin tap height was halved at a tap length of 7...8 mm. The tap widths were halved slightly earlier.



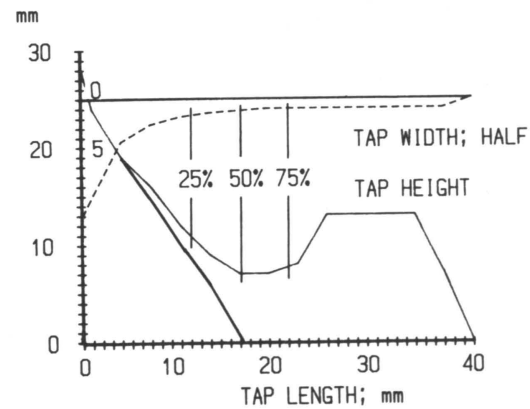
Knot diameter class 0-5 mm.
Oksan läpimitta 0-5 mm.



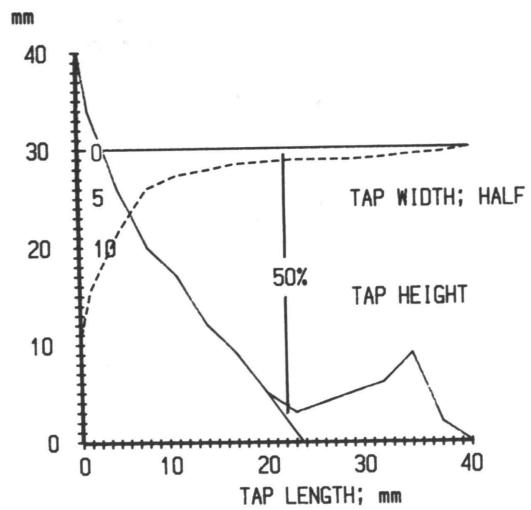
Knot diameter class 6-10 mm.
Oksan läpimitta 6-10 mm.



Knot diameter class 11-20 mm.
Oksan läpimitta 11-20 mm.



Knot diameter class 21-30 mm. (Scale is different).
Oksan läpimitta 21-30 mm. (Mittakaava on erilainen).



Knot diameter class 31- mm. (Scale is different).
Oksan läpimitta 31- mm. (Mittakaava on erilainen).

Fig. 6. Shape of the resin tap at different knot diameter classes. In the upper part of the picture is presented half of the resin tap width and in the lower part is the tap height. The percentages indicate points at which the corresponding part of the knots had become completely overgrown. Average shape of the resin tap in each of four tap length classes (0-25%, 26-50%, 51-75% and 76% of knots in a diameter class) is presented.

Kuva 6. Eri läpimittaisten karsittujen oksien pihkatabin muoto. Kuvan ylemmässä osassa on piirretty puolet pihkatabin leveydestä (WIDTH) ja alemmassa osassa on tabin korkeus (HEIGHT). Prosenttiluvut ovat kohdissa, jossa vastaava osuus läpimittaluokan oksista oli kyljestynyt. Läpimittaluokka on lisäksi jaettu neljään eri pihkatabin pituusluokkaan (0-25%, 26-50%, 51-75% ja 76% oksista), joiden muoto on esitetty.

4. Discussion

4.1. Knot diameter

According to the results obtained in this study the knot diameter and the location of the knot along the stem above the ground are of the greatest importance for the length of the resin tap forming after pruning.

A knot is considered as being healed-over when the cambium has covered the surface of the cut with a sufficient amount of wood. The influence of the knot diameter on healing-over is probably due to the fact that in healing-over of knots the process of overgrowing of the wound is more or less depending on the rate of growth irrespective of the influence of other factors. This is also so if in connection with pruning the cambium cells have been cut so that they still stimulate cambium growth (e.g. Mayer-Wegelin 1952). Thus the effect of other factors on the growth required for healing-over of knots is still diminished.

In this study, just as in the case of a number of other papers (Romell 1941, Krigul 1961, Heiskanen and Taipale 1963 and Andersson 1967) the conclusion was made that the regression is linear between the length of the resin tap and the diameter of the pruned knot. Furthermore, there is always a constant factor in the presented equations. Constant may be the distance corresponding to the depth at which the face of the knot is under the level of the bark surface before the wound starts to become overgrown (for a picture, see Mayer-Wegelin 1936, p. 51, for example). The pocket of about the same size as that of the knot thus formed has almost the same shape as the resin tap has near the knot. This pocket was sometimes empty, but in most cases it was filled with resin or park. When the growing wood begins to cover the knot end, lateral growth is relatively fast, and this decreases the influence of the knot diameter on the length of the resin tap. As can be seen from Fig. 4, we may sometimes be close to a situation in which the size of the resin tap is constant, which is independent on the knot diameter.

The next table is a comparison between the tap lengths obtained in the studies mentioned in the foregoing context. The diameters of the knots concerned are 10 and 20 mm, and it is assumed that the radial growth of the tree is 1.2 mm/year, the stem diameter 10 cm and the length of the knot stub 12 mm.

	Knot diameter	
	10 mm	20 mm
	Tap length (mm)	
Romell	11 (10)	14
Krigul	12	19
Heiskanen & Taipale	8 (9)	14 (16)
Andersson	7	12
This study	13	18
	(dry-pruned knots)	

As already mentioned in the foregoing context, the equations presented by Krigul and Andersson contain some presumptions concerning tree growth and length of knot stub.

The largest variations in resin tap length occur in the case of small knots. In the studies made by Heiskanen and Taipale as well as by Andersson the presented lengths of the resin taps were of more less the same length and smaller than in Romell's and Krigul's studies. In the case of larger knots the variation in tap length is smaller. The variation is due at least to differences in the methods of measurement and determination, and evidently at least partly, to the fact what part of the material remained completely unhealed, thus being unfit for use in forming of the equations. Moreover, it is possible that the results vary according to the tree's race and site.

As previously established, the average diameter of the overgrown knots in the material of this study was about 12 mm and the average length of the resin taps about 17 mm.

According to Romell (1941), resin tap length was about 15 mm when 90% of the knots had become overgrown. The average

knot diameter in this case was about 15 mm.

