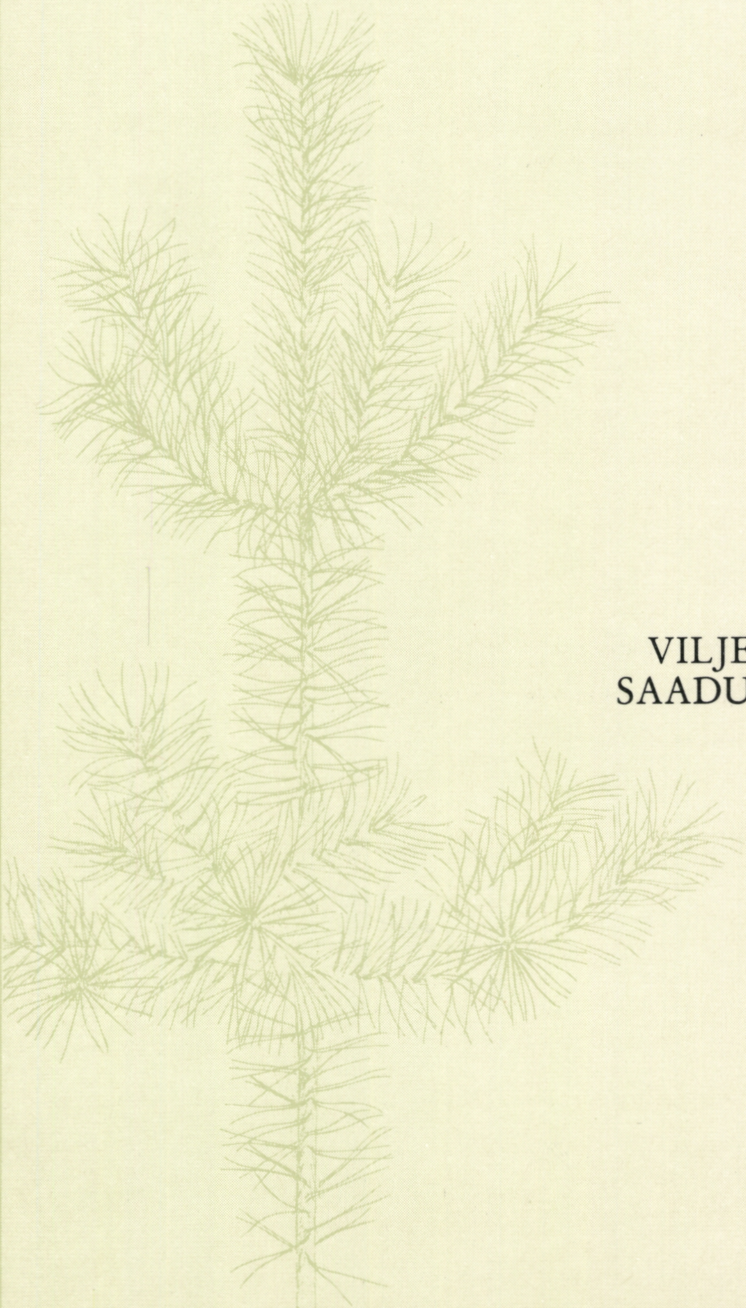
COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE 130

THE QUALITY AND VALUE OF SAWN GOODS FROM PLANTATION-GROWN SCOTS PINE

OLLI UUSVAARA



SELOSTE

VILJELYMÄNNIKÖISTÄ SAADUN SAHATAVARAN LAATU JA ARVO

HELSINKI 1985

COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE

THE FINNISH FOREST RESEARCH INSTITUTE
(METSÄNTUTKIMUSLAITOS)

Unioninkatu 40 A
SF-00170 Helsinki 17
FINLAND

telex: 125181 hyfor sf
attn: metla/

phone: 90-661 401

Director:
Professor Aarne Nyyssönen

Head of Information Office:
Olli Kiiskinen

Distribution and exchange of publications:

The Finnish Forest Research Institute
Library
Unioninkatu 40 A
SF-00170 Helsinki 17
FINLAND

Publications of the Finnish Forest Research Institute:

- Communicationes Instituti Forestalis Fenniae (Commun. Inst. For. Fenn.)
- Folia Forestalia (Folia For.)
- Metsäntutkimuslaitoksen tiedonantoja

Cover (front & back): Scots pine (*Pinus sylvestris* L.) is the most important tree species in Finland. Pine dominated forest covers about 60 per cent of forest land and its total volume is nearly 700 mil. cu.m. The front cover shows a young Scots pine and the back cover a 30-metre-high, 140-year-old tree.

COMMUNICATIONES INSTITUTI FORESTALIS FENNIAE

130

OLLI UUSVAARA

THE QUALITY AND VALUE OF SAWN GOODS FROM PLANTATION-GROWN SCOTS PINE

Approved on 12.4.1985

SELOSTE

VILJELYMÄNNIKÖISTÄ SAADUN SAHATAVARAN LAATU JA ARVO

HELSINKI 1985

UUSVAARA, O. 1985. The quality and value of sawn goods from plantation-grown Scots pine. Seloste: Viljelymänniköistä saadun sahatavaran laatu ja arvo. Commun. Inst. For. Fenn. 130: 1—53.

The material of the study comprised of 31 experimental pine stands established by planting and 30 experimental pine stands of natural origin in Southern and Central Finland. The quality characteristics of 630 and 1810 stems, respectively, and those of 165 and 150 butt logs from plantation-grown pines and pines of natural origin were measured. The butt logs were test sawn and the quality and grade of sawn goods were determined.

In pine plantations natural pruning of stems was slower and the development of branch thickness faster than in natural pine stands. Branchiness in particular, but also stem defects made the butt logs of pine plantations poorer in quality than logs from naturally grown trees.

A poorer sawing yield was obtained from plantation-grown pine logs on average and from certain quality class logs than from naturally grown pine logs. The u/s-percentage of sawn goods decreased and the share of poorer qualities increased when the annual ring widened in the vicinity of the pith.

Tutkimuksen aineisto käsitti 31 keinollisesti uudistaen perustettua ja 30 luontaista alkuperää olevaa mäntykoemetsikköä Etelä- ja Keski-Suomen alueelta. Viljely- ja luonnonmetsiköistä mitattiin 630 ja 1810 rungon sekä 165 ja 150 tyvitukin laatuominaisuudet. Tukit koesahattiin ja sahaustuloksesta arvioitiin sekä sahatavaran laatu että arvo.

Runkojen luontainen karsiutuminen oli viljelymänniköissä hitaampaa ja oksien paksuuskehitys nopeampaa kuin luontaisesti syntyneissä männiköissä. Erityisesti oksaisuuden mutta myös runkovikojen johdosta viljelymänniköiden tyvitukit olivat heikkolaatuisempia kuin luonnonrunkotukit.

Viljelymäntytukeista saatiin sekä keskimäärin että tietyn laatuluokan tukit luokittelemalla heikompi sahaustulos kuin luonnonrunkotukeista. Sahatavaran u/s-prosentti aleni ja heikompien laatujen osuus kasvoi kummassakin aineistossa vuosiluston levetessä ytimen ympäristössä.

ODC 832.10 + 851 + 228.7 + 174.7 *Pinus sylvestris*
ISBN 951-40-0697-6
ISSN 0358-9609

Helsinki 1985. Valtion painatuskeskus

CONTENTS

SYMBOLS — MERKKIEN SELITYS

r = correlation coefficient — *korrelaatiokerroin*
R^2 = coefficient of determination — *selitysaste*
y = mean — *keskiarvo*
x = mean — *keskiarvo*
s = standard deviation — *keskihajonta*
F = F-value — *mallin F-arvo*
DF = degrees of freedom — *vapausasteita*
t = t-value — *t-arvo*
M_e = median — *mediaani*
M_o = moode — *moodi*
N = number of observations — *lukumäärä*
x_1 = forest site type — *metsätyyppi*
x_2 = age of the stem, years — *rungon ikä, a*
x_3 = basal area of the stand, m^2 — *metsikön pohjapinta-ala,* m^2
x_4 = thickest branch of the butt log, mm — *tyvitukin paksuin oksa, mm*
x_5 = crown class — *latvuskerros*
x_6 = height of the tree, dm — *puun pituus, dm*
x_7 = breast height diameter, mm — *rinnankorkeusläpimitta, mm*
x_8 = taper $d_{1,3}$ — d_6, mm — *kapeneminen* $d_{1,3}$ — d_6, *mm*
x_9 = lowest limit of the stem with knot bumps, dm — *kyhmyisen rungonosan alaraja, dm*
x_{10} = lowest limit of the stem with dry branches, dm — *kuivia oksia käsittävän rungonosan alaraja, dm*
x_{11} = crown limit, dm — *latvusraja, dm*
x_{12} = diameter of the thickest dry branch, mm — *rungon paksuimman kuivan oksan läpimitta, mm*
x_{13} = height of the thickest dry branch, dm — *paksuimman kuivan oksan korkeus, dm*
x_{14} = diameter of the longest living branch, mm — *rungon pisimmän elävän oksan läpimitta, mm*
x_{15} = height of the longest living branch, dm — *pisimmän elävän oksan korkeus, dm*
x_{16} = knottiness class of the butt log — *tyvitukin oksaisuuslaatuluokka*
x_{17} = real quality class of the butt log — *tyvitukin todellinen laatuluokka*
x_{18} = top diameter of the log, cm — *tukin latvaläpimitta, cm*
x_{19} = length of the longest living branch, cm — *pisimmän elävän oksan pituus, cm*
x_{20} = height of the first complete whorl, dm — *1. täyden oksakiehkuran korkeus, dm*
x_{21} = mean diameter of branches, mm — *oksien keskipaksuus, mm*
x_{22} = number of annual rings/75 mm from the pith — *lustoja/75 mm ytimestä, kpl*
x_{23} = basic density at 75 mm distance from the pith, kg/cu.m. — *kuiva-tuoretiheys 75 mm matkalla ytimestä, kg/*m^3
x_{24} = basic density in exterior parts of the stem, kg/cu.m. — *kuiva-tuoretiheys puun pintaosissa, kg/*m^3
x_{25} = width of annual rings at 75 mm distance from the pith, mm — *lustojen leveys/75 mm ytimestä, mm*
x_{26} = width of annual rings in exterior parts of the stem, mm — *luston leveys puun pintaosissa, mm*
x_{27} = latewood percentage at 75 mm distance from the pith — *kesäpuuprosentti/75 mm ytimestä*
x_{28} = latewood percentage in exterior parts of the stem — *kesäpuuprosentti puun pintaosissa*
x_{29} = crown ratio, % — *latvussuhde, %*
x_{30} = volume of the log, dm^3 — *tukin tilavuus,* dm^3
x_{31} = sweep, mm — *lenkous, mm*
x_{32} = length of the part of the stem with knott bumps, dm — *rungon kyhmyisen alueen pituus, dm*
x_{33} = length of the part of the stem with dry branches, dm — *rungon kuivaoksaisen alueen pituus, dm*
x_{34} = length of the log, dm — *tukin pituus, dm*
x_{35} = u/s-percentage — *u/s-prosentti*
x_{36} = CT dummy variable — *CT-valemuuttuja*
x_{37} = VT dummy variable — *VT-valemuuttuja*
x_{38} = MT dummy variable — *MT-valemuuttuja*
x_{39} = OMT dummy variable — *OMT-valemuuttuja*

PREFACE

The study was first published in 1981 as No 27 in the Metsäntutkimuslaitoksen Tiedonantoja (Research Notes of the Finnish Forest Research Institute). Due to the timeliness of the study, its considerable forest economical significance, and its narrow distribution it was decided to republish it in the present form. In the main, it is the same as the original study. A few changes and additional analyses have been made.

The author wishes to thank all organizations and private persons who assisted in the various phases of the work.

Helsinki 15. 1. 1985

Olli Uusvaara

1. INTRODUCTION

The importance of artificially regenerated pine stands as a source of raw material is still small despite the comparatively large area they cover. Artificial regeneration was started on a large scale in the beginning of the 1950's, but the number of regeneration areas did not increase substantially until the next decade (Uusitalo 1979). The share of pine in the regeneration areas is now over 1 million hectares, or some 5 per cent of the forest land area, but owing to the young age of the pine stands they do not yet produce much saw timber.

During the last few decades, the aim in forestry has been to increase timber production and to attain quantitative goals (Vuokila 1972). No information concerning the quality of man-made forests has, however, been available. These questions first received attention at the end of the 1960's, when the Finnish Forest Research Institute started studies on the quality of planted pine stands and on the traits by which to examine the quality (Uusvaara 1974).

Knowledge about the differences between qualities of planted and natural stands had, to some extent, been attained earlier when studying the basic density of the timber in planted spruce stands and when comparing that to the density of natural stands (Hakkila and Uusvaara 1968). Attention was, however, now focused on pine, whose quality is most prone to external influence, and whose good and poor qualities have the largest differences in value (Heiskanen 1965). The results of the study showed clearly that the quality of pine is heavily dependent on changes in external growth factors, especially in the early stage of the stock, in addition to natural aging. Because of this, textbooks and studies on the growing of pine earlier emphasized the effect of stand density on quality until that stage of development, when the branches on the length of the butt log have died (Kalela 1945, Heiskanen 1954b, 1962, Sarvas 1956).

Although there are not any studies proper on the quality differences of planted and natural pine stands, it became clear from various sources that artificially and naturally established stands have, at the beginning of their development, differences that bring about changes in the external and internal qualities of the stem (Laitakari 1937, Heikinheimo 1953). As late as in the 1930's, the number of cultivation spots per hectare was 5 000 to 6 000, and pine was mostly regenerated by sowing (Kalela 1945). The most common regeneration method for pine today is planting (Uusitalo 1979), and the standard planting density today is 1 600 to 2 500 seedlings per hectare, depending on the site (Takala 1978, Ohjekirje . . . 1978, Kaila 1979). Recent studies show that the final number of seedlings in stands usually remains considerably lower than the goal (Leikola et al. 1977, Rautiainen and Räsänen 1980). Räsänen (1981) emphasizes the high quality of the seedlings to ensure successful regeneration and a sufficiently dense, uniform seedling stand of high quality. When talking about the quality of seedlings, however, the good health condition and fast growth capacity of the seedlings is usually refered to.

If the conditions in which the planted and natural stands develop is compared, the differences are great already from the beginning of the development of the stands. Saw logs, which the Finnish sawmill industry uses as its raw material nowadays, mostly come from forests established at the end of the 1800's. These forests developed usually as thickets and mixed stands, often in virgin condition and left uncut. The activities carried out in them, such as woodland burning, selection felling according to minimum diameter limit, tar burning and forest fires have also left their mark on the present pine stands. Woodland burning and forest fires have additionally strengthened the position of pine as compared with other tree species (Vuokila 1980b). Because the powerful sawmill industry showed interest in the large-sized stems of the stands, selection cutting was maintained still long into this century.