In Krigul's (1961) material the average knot diameter was about 11 mm. The average length of the resin taps is not mentioned, but using the formula presented by him for calculation gives about 12 mm as result. In Heiskanen and Taipale's (1963) study the average tap length was 11 mm. Andersson (1967) presents no averages for knot diameter and tap length in his material. On the other hand, he states that knot diameters were determined under bark, which partly has influence on both the average knot diameter and the corresponding tap length.

Fig. 7 shows a comparison between the resin tap lengths and knot diameters as determined by use of the equations presented in the above-mentioned studies and in the present study.

The diagram shows that the tap lengths in the material of this study are larger than in those of the other studies. There may be several reasons for this situation. In the case of Heiskanen and Taipale's material, for example, the share of unhealed knots was 40 %, which fact caused a decrease in the average tap lengths because this part of the material was left beyond calculation. In the present study about 6 % of the material was rejected because the knots were not healed-over.

In the methods of measurement there may be differences which lead to systematic differences in the case of either tap length or knot diameter. For example, the results depend on the direction in respect to the pith of the knot the knot diameter is measured or whether the question is about the diameter on or under bark.

The method used to uncover the knots from the stem for measurement is of importance for the results to be obtained. The peeling method used in the present study gives larger resin tap lengths than sawing discs along the radius. If in the case of sawing we do not hit the middle of the resin tap exactly, the tap lengths obtained will be smaller than according to the peeling method. If on the other hand we hit the resin tap in the middle, there is the possibility that we lose the thinnest part of the tap with the sawdust. In both these cases

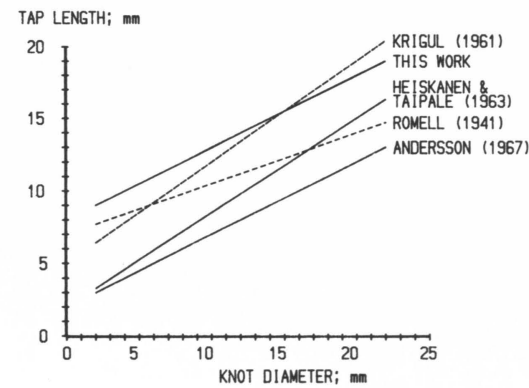


Fig. 7. Dependence of the length of the resin tap on the knot diameter according to various sources.

Fig. 7. Pihkatapin pituuden (TAP LENGTH) riippuvuus oksan läpimitästä (KNOT DIAMETER) eri lähteiden mukaan.

underestimation is systematic. In the studies mentioned in the foregoing context the sawing method was employed, which may explain the differences partly.

The dependence between knot diameter and resin tap length was best visible in Heiskanen and Taipale's as well as in Krigul's materials and weakest in Romell's results.

In Krigul's material the resin tap lengths were of a magnitude similar to those of the present material. The largest differences in comparison with the results of this study occurred in Heiskanen and Taipale's and in Romell's studies.

42. Location of knots

As shown by Table 8, the average resin tap length decreases with increasing height of the knot above the ground. The radial growth during the period of healing-over is of no importance in this respect because it is of similar magnitude at all heights and the average diameter of the branches increases with increasing height above the ground. The decrease in resin tap length consequently is very distinct. Moreover, the length of the resin tap is better explained by the knot diameter at higher levels along the stem than in the butt end, where tap length

is more or less constant irrespective of knot diameter. In the butt end there were thin knots the healing-over of which is extremely slow.

Results of more or less the same kind concerning the influence of the height above the ground on resin tap length were obtained by Laakso and Saikku (1979) in a study of peeled bolts of pruned pine. In these bolts, the diameter of which was over 20 cm, the resin taps were about 5 mm longer than in the present material. In smaller bolts in respect to their diameter the tap length was not decreasing with increasing height above the ground.

Other research workers mention nothing about a possible effect of the height above ground on the length of the resin tap. Nevertheless, there has probably occurred a decrease in tap length with increasing height above ground of similar kind in their materials, too, because the position also determines the diameter of pruned branches, and the lines in Fig. 7 do not deviate from each other more than presented.

There are at least three explanations which can be thought to explain the decrease in resin tap length with increasing height above the ground.

At higher levels the proportion of living branches removed in pruning is larger, and this means faster overgrowing and, maybe, shorter resin taps, because overgrowing takes place by the cambium of the branches proper (Mayer-Wegelin 1936).

Another possible explanation is that the cambium growing over a wound at higher levels along the stem receives more of some hormone or hormones which stimulate overgrowing. Vuokila (1968), for example, states that the weightpoint of stem growth is transferred to a higher level after pruning.

The third reason may be that for the reason mentioned growth is retarded at lower levels and that more resin is secreted in wounds at lower levels than higher up along the stem. In this case the final healing-over is retarded. As can be seen from Fig. 6, a knot is quite fastly overgrown into a small tap the diameter of which is a few millimeters and which forms the main part of the tap length. In such cases even a small addition of resin may slow down the final

healing-over of the wounds. On the other hand, we do not know for how long a time resin is secreted from pruned knots on the whole.

All in all this long peak caused a considerable increase in the variation in resin tap lengths. Mainly such peaks are formed in the lower parts of the stem, but the reason for the forming of them remains unexplained. Evidently, if we find an explanation to this phenomenon, we even better can explain the length of the resin tap.

43. Rate of growth

According to the results obtained, radial growth during the time of healing-over does not directly affect the length of the resin tap. On the other hand, there might be an indirect influence as in well-growing trees the branches are thicker, whereby the resin tap formed is longer than on the average. A similar result was obtained by Andersson (1967). This may also explain Romell's (1941) result, according to which longer resin taps are formed in well-growing trees. Romell grouped the diameters into classes, but it is not known how the averages of each class were distributed within the diameter classes concerned.

According to the results obtained by Krigul (1961), an increase in the rate of growth leads to a decrease in the length of the resin taps. The influence of the growth rate on tap length, however, was of minor importance.