The above-mentioned development stages affected the quality of the pine stands in many ways, and in many respects also negatively. The development from dense natural and cultivation forests established mostly by means of natural seeding to open plantation forests has undoubtedly also had its effect on the quality of saw-timber. These effects are not yet known in the sawmill industry, however, because the timber coming from the planted stands has not yet any significant role as raw material.

Questions of quality have recently been paid so much attention that the past decade can be called the decade of timber quality. Attention has also been paid to the quality of saw logs, because the value of the product is highly dependent on the quality of the raw material. Studies have been made on the use of objectively measurable factors in the classification of saw logs (Orvér 1970a, 1970b). Also in Finland, a more precise quality classification and payment according to quality have raised some discussion (Isomäki 1978, Kärkkäinen 1978, Oksanen 1978). By means of quality traits, an attempt has been made to determine the quality of trees as far as the value of saw-timber is concerned (Dahlen and Warg 1978, Kärkkäinen 1980a, 1980b).

The effect of the growing space and growth of the diameter of pine on the branchiness properties, and the quality of saw-timber and pulp has been analyzed in Sweden (Persson 1975, 1976, 1977). In Finland, great attention has been paid especially to the poor quality of plantation-grown pine stands (Arnkil 1978, Koivisto 1980, Uusvaara 1979, 1980a, 1981a, 1981b). Thick branches, which are perhaps the most serious defect in plantation-grown pine stands have once again raised discussion about the possibilities of artificial pruning as a quality raiser (Uusvaara 1980a, 1980b, Vuokila 1979a, 1980a, Kärkkäinen 1981). According to several studies, in addition to branchiness, the defects often lower the quality of the butt logs of plantation-grown pines even beyond sawn timber standards (Uusvaara 1981a, 1981b, 1981c, 1981d, Varmola 1980).

In the study by Uusvaara (1974) the traits, fluctuation and relations of the external and internal qualities of plantation-grown pine stands were measured. The differences in the quality of planted and natural stands were also compared, but owing to insufficient information and the difference of the comparable material, the results remained incomplete. The studies made represented, in a way, indirect quality studies by means of such characteristics that have a compound effect on the final quality of the timber.

When estimating the quality of saw logs, internal faults create a problem because the real quality of the timber cannot be studied merely by judging from external traits. The importance of the in-grown stubs, for example, as a factor affecting the quality of old stems from good sites, cannot be estimated only on the basis of external examination.

The aim of this study is to clarify the quality and value of the saw-timber obtainable from plantation-grown and natural stands, as well as to determine which quality traits of the stem and the timber have the greatest effect on the value of sawn timber. This is done by determining the quality directly on the basis of the test sawings and the grading of the sawn goods. The quality will be compared on the basis of both the normal export classification and stress grading, which seems to have an increasing importance in the use of construction timber (Raveala 1979). When making comparisons, attention is totally centered upon butt logs partly because they constitute over a half of the value of the stem (Orvér 1970b). On the basis of butt logs, differences in values of stems can also best be compared. This is much more difficult with other logs (Persson 1976).

The study will be geographically restricted to concern Southern and Central Finland, where the quality problems concerning regeneration of pine are most pressing.

The aim is also to study the natural pruning of the stems, the development of the thickness of the branches and factors affecting these in plantation-grown and natural pine stands. Another question is, whether these quality factors have any significant difference between stands of different origin.

Because the main goal in the growing of a plantation is the production of saw logs and because the quality of sawn goods depends directly on the quality of the logs, attention is also being paid to the quality of the butt log and its dependence on the quality variables of the stem, especially on branchiness and stem defects. All comparisons will be made with stems from pine plantations and stands of natural origin.

The studies will be limited, as concerns plantation-grown pine stands, to successful, pure and healthy stands, where the age and size already allow some felling of saw logs. An attempt will be made to avoid broadcast sowing areas, because they greatly resemble naturally seeded areas with regards to establishment and structure. The successfulness of the comparison between different origins will depend on the successful choice and comparability of different research materials. This question will be dealt with more closely in conjunction with the explanation of the methods as well as in the chapter concerning the representativity and examination of the results.

2. RESEARCH METHODS AND MATERIAL

21. Research methods

Regionally the studies were mainly focused on Southern and Central Finland, because in this way it was possible to reduce the effect of geographical variation and because the quality defects of stands seem to be more obvious in these areas (Table 1). The number of old plantation-grown pine stands that are already able to yield saw timber and that have sufficient data on origin and treatment available are few. Because most of them are situated in areas owned by the Finnish Forest Research Institute, in demonstration forests of Forestry Colleges, or under the National Board of Forestry, the studies were carried out in these areas. This was necessary partly for practical reasons. The felling and scientific use of trees is easier to carry out in State-owned areas.

In several research areas, all or nearly all available stands were chosen owing to the shortage of plantation-grown pine stands. If there were plenty of acceptable spots they were chosen by casting lots. The pine stands had to at least be able to yield saw timber, be typical of the location, be pure as concerns tree species, be even-aged and as uniform as possible with regards to terrain and forest site type. The principle was that various site quality classes should be represented in the same proportion as is the average for pine. Otherwise the criteria and the location of the spots were the same as in an earlier study by the same author (Uusvaara 1974, page 19).

Stands established by both planting and sowing were included in the study, but the share of the former remained rather limited, for sowing was the commonest method of artificial regeneration at the beginning of the century (c.f. page 12). An attempt was made to avoid broadcast sowing.

From each locality, natural pine stands, which conformed as closely as possible to plantation-grown stands as far as age, stock and soil quality are concerned, were taken as comparison material. The choice was not very successful in every respect, for natural pine stands were mostly located, as opposed to plantation-grown pine stands, on the *Vaccinium* site type (c.f. page 12) and were in most localities older than plantation-grown stands (page 47).

The sample plot was located in the stand in the following manner. First, the largest dimension of the plot was divided into equal sections, and one of the sections was chosen by the casting of lots. Next, the sample plot was situated in the middle of the chosen section, but if the site did not fill the specified general requirements for a sample plot, the plot was moved to the adjacent section.

In order to get sufficient material and still keep the amount of work reasonable, sample plots were taken from each plantation-grown stand, including a minimum of 20 sample trees. The sample plot was made rectangular by using a prism, and the size of the sample plot varied depending on the size and density of the stock. The method of stand establishment and treatment at various development stages as well as forest site type, basal area and age were determined as precisely as possible. In natural stands, the number of sample trees was raised to 60 stems owing to the greater variation of age and size of the stock. The ages of the trees were determined by taking increment cores from the butts of ten stems which were chosen by the casting of lots. The heights of natural stems were measured from every fifth stem on the sample plot.

As for the measurements concerning the stems, branchiness and defects of standing trees, reference is made to an earlier study (Uusvaara 1974, pages 19 to 21). As an exception, it could be mentioned that the quality of the butt log was measured in accordance with the normal classification, and separately with only branchiness as a criterium.

The butts of the felled trees were cut into logs, and the diameter under bark was measured at the top of the log, in the middle and at the butt of the log crosswise, with the precision of one millimetre, together with the diameter of the heartwood area and the length of the log. The top diameter of the log was measured over bark in accordance with the measurement standards for logs. Diameters under bark were also measured just below the area with knot bumps and under the dry branches. The defects of the log were taken into account separately from the stems and the sweep of the log was measured for the total length of the log with a commonly used method (Definitioner . . . 1980).

Branchiness was taken into consideration by measuring the thickest dry branch of the log and its location as well as the number and mean diameter of the dry branch stubs and branches that were healing over.

As for stem defects, only crooks, sweep and vertical branches were taken into account, because the importance of other defects has earlier proved to be generally minimal (Uusvaara 1974). The location of the defect was studied to establish whether the defect was worse at the butt or in the stem.

Five stems from each sample stand were cut after casting lots. Contrary to previous practice, the height of the first living branch whorl was measured from the butt of the tree. One meter from this whorl, the diameter of the thickest branch in the closest branch whorl was measured immediately off the basal swelling of the branch (Definitioner . . . 1980, page 50).

The sample logs were sawn at each different

Table 1. The investigation material by localities.
Taulukko 1. Tutkimusaineisto paikkakunnittain.

Locality *Paikkakunta*	Plantations — *Viljelymänniköt* Sample plots *Koealoja*	Stems *Runkoja*	Logs *Tukkeja*	[1])Natural stands — [1])*Luonnonmänniköt* Sample plots *Koealoja*	Stems *Runkoja*	Logs *Tukkeja*
Tuusula	3	60	15	3	240	15
Punkaharju	6	130	40	6	378	30
Koli	2	40	10	2	120	10
Pieksämäki	1	20	5	1	40	5
Ähtäri	5	100	25	5	299	25
Kuru	3	60	15	3	180	15
Virrat	3	60	15	3	175	15
Juupajoki	3	60	15	2	100	10
Evo	2	40	10	2	100	10
Tammisaari	2	40	10	2	120	10
Tenhola	1	20	5	1	60	5
Total — *Yhteensä*	31	630	165	30	1812	150

[1]) Natural stand = stand born by natural seeding.
[1]) *Luonnonmännikkö = luonnonsiemennyksestä syntynyt männikkö*

location with a portable circular saw. In the sawing process, only the most common blade settings were used; these settings were determined according to the top diameter of each log, which was measured under bark. The side board thickness used was 19 millimetres. The blade settings for centre goods were the following:

Top diameter of log (mm)	Blade setting
150 — 165	50 × 100
165 — 180	50 × 100
180 — 195	50 × 125
195 — 210	50 × 150
210 — 225	63 × 150
225 — 240	75 × 150
240 — 255	63 × 175
255 — 270	75 × 175
270 — 285	75 × 200
285 — 300	75 × 225

The sawn goods were sorted in accordance with the classification standards for exportable sawn goods (Vientisahatavaran ... 1979) without making any classification between the u/s qualities 1 to 4. In practice, the price of the u/s sawn goods is only slightly dependent on the internal distribution within the quality class, nor will the qualities be sold separately. Schaalboards were separated according to exportable qualities (PL/VL) and domestic qualities (PL/KL), so that the number of quality classes was six, including rejected timber.

The centre goods were prepared, in accordance with the chart described above, into battens or planks, depending on the top diameter of the log. Battens are pieces of sawn goods whose thickness is over 38 but under 75 millimetres and whose width is 75 to 175 mm. Planks are sawn goods with thicknesses over 38 but under 100 mm, and widths exceeding 175 mm.

The sawn goods were priced according to the wholesale prices and the pricing standards of exportable sawn goods (Sahatavaran ... 1980). When calculating the proportion of the value of sawn goods, the unit price for the u/s board was marked with the figure 100, in relation to which the values of other classes were obtained (Appendix 1).

In addition to the normal classification, the battens and boards were classified visually into normal T stress grades, and in accordance with the glue beam classification (RIL 120, 1978). The grades in the visual T classification were T40, T30, T24 and T18, and in the beam classification LT40, LT30, LT20 and LT10 (RIL 120, 1978).

Each piece of the sawn goods was classified both in the normal and in the T and LT classifications, in addition to the real quality. In further classifications solely on the grounds of branchiness, different production defects and other defects, such as wanes, were not taken into account.

The reason for the potential fall from the best class was recorded. Such defects causing a fall in quality can be classified, for example, into defects caused by the sawing technique, deterioration of the woody material, or the form and defects of the stem. Already when choosing the experimental material, stems with unsatisfactory external factors and stems with decay and blueing were discarded. If, however, defects such as these did appear in the sawn goods, they were not considered when carrying out the quality classification.

The randomly chosen second centre piece from every second log was classified visually, and to check the visual classification a stress grading machine was used, which gave the stress grade of the sawn goods on the basis of their bending qualities. The stress grades used were the same as in the visual classification. If there was a total of three centre pieces, one of the outermost pieces was taken into mechanical grading.

In stress grading, only such pieces, whose length and thickness variations are relatively small, can be compared with each other. An attempt was made to keep the length variation of sawn goods within 31 to 46 dm; pieces which were too long were shortened from the top. One factor which affects the stress grade more than length is its nominal thickness, which in circular sawing fluctuated more than in the usual frame sawing. That is why, in conjunction with classification, the thicknesses of each piece were measured at five different points of the length axis. The stress grades obtained in the mechanical classification and caused by the deviations from the measuring precision were corrected by means of coefficients.

Mechanical classification also requires even low moisture conditions. For this reason, the sawn goods to be sorted were dried at the sawmills to a moisture content of 20 per cent.

A half of the mechanically classified pieces were then planed, to remove differences in thickness, to a lower full millimetre thickness, and were then reclassified. Real thicknesses of the sawn goods were thus 46, 60 and 71 mm.

In conjunction with sorting, a ten-centimetre-long cut was taken from each end of the pieces to determine the basic density of the sawn goods.

The quality of timber changes crucially when going outward from the pith of the tree to the sapwood, and the conditions that were prevalent during the early years of the tree have an effect on the quality of the developing saw timber later also (Heiskanen 1965). For this reason, the cuts from the stumps of the felled trees were divided into two parts, at the radius of 75 mm from the pith. The earlier class requirements for logs included the condition that the annual ring of the third class saw log does not exceed the 3-mm limit, within this 75-mm distance (Heiskanen 1954b).

Samples taken from both the sawn goods and the stumps of the felled trees were used at the laboratory to determine the mass of the piece after kiln drying and the volume based on sinking the piece into water. On these grounds the basic density was calculated. Samples taken from the stump were also used to determine the width of the annual ring by applying an annual-ring meter in different zones and the late wood percentage of the sample.

22. Research material

The study was geographically limited to concern the old plantation-grown stands growing in the southern and central parts of Finland (Table 1). The material was mostly composed of the same areas that were measured during the years 1968 and 1969 (Uusvaara 1974), but the growing stock was now older and larger in size. When the goal was set to such a point where at least some of the stems in the stand would already be within the required size to yield butt logs, the youngest stands were approximately 35 years old. Only those plantation-grown stands where the share of natural seedlings was known to be small and which had a sufficient amount of information on origin and treatment available were accepted as research material. The accepted maximum amount of different species within a stand was 10 per cent of the stand's cubic volume.

The sample plots were situated in each stand on a uniform area concerning soil and forest site type so that the plantation-grown stands had a very uniform and even structure. The natural stands selected as comparison material were, on the contrary, considerably more heterogenic as far as the structure of the stand was concerned because of the method of establishment and development differences.

The total number of sample stands was 61 in 11 different localities; 31 were plantation-grown and 30 naturally regenerated stands. The majority of the areas (40 stands) were situated in the forests of the National Board of Forestry or Forestry Colleges and the remaining 21 in forests of the Finnish Forest Research Institute. 26 per cent of the plantation-grown stands had been established by planting and 74 per cent by sowing, which was the commonest method of regeneration at the beginning of the century. Earlier the prevelent method of sowing was patch sowing, the patches being situated more densely then than today, often 1.5 by 1.5 metres or 1.8 by 1.8 metres. 16 per cent of the sowing was broadcast sowing. Also about a half of the plantations were established with smaller distances between the seedlings.