This leads to the conclusion that the mantle of overgrowing in both poorly and better-growing trees is of more or less the same thickness because amount of radial growth required for overgrowing of the wound is independent on the rate of growth. For the same reason the shape of the resin tap, too, is similar in both fast- and slow-growing trees.

Several research workers have come to the conclusion that the number of years required for healing-over diminishes at faster growth. This also became visible in the present study. There is a very logical explanation to this situation. As the length of the resin tap is independent of the rate of growth, a tree the rate of radial growth of

which is faster produces a mantle of wood covering the wound at a faster rate. However, radial growth has an influence on the quantity of knotless wood to be obtained through pruning because a fast-growing tree produces more knotless wood than a slow-growing one in the same time.

44. Other factors

The slight positive correlation prevailing between the density of wood and the length of the resin tap is probably independent of pruning. This correlation is caused by the fact that both tap length and wood density decrease with increasing height above the ground. On the other hand, the density of stemwood decreases in unpruned pine stems, too, with an increase in the height above the ground (Hakkila 1966). The reason for the decrease in resin tap length and in the wood density may be the same, but according to the results of the present study, wood density does not explain the length of the resin tap.

It seems that resin tap forming in the end of green-pruned knots on the average is one millimeter shorter than that forming in the end of dry-pruned knots. This result, however, is uncertain because the peeling method employed in this study did not allow separation of dry-pruned knots from green-pruned ones in the case of which a long knot stub had been left in connection with pruning. However, there is no reason to believe that in these cases the cambium was living at the time when the resin tap appeared. A difference of similar magnitude was noticed by Romell (1941) as well as by Heiskanen and Taipale (1963), too.

The differences between the stands of this study were of a considerable magnitude. When knot diameter and, on the other hand, the height of the knots above the ground were constant, the average difference in resin tap length was five millimeters. On the other hand, it was not possible to find out what factor or what factors caused this difference between individual stands. Probably the question is about a joint effect of several factors. A variation of similar kind also comes out of the results presented by Romell (1941) and Krigul

(1961). On the other hand, in the case of the largest resin tap lengths no differences could be observed between the sample plots. This was the situation in the case of Radiata pine in New Zealand, too; the overgrown mantle was of the same thickness in logs that had been obtained from various parts of the country (Park 1983).

The differences in resin tap length between individual stands may be caused either by differences in race or by the fact that they have been treated in different ways. It was not possible to get a clear view of the differences in tap length between individual trees in the same stand. In some stands, plots 2 and 6, for example, there was a very large variation, whereas in some cases, as in stands 4 and 7, the differences were negligible. The question concerning the occurrence and magnitude of the variation remained open in this study.

It is possible that different pine races produce resin taps of different length, but this topic has probably never been studied; at least I have not found any paper on it in literature.

The effects of treatment may be of several kinds. If a stand is pruned at a young age, the branches are relatively thin and the resin tap forming in the knot ends relatively short.

When pruning trees that are not dominants or if the growth of a tree is retarded because of pruning, it might be assumed that this leads to an increase in tap length or at least to a prolonged time of healing.

If a branch is pruned without carefulness or if in connection with pruning the basal swelling is damaged, the length of the resin tap produced is much greater than otherwise because overgrowing of the knots turns into overgrowing of a wound. Romell (1941) compared resin tap lengths in knots that had been pruned using the saw and, on the other hand, the pruning chisel. According to the results obtained, the resin tap was longer in the case of knots that had been pruned by saw, but this was not definitely clear. According to Krigul (1961), in some stands evenly cut knots become overgrown at a faster rate, and in other stands, roughly cut knots, but he found no regularity in this respect.

According to Andersson (1967), the di-

ameter of a tree is of no importance for the length of the resin taps at the same knot diameters. On the other hand, the present study seemed to indicate that large trees have thick branches and that for this reason they produce longer resin taps and require a longer time for healing-over. This result was not completely clear because there were other factors disturbing interpretation.

Stand treatment after pruning may have an effect on the time required for healing. With thinning or fertilization, for example, the growth of pruned trees may be speeded up, and thus, the time of healing and even the resin tap produced, shortened.

45. Shape of the resin tap

At the initial stage knots are overgrown at a fast rate. This can be seen in particular in the case of large knots and in such a way that they need relatively less radial growth for overgrowing than do smaller knots.

The resin taps have more or less the same shape in various diameter classes. Likewise, comparison of the shape of long and short resin taps showed that the shape near the knot is almost the same and that the difference in length is due to the point of the tap, the size of which is more or less constant.

When 75 % of the knots in a certain diameter class have become overgrown, the shape of the resin taps do not change to any degree deserving of mentioning, but it is the point, the breadth of which is about 2 mm and the height 2-4 mm depending on the diameter class. The cross section of the resin tap changes with the proceeding of overgrowing from circular to elliptical.

46. Sources of error

The selection of sample trees took place at random, and as the material was small, we do not know how well the sample trees represented the pruned trees in each stand concerned. For this reason the variation between single trees was left beyond more detailed study. The range of different forest site types was well represented in the material.

A part of the knots was left beyond

measurement because they did not become overgrown at all. This to some extent caused a decrease in the average length of the resin taps, particularly in the case of stand 2. In the case of stands 4 and 7 there may occur overestimation of the resin tap lengths because a part of the taps could not be measured as the knots were in the peeling core. It is possible that in these cases the resin tap was shorter than otherwise. Another part of knots were not measured because they happened to be in places where the logs had been cut. These knots obviously do not cause a systematic error, but it may be assumed that leaving them beyond treatment is of no importance for the average lengths of the resin taps.

The method of measurement employed led to an underestimation of 1...2 mm in the lengths of the resin taps because, as was mentioned in Section 2, the taps were measured at a distance of 3 mm from each other.

The unexplainable variation in tap lengths may be due to the fact that at time of pruning the data registered concerning the stands in question was not collected with a pruning study in mind. For this reason we do not know how the stands have been treated afterwards or on what grounds the trees to be pruned were selected.

There may also be an error in the differences between green- and dry-pruned trees because, as mentioned previously, these could not for sure be separated from each other afterwards.

47. Conclusions

There are several factors that have an influence upon the length of the resin tap appearing after pruning. According to this study such factors are the diameter of the knot and its location on the stem above the ground as well as possibly the fact whether the branches have been green- or dry-pruned. The effects may be contradictory, and the unexplainable variation large both within and between stands. On the basis of the material of the present study it was not possible to work out a model by the aid of which it could be possible to predict the length of a resin tap to be formed at a

certain knot diameter. However, it seemed that if a knot is to be overgrown, healing takes place at a relatively fast rate.

If pruning is restricted to branches less than 20 mm in diameter, as is recommended by instructions, the diameter of the stem has to grow about 6 cm until knotless wood begins to form.

For pruning there is reason to select well-growing dominants with thin branches. Pruning is worthwhile in stands growing in Myrtillys site type and on better soils. On poorer sites healing is uncertain and the total amount of knotless wood small. Large knots will be overgrown, too, but there is not reason to prune them because it may lead to dying of the tree or fungal diseases may lead to a decline in the quality of the wood (Räisänen et al. 1986). In such cases the resin tap produced also will be so long and large that the quality of the timber will be poorer. Vuokila (1968) states that up to 20 % of the living crown of a tree may be pruned without any considerable risk of diseases or increment loss.

The point appearing in the end of the resin tap, and the share of which in the total length of the tap is considerable, has an effect of the quality of sawn goods which is unclear so far. The point is visible in the sawn goods as a pearl knot, the influence of which on the quality of sawn

goods is unclear, and there is no mentioning about it in, for example, the Instructions for grading sawn goods for export (1979). The effect probably is of a different nature in different cases.

The part of a stem near the pith in which the pruned knots and resin taps appear has the shape of a cone the cone-shape of which is similar to that of the stem that has been pruned. The knot ends produced in connection with pruning at time of pruning occur at a relatively great distance from the pith of the stem, but on the other hand, the knot is shorter than higher up along the stem. This is compensated for by the fact that at higher levels the resin tap formed is shorter than in the butt although the knot diameter is larger higher up along the stem. Taking this fact into consideration, it would be recommendable to carry out pruning in two phases: in the first pruning operation the branches would be cut up to a height of about two meters and in the second operation up to the final height of five meters. This also would make it possible to maximise the total volume of knotless wood to be obtained. We do not know, however, whether the extra costs caused by two pruning operations would be compensated for by a larger quantity of better pruned wood.

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Seloste

Pystykarsitun männyn oksien kyljestyminen

Karsittaessa katkaistun oksan katkaisukohtaan rajoittuvat solut ja osin rungonkin solut kyllästyvät erilaisin ainein niin, etteivät sienet pääse tunkeutumaan puuhun. Mikäli katkaisu vahingoittaa rungon jälttä, tämä muuttuu haavajälkeksi. Rungon paksuuskasvu oksakohdassa on normaalia siihen saakka kunnes se kasvaa katkaistun oksan pään tasalle, jolloin kyljestyminen alkaa. Kyljestymisessä jälsi leviää tynkän päälle, koska tällä suunnalla ei ole kasvua rajoitettavaa solukkoa. Kyljestyminen on nopeinta reunoilta käsin, sitten yläosasta ja oksan alaosa kyljestyy hitaimmin. Katkaistun oksan pään ja kyljestymällä syntyneen puun välille ei synny orgaanista yhteyttä, ja havupuilla erittyvä pihkaa oksantynkän päähän.

Oksan kyljestymisaikaan vaikuttavat monet eri tekijät. Näitä ovat ainakin puulaji, karsitun oksan koko, karsinnassa jääneen oksantynkän pituus sekä puun kasvu ja asema metsikössä.

Yleisesti ottaen lehtipuut kyljestyvät havupuista nopeammin. Oksakoon kasvaessa kyljestymiseen kuluu pitempi aika, koska jälsi, joka kyljestää oksan, kasvaa suunnilleen vakionopeudella. Parempikasvuissa puussa oksa kyljestyy nopeammin kuin heikkokasvuissa, ja mitä lyhyempi tynkä oksasta jää, sitä nopeammin oksa kyljestyy.

Tämän tutkimuksen tarkoituksena oli selvittää, mitkä tekijät vaikuttavat kyljestyneen männyn pihkatapin pituuteen ja miten paljon puun pitää kasvaa, ennen kuin sen oksa on täydellisesti kyljestynyt.

Tutkimusta varten hankittiin 1930- ja 40-luvuilla pystykarsittuja mäntyjä. Taulukossa 1 on esitetty näiden metsiköiden tiedot, joista koepuut saatiin. Koepuut on kuvattu taulukossa 2. Koepuista otettiin karsittu tyvitukki erilleen ja se sorvattiin viiluksi. Tällöin jokaisesta oksasta ja pihkatapista saatiin poikkileikkaus 1,5 mm:n välein, kuten liitteen valokuvasta ilmenee. Joka toisesta leikkauksesta mitattiin oksan pysty- ja vaakasuora läpimitta sekä oksan laatu. Laatu mitattiin luokittamalla oksat elinvoimansa perusteella viiteen luokkaan, joiden ääripää olivat täysin elävä oksa ja kyljestyvä pihkatappi.

Koko aineistosta laskettu oksan karsintakohdan läpimitan keskiarvo oli 12 mm ja pihkatapin keskipituus oli 17 mm eli pihkatapin pituus oli noin puoli-toistakertainen karsitun oksan läpimitaan verrattuna. Taulukossa 5 on esitetty karsittujen oksien ominaisuudet metsiköittäin. Pienten oksien pihkatapit olivat suhteellisesti ottaen pidempiä kuin suurten, kuten kuvasta 1 ilmenee. Metsiköiden ja puiden välinen vaihtelu tapin pituudessa oli suurta. Kuvassa 4 on esitetty pihkatappien pituudet ja pituuden vaihtelu oksan läpimittaluokittain. Saman kokoisten oksien pihkatapin pituudet voivat vaihdella paljonkin.