Stands that had silviculturally been treated regularly were generally chosen as sample stands. It was possible to document both the establishment data and the methods and times of treatment in different stages of development of the plantation-grown stands, almost without exception, on the basis of notes or remembered knowledge. Little information was found on the establishment and treatment of the natural stands, especially regarding the beginning of the development. As for the density and size of the stand both plantation-grown and natural stands were very easily comparable, for the basal areas of both, for example, were on the average almost equal. Natural stands were, however, somewhat larger in size and possibly more heavily thinned than the plantations, which is clarified by the following figures. The number of stems per hectare in natural stands is also attributable to the fact that the sample plots were mainly situated in the *Vaccinium*-type forests.

	Sample plot, sq.m.	Stems per ha
Plantation-grown stands	267	852
Natural stands	1184	639

The stands were divided, by forest site types, according to the size of the sample plots in the following way:

	Plantation-grown stands	Natural stands
	per cent	
CT	3	7
VT	45	82
MT	28	7
OMT	25	4

Almost a half of the plantation-grown stands were situated in areas which were more fertile than normal pine sites, which partly describes the trend in the regeneration of pine at the beginning of artificial regeneration. Naturally regenerated stands, on the other hand, usually locate on *Vaccinium* types of soil or on more barren sites, because of their physiological requirements.

A total of 630 standing sample trees were measured in plantation-grown stands and 1810 in natural pine stands, a total of 2440 stems. Of these, after casting lots, 165 and 150 stems were cut in plantation-grown and natural stands respectively. Their butt logs were scaled for cross-cutting in accordance with the generally applied classification standards (Heiskanen and Siimes 1959). The classification was adjusted, however, for the lake district of Finland. A sector was cut from the butt of each log; this sector was taken from the middle of the largest and smallest diameter between the surface and the pith. This was used to determine the basic density of the wood, the width of the annual ring and the late wood percentage. When each sector was treated in two parts, the total number of samples such as these was 600.

All logs were sawn and the sawn goods were sorted visually. One batten or plank was taken from every second log and graded mechanically, producing about 150 sawn pieces.

3. RESULTS CONCERNING STEMS AND LOGS

31. The self-pruning of stems

Figure 1 presents the dependence of different branchiness zones of the stem on the age of the tree in plantation-grown and natural stands. The height of the stems increases with age, but the height growth is especially quicker in old plantation-grown stands than in natural stands. This is partly due to the better forest site type (page 12).

The branchless part of the stem gets longer with age, but the growth is especially quicker after the 60th year. The top limits of the branchless part and the part of the stem with knot-bumps are, however, constantly higher in natural pine stems than in plantation-grown stems. When the branches fall off faster, then the length of the portion of the stem that has knot-bumps seems to remain somewhat stable. In plantation-grown stands, that part of the stem with dry branches and the crown lengthen clearly with age, whereas the development in naturally regenerated pine stems seems to be the contrary (c.f. Table 2).

A long zone of dry branches is obviously attributable to the fact that plantation-grown stems have thicker branches than natural stems and that plantation-grown pine branch is dry and fall off at a slower pace even at a

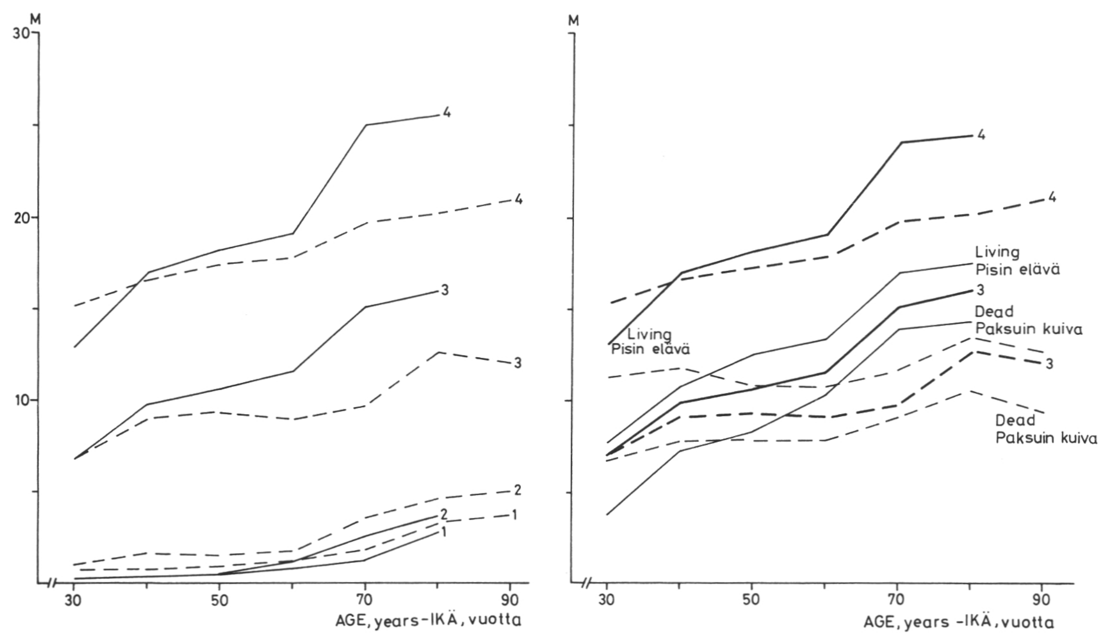


Fig. 1. Development with age of the branchiness zones, the tree height and the biggest branches. Broken line = natural pine stands. 1 = knot bump limit, 2 = branch limit, 3 = crown limit, 4 = tree height.

Kuva 1. Rungon eri oksaisuusvyöhykkeiden, puun pituuden sekä suurimpien oksien kehitys iän mukana. Katkoviiva = luonnonmänniköt. 1 = kyhmyraja, 2 = oksaraja, 3 = latvusraja, 4 = puun pituus.

Table 2. Relative heights of the branchiness zones by age classes.
Taulukko 2. Eri oksaisuusvyöhykkeiden suhteelliset pituudet ikäluokittain.

Age class *Ikäluokka*	Knot bump limit *Kyhmyraja*		Dry branch limit *Kuivat oksat*		Crown limit *Elävät oksat*	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
			Plantations, % — *Viljelymänniköt, %*			
30	1,4	0,7	1,6	1,1	52,3	9,9
40	2,1	1,5	3,1	2,7	55,8	10,0
50	2,8	2,1	5,1	5,4	57,2	12,6
60	4,3	3,4	7,5	6,3	61,7	11,7
70	4,8	1,2	9,4	4,2	60,4	4,2
80	10,8	6,1	14,0	5,2	62,2	5,2
90						
			Natural stands, % — *Luonnonmänniköt, %*			
30	3,7	2,2	3,9	2,2	44,7	9,8
40	3,7	2,0	9,1	9,4	52,7	10,6
50	4,1	2,6	7,8	7,7	52,8	8,3
60	5,3	2,9	8,5	5,9	50,1	8,0
70	5,4	2,8	17,7	16,2	51,5	11,2
80	17,3	6,6	20,8	14,2	54,2	12,5
90	17,6	7,5	23,8	13,8	57,0	11,2

late age. Differences can also be seen among various regeneration methods. The self-pruning of plantation-grown stands is slower than in sown pine seedling stands, and the comparison between various sowing methods shows, for its part, that in areas where broadcast sowing has been applied self-pruning of stems is quickest. The differences caused by various regeneration methods are evident in the following table, which describes the distance of the lowest dry branch from the ground and the thickness of the thickest dry branch of the stem in a 40- to 60-year-old plantation-grown stand.