Pihkatapin pituus riippuu lineaarisesti karsitun oksan läpimitasta. Pihkatapin pituuden riippuvuus oksan läpimitasta voidaan kuvata yhtälöllä

$$Y = 9,5 + 0,41X,$$

jossa Y on pihkatapin pituus ja X on karsitun oksan läpimitta. Kuvassa 7 on vertailtu pihkatapin pituuden riippuvuutta oksan läpimitasta eri tutkimusten perusteella. Tässä tutkimuksessa pihkatappien pituus oli suurempi kuin aikaisemmissa tutkimuksissa. Pääsyy saattoi olla se, että karsitut oksat otettiin esiin sorvaamalla eikä sahaamalla.

Taulukossa 8 on esitetty oksan korkeusaseman vaikutus pihkatapin pituuteen. Mitä korkeammalla oksa oli, sitä lyhyempi pihkatappi siitä jäi, vaikka oksakoko kasvoikin oksan korkeusaseman kasvaessa. Tulos on piirrettyä kuvaan. Pihkatapin pituuden suhde karsitun oksan läpimitaan pienenee korkeusaseman kasvaessa, joten saman suuruudesta oksasta muodostuva pihkatappi on tyvellä pidempi kuin latvassa.

Sädekasvu ei suoranaisesti vaikuta pihkatapin pituuteen, mikä käy ilmi taulukosta 9. Vaikutus oli välillinen, eli mitä paremmin puu kasvoi, sitä paksummat oksat siinä keskimäärin olivat, ja tämä pidenesi pihkatappia. Mikäli oksakoko on sama, puun paksuskasvu ei vaikuta pihkatapin pituuteen, mutta kylläkin kyljestymisaikaan, kuten loogista on.

Metsikön vaikutus pihkatapin pituuteen oli suuri, vaikka kasvu olisikin ollut sama. Tässä tutkimuksessa pituuseroksi saatiin keskimäärin 5 mm, kun oksan koko ja korkeusasema oli sama. Syytä tähän ei saatu selvitettyä, mutta kyseessä lienee usean eri tekijän, kuten puiden rodun ja metsiköiden erilaisen käsittelyn yhteisvaikutus.

Pihkatappien muoto on esitetty läpimittaluokittain kuvassa 6. Kuviin on lisäksi merkitty etäisyydet, joissa oksista oli kyljestynyt 25, 50 ja 75 %. Oksat kyljestyvät alkuvaiheessa nopeasti. Kaiken läpimittaisten oksien pihkatappien keskimääräinen korkeus puolittui, kun tapin pituus oli 7...8 mm. Pihkatappien leveydet puolittuivat hieman aikaisemmin. Pihkatapin muoto on suunnilleen samanlainen eri läpimittaluokissa. Vertaillaessa lyhyiden ja pitkien pihkatappien muotoa havaitaan, että oksan pään lähellä näiden muoto on lähes sama, ja pituusero syntyy pihkatapin piikistä, jonka koko on lähes vakio.

Pihkatapin pituuteen vaikuttavat useat eri tekijät, joiksi tätä tutkimuksessa osoittautuivat oksan koko ja korkeusasema sekä mahdollisesti se, karsitaanko eläviä vai kuolleita oksia. Selittämättömän vaihtelun osuus oli suuri sekä metsikön puiden välillä ettei metsiköiden kesken. Mikäli pitäydytään läpimitaltaan alle 20 mm oksien karsintaan, puun läpimitan pitää kasvaa keskimäärin 6 cm, ennen kuin täysin oksatonta puuta alkaa muodostua. Karsittavaksi kannattaa valita mahdollisimman hyvin kasvavia hento-oksaisia puuta. Karsinta kannattaa mustikkatyypin ja tätä paremmilla metsämailla. Heikommilla boniteeteilla kyljestyminen oli epävarmempaa ja saadun oksattoman puun kokonaismäärä pieni. Suuretkin oksat kyljestyvät, mutta tällöin pihkatapista tulee niin suuri ja pitkä, että se alentaa sahatavaran laatua.

Appendix 1. Average data on the knots by trees.

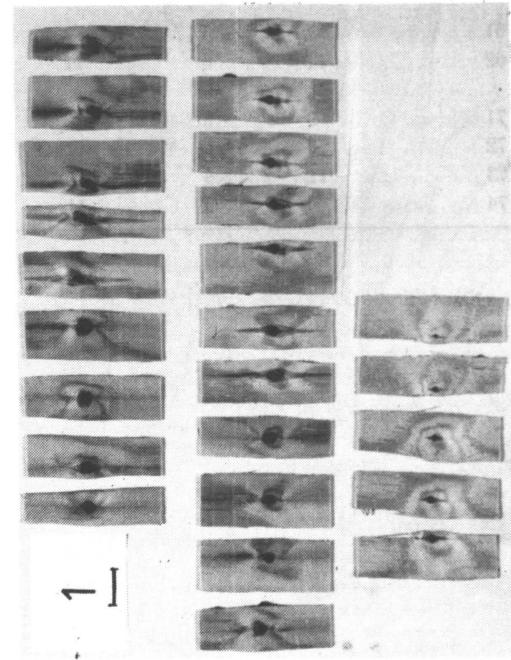
Liite 1. Puiden keskimääräiset karsitut oksat.

Tree no. Puu no	Knot diameter, mm		Tap length, mm		Growth, mm/y Kasvu, mm/y		Ratio tap length/ knot diameter Pihkatapin pituus/ oksan läpimitta
	\bar{x}	s	\bar{x}	s	\bar{x}	s	
11	15	10	14	8	2,2	0,3	1,4
12	17	9	17	9	2,4	0,3	1,1
13	19	13	18	9	2,4	0,3	1,5
21	11	5	25	14	2,2	0,6	3,1
22	8	3	14	6	2,4	0,1	1,9
23	9	5	16	10	1,7	0,5	2,6
31	8	4	9	4	1,8	0,2	1,3
32	8	4	12	4	2,5	0,3	1,6
33	11	5	16	6	1,7	0,3	1,7
41	8	3	10	4	1,4	0,2	1,2
42	7	4	11	5	1,4	0,2	1,6
43	6	2	11	7	1,0	1,2	2,3
51	11	6	12	7	1,3	0,3	1,2
52	10	6	12	6	1,6	0,1	1,5
53	12	5	15	6	1,9	0,2	1,2
61	11	6	19	12	2,0	0,3	2,2
62	11	6	11	6	1,3	0,3	1,0
71	9	5	12	6	1,9	0,1	1,7
72	10	5	11	5	1,8	0,1	1,2
73	11	5	14	5	2,2	0,1	1,2
74	9	4	11	4	2,0	0,2	1,3