	Height of the lowest dry branch, cm	Thickness of the thickest dry branch, mm
Planting	50	38
Patch sowing	70	28
Broadcast sowing	40	25

The early development of the seedling stand, primarily the growth density, is obviously reflected in the branchiness of the lowest part of the stem, although the effect of the density at the stage of stand establishment vanishes with age. This is clarified by the width of the annual ring of plantation-grown stems, established by different means, in the area around of the pith (within a 75 mm radius from the pith) at the 0-level of the stem.

Planting	Patch sowing Width of annual ring, mm	Broadcast sowing
3.4	2.7	2.2

Also in relation to the length of the stem the lengths of the defect-free part and the part of the stem with knot-bumps are shorter in plantation-grown stands, whereas the part of the stem with dry branches is correspondingly longer but the crown shorter (Table 2). The result is significant from the viewpoint of the utilization value of the stem, for dry branches decrease the value of sawn goods more than living branches.

In naturally regenerated stands, the width of the annual ring in around the pith in stems of 40 to 60 years of age, is on an average, 1.8 mm and the distance to the lowest dry branch 16 dm. From among different regeneration methods, a timber stock established by broadcast sowing seems to most resemble the naturally regenerated stock as concerns branchiness characters and quality. The results of the development of sown stands obtained by Kallio (1960) also suggest this. The development of self-pruning of the stems was, according to these studies that contained plenty of information on broadcast sowing areas, even quicker than the self-pruning which Nyyssönen (1954, page 87) found out in pine stands that had been thinned repeatedly.

Table 3. Correlation between the height of stem branchiness zones and age and DBH.
Taulukko 3. Rungon eri oksaisuusvyöhykkeiden korkeuden riippuvuus iästä ja puun rinnankorkeusläpimitasta.

Dbh, cm	Knot bump limit, dm — *Kyhmyraja, dm* Age, years — *Ikä, a*						Branch limit, dm — *Oksaraja, dm* Age, years — *Ikä, a*						Crown limit, dm — *Latvusraja, dm* Age, years — *Ikä, a*					
$D_{1.3}$, cm	< 45		46—65		> 66		< 45		46—65		> 66		< 45		46—65		> 66	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
							Plantations — *Viljelymänniköt*											
15	2	2	4	2	5	2	4	5	6	7	17	11	79	18	85	19	50	12
20	3	2	5	4	10	16	5	5	8	8	5	2	88	25	101	25	125	19
25	3	2	5	5	10	5	6	5	8	8	22	14	103	29	111	26	139	22
30	4	2	5	5	21	18	5	3	8	9	28	21	99	34	111	25	151	18
							Natural stands — *Luonnonmänniköt*											
15	4	1	6	5	10	8	5	2	13	12	26	25	58	4	71	21	80	19
20	5	2	7	6	13	9	9	7	15	13	33	31	85	30	92	17	94	24
25	5	5	6	4	14	9	8	7	17	15	35	33	86	20	97	18	111	34
30	..	..	8	4	13	8	..	..	14	9	36	33	..	..	102	17	118	34

The lengths of different stem zones, as far as branchiness is concerned, increase with age, with the exception of the crown, but the diameter growth rate of the stems also has an effect on self-pruning. In young stands, the part of the stem that had shed its branches and the part that is defect-free did not lengthen enough to deserve mentioning as the stem grew larger. In the thickest stems of a specific age, however, self-pruning had been poorer and thus the stems were of poorer quality both in plantation-grown and naturally regenerated stands (Table 3). In the oldest age group the quality was poorer when the stems were thinnest, although their branches had dried rather high up the stem and the crown had thus remained short. The crown limit, on the other hand, rose as the diameter increased also in young stands, which signifies small crowns and a long dry-branched part of the stem in quickly grown stems (Figure 1 and Table 2).

It has already been stated that clear differences in the self-pruning of stems, both between various stands and within them, exist in such a way that self-pruning is poorest in both the largest and the smallest trees in a stand (Uusvaara 1974). In the present study the same trend was found in plantation-grown stands, but in naturally regenerated pines the correlation between the size of the stem and the self-pruning stage was weaker. Results such as these seem to favour selective thinning from above thinning methods, where, in addition to hold-overs, the largest trees of the first crown layer would be removed. This possible cutting method has also been presented by Nyyssönen (1954), Heiskanen (1965) and Vuokila (1977).

The forest site type also affects self-pruning, healing over, and the location of the crown limit. This is described by the height of the first full branch whorl of the stem, which is lowest in *Oxalis-Myrtillus* and *Vaccinium* site types, when the stems under comparison are of the same age.

Forest site type	Age class, a ≦45	46 to 55
	First branch whorl from ground, dm	
VT	16	31
MT	16	36
OMT	11	12

Similar differences in self-pruning between stems in different site types were already found in an earlier study by the same author (Uusvaara 1974), where the difference between the best two forest site types was especially clear.

The following equations describe the correlation between the height of stem parts with different branchiness zones and the age of the tree in plantation-grown and naturally regenerated stands:

Plantation-grown stands

Regression equation	$\bar{y}$	r
$y_1 = 2.0719\ x + 9.9864$	17.96	0.693
$y_2 = 0.4983\ x - 19.406$	0.61	0.689
$y_3 = 0.7266\ x - 27.895$	0.92	0.695
$y_4 = 1.5396\ x + 24.365$	10.39	0.616

Naturally regenerated stands

Regression equation	$\bar{y}$	r
$y_1 = 0.5424\ x + 144.73$	18.07	0.307
$y_2 = 0.2014\ x - 3.6298$	0.97	0.467
$y_3 = 0.4711\ x - 7.6826$	2.31	0.342
$y_4 = 6.3571\ x + 71.402$	9.51	0.224

In equations

y_1 = height of tree, dm
y_2 = height of the part of stem with knot-bumps, dm
y_3 = height of dry-branched part of stem, dm
y_4 = crown limit, dm
x = age of tree, years

It can be seen that the correlation coefficients calculated in equations from plantation-grown stands are considerably higher than those from natural stands. On the basis of age, the fluctuation of branchiness limits cannot be determined to as great an extent in natural stands as in plantation-grown stands. The descriptive percentages of various branchiness limits in plantation-grown stands are 47, 48 and 38. The interdependence of variables describing the external quality characters of the stems measured from some standing sample trees and from sample plots is presented in tables 4 and 5. The tables show that the correlations between the variables are usually higher in plantation-grown stands than in naturally regenerated stands. This is owing to the greater fluctuation of the values of the variables in natural stands.

Tables 6 and 7 present the properties of standing trees and butt logs measured in plantation-grown and naturally regenerated stands and characteristics grouped according to the branchiness class of the butt log. When examining the measurement results of the stems one can infer that the logs of poorer quality come, on one hand, from young, small-sized stems and, on the other hand, from comparatively large-sized, quick-growing stems. The poorest quality logs come from among the largest stems, but not, however, from among the tallest ones.

The poorer the quality class is, the weaker the self-pruning quality of the stem is and the greater the thickness of the branches. The table that presents the properties of natural pine stems verifies, on the basis of diameter measurements, the earlier statement that the best logs do not come from the largest stems of the stand. On the basis of age and branch thickness, it can be seen that the quality of the log is best in old, slowly-grown stems (Table 6). The plantation-grown logs in the first branchiness class do not obviously always, despite their larger size, fall into the best quality class, but the defects caused by quick youth development are hidden inside the stem (page 30).