Appendix 2. Photos of overgrowing. Photos 1–18 show different kind of knots and their overgrowing. Distance of the samples from the stem pith increases from left to right and from top to bottom. The sample closest to cutting point of the knot is marked with (X). Samples from the cutting point to the stem pith are marked negative with their distance (in millimeters) from the cutting point. To the right from the cutting point is resin tap by each 1.5 mm. Length of the segment under the distinctive number is 2 cm.

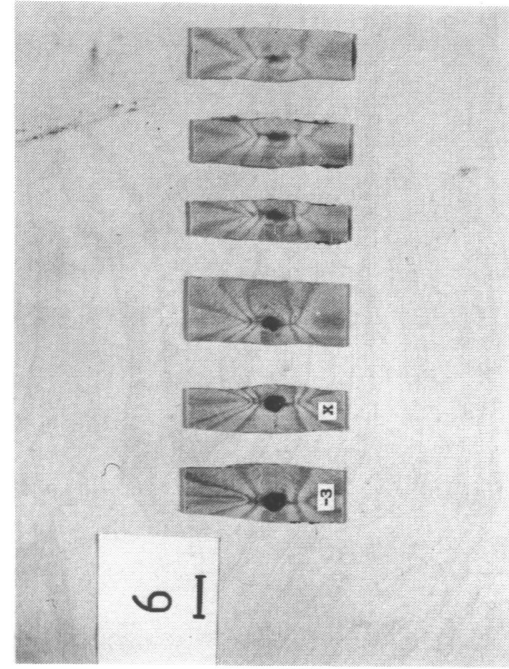
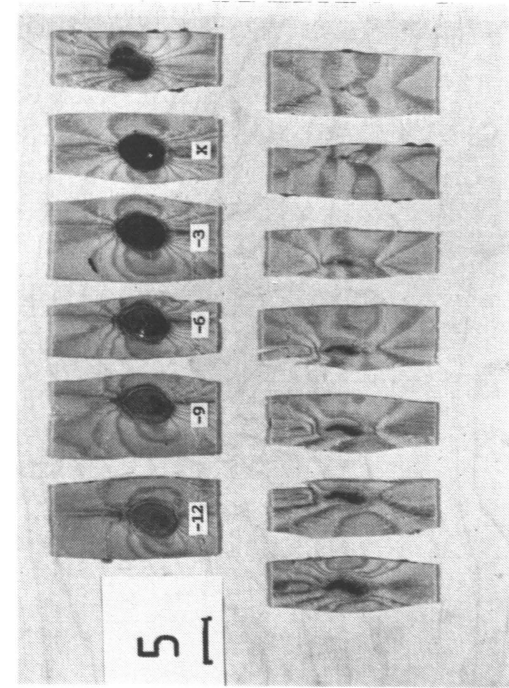
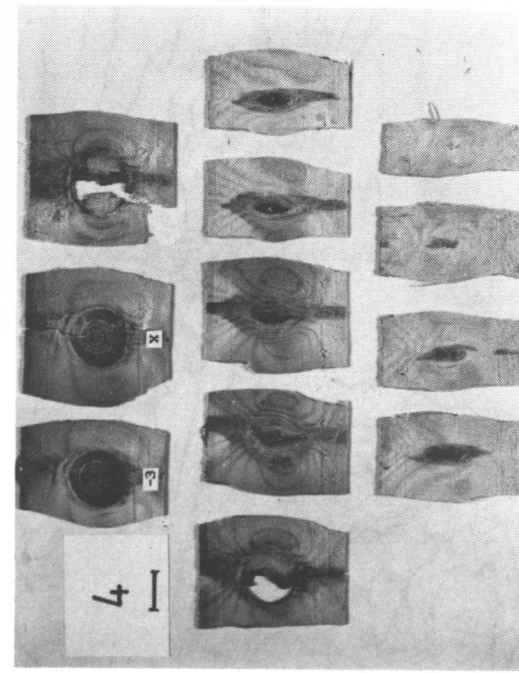
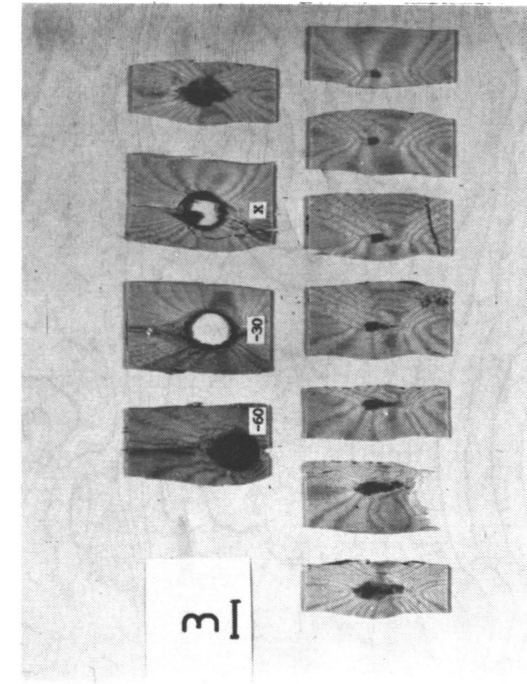
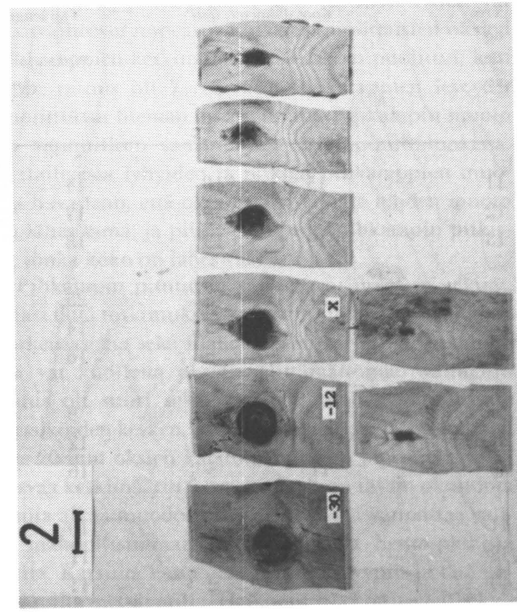
Liite 2. Valokuvia kyljestyemisestä. Kuvissa 1–18 on esitettynä erilaisten oksien kateisuskohtia on merkitty (X):llä. Poikkileikkaukset tästä pisteestä ytimeen päin on ylhäältä alaspäin siirryttäessä. Näyte, joka on lähimpää oksan katkaisukohtaa on merkitty (X):llä. Poikkileikkaukset tästä pisteestä ytimeen päin on merkitty negatiivisena lukuna, joka ilmoittaa näytteen etäisyyden oksan katkaisupisteestä millimetreinä. Katkaisupisteestä oikealle on kuvattu pikkatappi puolentoista millimetrin välein. Kunkin tunnustenumeron alla olevan janan pituus on 2 cm.

Photo 1. A small branch which was not pruned, distance from the ground level 0.7–1.4 m.
Valokuva 1. Karsimatta jäänyt hento oksa, metsikkö 2, oksan etäisyys maasta 0.7–1.4 m.



Photos 2–14. Different kinds of pruned branches. In some samples dead knot is missing, because it fell during peeling. See that in photo 15 sample number 3 in the middle row should be one row higher.

Valokuvat 2–14. Erilaisia karsittuja oksia. Joistakin näytteisistä oksia puuttuu, koska kuiva oksa putosi viilua sorvattaessa. Huom. Valokuvassa 15 näyte n:o 3 on riviä liian alhaalla.



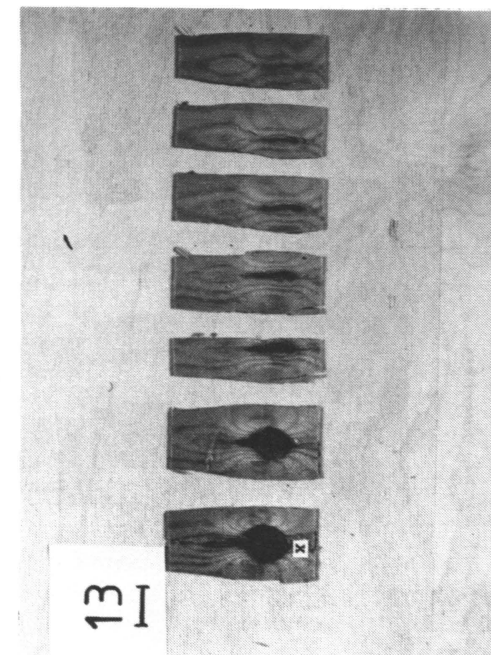
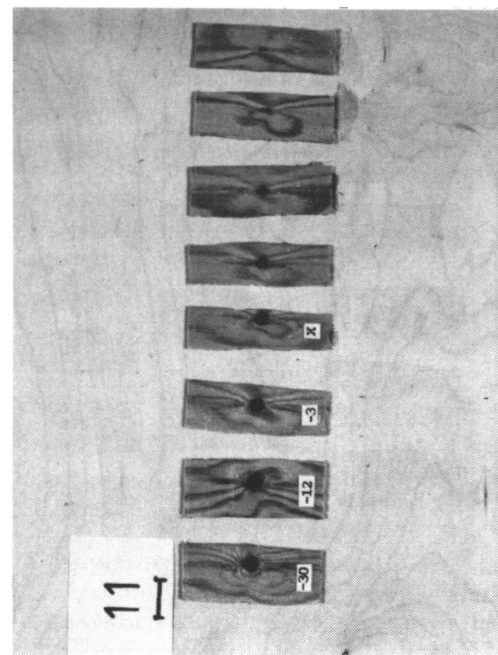
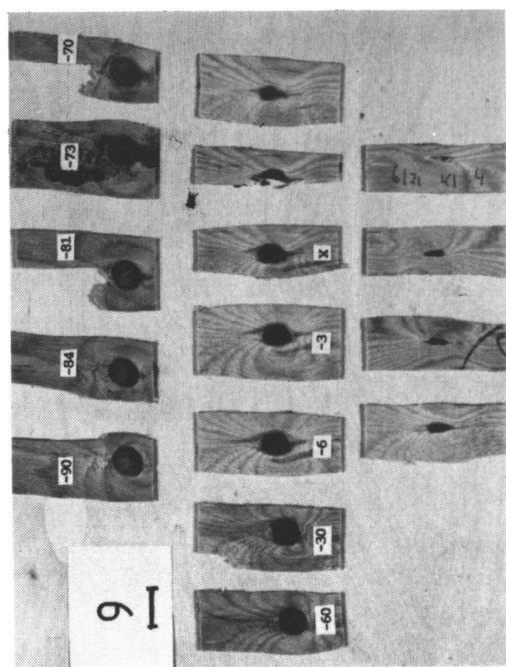
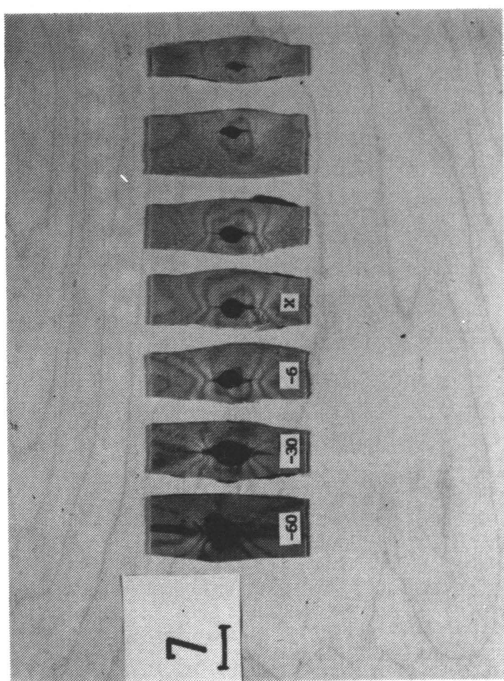
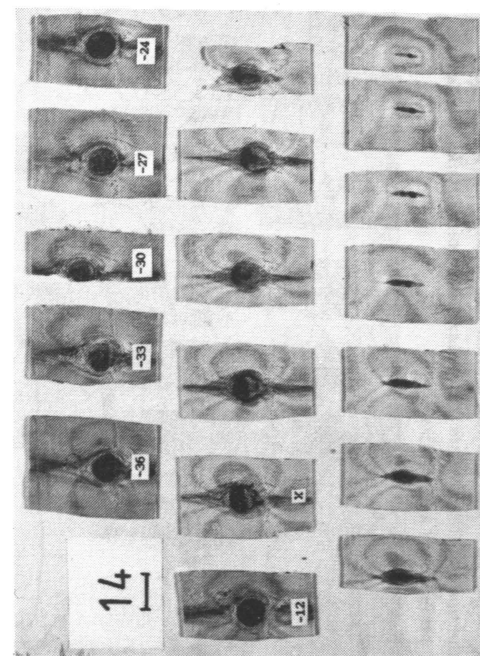
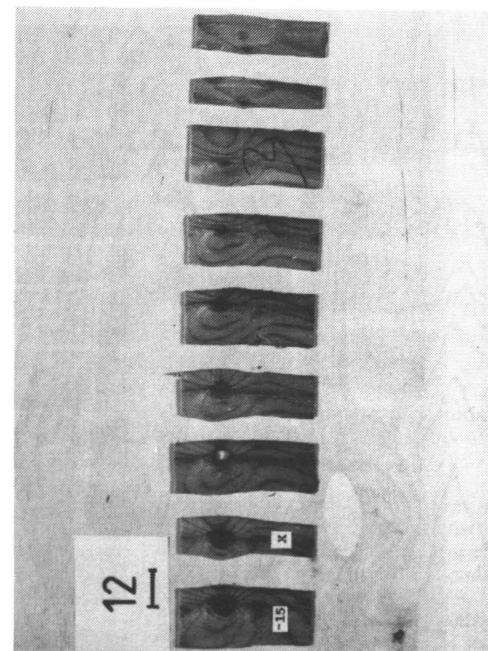
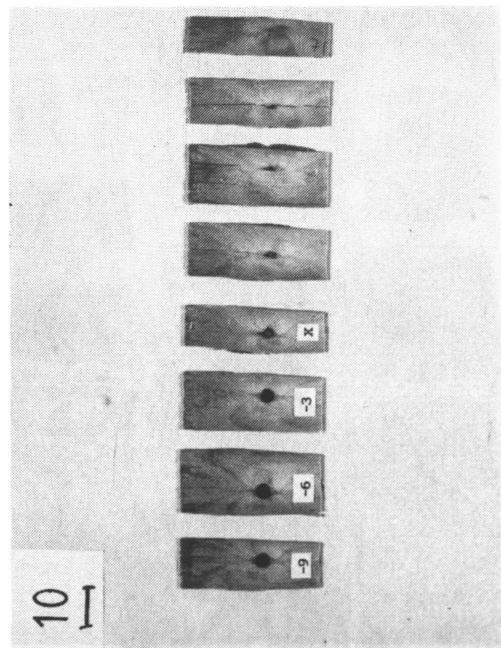
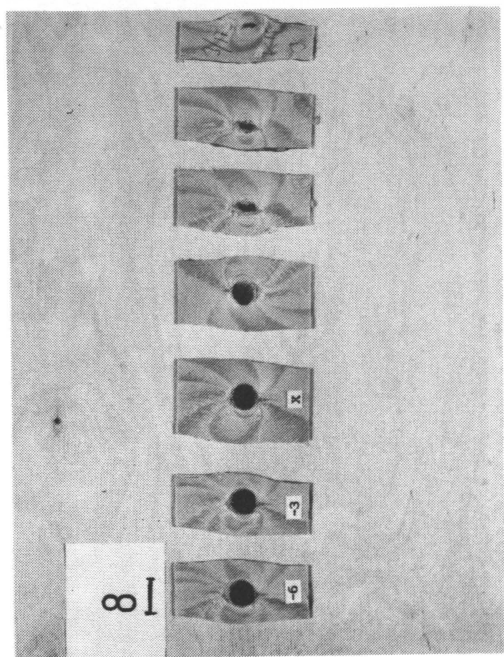
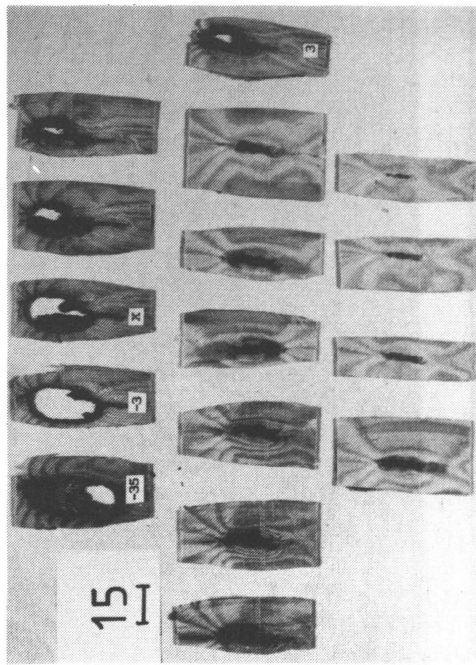


Photo 15. Pruned vertical branch.
Valokuva 15. Karsittu poikaoksa.



Photos 16-18. When pruned, branch was broken into long stub.
Valokuvat 16-18. Oksista jäänyt karsitussa piikkä tynkä, koska oksa on revennyt karsittaessa.