The longest branch in the stem describes the quality of the butt log better than the thickness of the largest dry branch of the stem does. In plantation-grown stands the length of the longest branch also grows as the quality of the log weakens, which partly describes the correlation between the width of the crown and the general quality of the tree.

In his studies, Heiskanen (1965) emphasizes the importance of the length of the branchless part of the stem and branchiness with regards to quality of saw logs. The faster the growth rate has been, the shorter the branchless part of the stem is in all diameter classes and the thicker the branches of the butt are. According to Heiskanen, the height of the branchless part of the stem rises up to 4 meters at approximately the age of 80 years, and is then about 15 per cent of the height of the stem. Heikinheimo (1953) states correspondingly that the butt section free of branches is 14 per cent of the stem already at the age of 50. Also Kallio (1960) found out that a stand established by sowing had self-pruned up to the height of 4 meters in the *Myrtillus* type already at the age of 55 years. The comparability of his studies with the results of this study is weakened by the fact that the material unrestrictedly included trees in broadcast sown areas also. Also, pine stands in the OMT site types had been excluded from the study. In the studies of Kärkkäinen (1980a) the height of the branchless part of the stem fluctuated in natural pine stands from 2,6 to 7,5 meters in conformity with the quality of the log. Correspondingly, in another study by Kärkkäinen (1980b) the stems of a good-quality marked stand had self-pruned up to the height of 8.9 meters, but in marked stands of poorer quality self-pruning occurred only up to 3.6 meters. The results are not fully comparable with this study, which had to mainly include trees from youngish naturally regenerated pine stands in the material.

Because usually only butt logs are fully self-pruned, it has been suggested as a criterium in quality grading that the butt logs be separated from other logs (Heiskanen 1971, Asikainen 1980, Kärkkäinen and Salmi 1981).

Table 4. Correlation matrix of variables that explain plantation-grown pine stems.
Taulukko 4. Viljelymäntyrunkoja kuvaavien muuttujien korrelaatiomatriisi.

	x_{1}	x_{2}	x_{3}	x_{4}	x_{5}	x_{6}	x_{7}	x_{8}	x_{9}	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}
x_{1}	1,000																		
x_{2}	—0,053	1,000																	
x_{3}	0,288	— ,036	1,000																
x_{4}	0,497	— ,219	,391	1,000															
x_{5}	— ,158	— ,152	,014	— ,359	1,000														
x_{6}	,357	,699	,146	,074	— ,462	1,000													
x_{7}	,374	,511	,077	,437	— ,679	,787	1,000												
x_{8}	,093	,211	— ,050	,340	— ,370	,250	,592	1,000											
x_{9}	,238	,693	— ,113	— ,064	— ,182	,552	,489	,259	1,000										
x_{10}	,187	,687	— ,121	— ,126	— ,156	,569	,451	,216	,777	1,000									
x_{11}	,400	,630	,161	— ,017	— ,230	,812	,533	,113	,506	,529	1,000								
x_{12}	,402	— ,020	,349	,729	— ,122	,149	,331	,249	,186	— ,069	,165	1,000							
x_{13}	,052	,880	,084	— ,316	— ,105	,835	,412	— ,064	,699	,525	,828	,035	1,000						
x_{14}	,177	— ,010	,155	,500	— ,123	,053	,313	,278	,103	,056	— ,078	,362	— ,012	1,000					
x_{15}	,390	,798	,237	— ,165	,139	,854	,354	— ,040	,651	,564	,964	,075	,728	— ,043	1,000				
x_{16}	,060	— ,527	,311	,559	— ,001	— ,376	— ,126	,032	— ,563	— ,585	— ,416	,263	— ,418	,222	— ,405	1,000			
x_{17}	,046	— ,498	,256	,521	,002	— ,362	— ,362	,063	— ,542	— ,512	— ,359	,170	— ,467	,177	— ,421	,810	1,000		
x_{18}	,413	,577	,023	,326	— ,189	,653	,653	,429	,600	,576	,488	,429	,420	,381	,473	— ,163	— ,175	1,000	
x_{19}	,245	,012	,136	,393	— ,102	,145	,145	,214	,169	,067	— ,034	,321	— ,012	,740	— ,014	,135	,098	,456	

Table 5. Correlation matrix of variables that explain natural pine stems.
Taulukko 5. Luonnonmäntyrunkoja kuvaavien muuttujien korrelaatiomatriisi.

	x_{1}	x_{2}	x_{3}	x_{4}	x_{5}	x_{6}	x_{7}	x_{8}	x_{9}	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	x_{17}	x_{18}	x_{19}
x_{1}	1,000																		
x_{2}	— ,111	1,000																	
x_{3}	,327	,115	1,000																
x_{4}	,012	,133	— ,214	1,000															
x_{5}	— ,091	— ,079	— ,117	— ,284	1,000														
x_{6}	,285	,336	,566	,013	— ,367	1,000													
x_{7}	,258	,425	,463	,390	— ,614	,624	1,000												
x_{8}	— ,046	,273	,156	,400	— ,292	,167	,576	1,000											
x_{9}	— ,079	,475	— ,013	— ,083	— ,080	,153	,194	,128	1,000										
x_{10}	— ,065	,320	,182	— ,089	— ,092	,316	,196	,091	,458	1,000									
x_{11}	,123	,212	,725	— ,012	— ,161	,699	,373	,100	,165	,545	1,000								
x_{12}	,284	— ,299	,257	,507	— ,047	,204	,262	,227	— ,236	— ,140	,159	1,000							
x_{13}	,117	,223	,573	— ,133	,186	,567	,125	— ,179	,366	,388	,800	,175	1,000						
x_{14}	,239	,021	,053	,172	— ,090	,042	,301	,347	— ,041	,007	— ,102	,421	— ,126	1,000					
x_{15}	,203	,109	,598	— ,292	,152	,601	,152	— ,133	,282	,282	,760	,176	,733	— ,019	1,000				
x_{16}	,137	— ,327	— ,101	,639	— ,020	— ,247	— ,004	,029	— ,327	— ,489	— ,251	,282	— ,374	,193	— ,353	1,000			
x_{17}	,066	— ,258	— ,135	,543	— ,009	— ,239	— ,044	,032	— ,268	— ,395	— ,215	,228	— ,239	,069	— ,296	,779	1,000		
x_{18}	,395	,320	,425	,338	— ,198	,490	,797	,380	,107	,107	,263	,310	,192	,327	— ,207	— ,077	— ,138	1,000	
x_{19}	,320	,103	,025	,469	— ,046	,005	,238	,276	— ,138	— ,116	— ,263	,446	— ,173	,749	— ,222	,347	,258	,297	

Table 6. Properties of butt logs and stems of differing branchines classes. Plantation-grown pine stands.
Taulukko 6. Oksaisuusluokaltaan erilaisten tyvitukkien ja runkojen ominaisuuksia. Viljelymänniköt.

Property	Branchiness class — *Oksaisuuslaatuluokka* 1			2			3			4	
Ominaisuus	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	n
x_6	222	40	56	197	30	185	177	27	173	198	4
x_7	259	60	56	216	37	188	224	34	173	300	4
x_2	69	15	56	54	11	188	48	9	173	47	4
x_5	1,1	0,3	56	1,3	0,5	188	1,2	0,4	173	1,0	4
x_8	47	14	56	39	10	188	44	11	172	65	4
x_{18}	22	5	55	18	3	187	19	3	169	25	4
x_{17}	1,3	0,7	56	2,2	0,5	188	3,2	0,4	173	4,0	4
x_{34}	48	7	55	49	7	187	47	8	168	49	4
x_4	12	—	4	20	4	149	30	7	112	56	4
x_9	24	19	47	6	5	188	4	3	173	1	4
x_{10}	35	25	45	11	19	188	5	5	173	1	4
x_{11}	140	32	56	113	29	185	98	27	170	116	4
x_{12}	32	13	50	27	6	140	33	7	112	..	4
x_{14}	34	9	50	33	6	140	38	8	112	44	4
x_{15}	148	37	50	124	31	140	104	29	112	98	4
x_{19}	273	61	50	281	60	140	292	53	112	380	4
x_{13}	110	43	50	89	28	140	67	29	112	50	4
x_{23}	419	36	18	433	40	63	420	54	70	..	..
x_{24}	418	39	18	436	49	64	428	60	70	..	..
x_{25}	2,1	0,4	18	2,6	0,6	64	3,4	1,0	70	..	..
x_{26}	1,9	0,4	18	2,2	0,7	64	2,5	1,0	70	..	..
x_{27}	29	5	18	26	5	64	25	5	70	..	..
x_{28}	36	5	18	33	6	64	30	6	70	..	..

Table 7. Properties of butt logs and stems of differing branchiness classes. Natural pine stands.
Taulukko 7. Oksaisuusluokaltaan erilaisten tyvitukkien ja runkojen ominaisuuksia. Luonnonmänniköt.

Property	Knottiness class — *Oksaisuuslaatuluokka* 1			2			3		
Ominaisuus	$\bar{x}$	s	n	$\bar{x}$	s	n	$\bar{x}$	s	n
x_6	195	32	132	184	23	173	179	21	119
x_7	235	54	460	220	41	629	240	44	215
x_2	76	17	120	68	19	150	60	10	130
x_5	1,3	0,5	457	1,3	0,5	603	1,2	0,5	189
x_8	46	13	460	44	13	628	47	17	215
x_{18}	20	4	427	19	3	579	20	4	201
x_{34}	49	8	427	49	6	588	49	6	207
x_{17}	1,3	0,6	460	2,2	0,5	629	3,1	0,3	215
x_4	11	4	460	18	6	628	25	6	215
x_9	14	14	453	9	5	269	7	4	214
x_{10}	44	37	418	19	12	629	11	8	214
x_{11}	113	34	182	99	27	219	97	20	130
x_{12}	26	7	182	26	7	219	34	7	130
x_{14}	35	7	182	34	8	219	41	10	130
x_{15}	130	27	182	113	26	219	102	19	130
x_{19}	251	55	182	259	47	219	319	51	130
x_{13}	999	276	182	839	225	219	706	252	130
x_{23}	447	33	45	449	48	68	447	35	21
x_{24}	478	53	45	467	48	68	464	47	21
x_{25}	1,6	0,6	45	1,7	0,7	68	2,4	0,6	21
x_{26}	1,7	0,5	45	1,8	0,7	68	1,8	0,6	21
x_{27}	33	5	45	33	5	68	27	5	21
x_{28}	33	5	45	34	7	68	33	5	21

Drying and healing over of the branches of the stem are closely related to the development of the height of the crown. Nilsson (1968) has said that the height of the crown is also a hereditary quality, but its effect is usually buried by the changes in stand density. The effect of stand density on the length of the dry branched part of the stem and the crown ratio has been the subject of several studies (Näslund 1944, Erteld 1967, Mathieu 1967, Persson 1977, Varmola 1980). Kellomäki and Tuimala (1981) stated that the number of living branch whorls decreased clearly, that is, the crown grew narrower as the density of the stand increased. Kellomäki (1980 and 1981) has studied the formation and growth of the branches, needles and the stem of young pine stands and the dependence of the division ratio on light conditions. According to his studies, the share of the growth of the pine stem is greatest, when the light fall on the crown is 60 to 70 per cent of the light of a corresponding open area.

32. The branchiness of the stems

The term "branchiness" in this context means the abundance, thickness, number and self-pruning stage of the branches outside the surface of the stem (c.f. Uusvaara 1974, page 10).

Branches are an essential part of the tree, because the thickness and volume of the branches and their share of the volume of the stem are dependent on the diameter of the stem. The thickness of the branch increases mostly in conjunction with the diameter growth of the stem and is not nearly as strongly dependent on the age of the tree.

Already in an earlier study (Uusvaara 1974) the breast height diameter proved to be the best independent variable of the thickness of the thickest dry and living branch of the stem. By using these variables 63 and 54 per cent of the fluctuation of the thickness of the largest branches of plantation-grown stems could be explained. The inexplicable fluctuation is dependent on the external growth conditions, such as the effect of neighbouring stems, light conditions and, on the other hand, on the genetic basic structure of the stand.

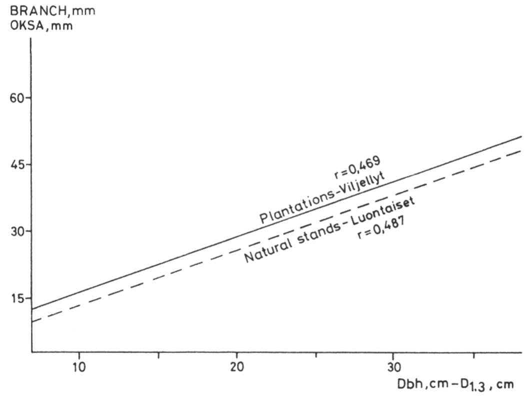


Fig. 2. Correlation between the diameter of the thickest dead branch of the stem and breast height diameter.
Kuva 2. Rungon paksuimman kuivan oksan paksuuden riippuvuus puun rinnankorkeusläpimitasta.

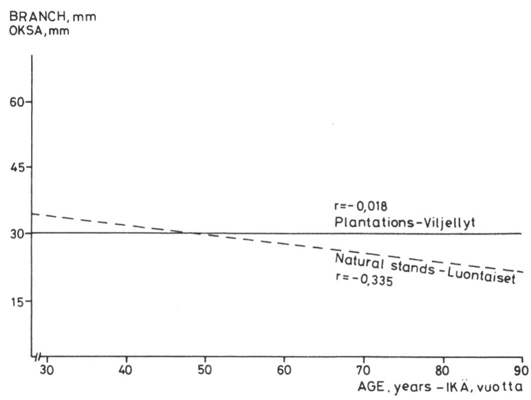


Fig. 3. Correlation between the diameter of the thickest dry branch of the stem and age.
Kuva 3. Rungon paksuimman kuivan oksan paksuuden riippuvuus iästä.

In this study as well there was a strong correlation between the breast height diameter and the largest branches of the stem in the material of both origins, whereas the thickness of the branches correlated even negatively with age (Figures 2 and 3). A development trend such as this is still clearer in naturally regenerated stands than in plantation-grown stands.

The correlation is described by the following equations:

Plantation-grown stands

Regression equation	$\bar{y}$	r
$y_1 = -0.1265\ x_1 + 31.808$	31	—0.018
$y_2 = 0.00505\ x_1 + 35.901$	36	—0.009
$y_1 = 1.2255\ x_2 + 4.2698$	31	0.469
$y_2 = 0.96424\ x_2 + 14.502$	36	0.448

Naturally regenerated stands

Regression equation	$\bar{y}$	r
$y_1 = -0.14244\ x_1 + 37.562$	27	—0.335
$y_2 = -0.02596\ x_1 + 37.529$	35	—0.055
$y_1 = 1.2967\ x_2 - 0.77168$	27	0.487
$y_2 = 1.6765\ x_2 - 0.88920$	35	0.567

In equations

y_1 = thickness of thickest dry branch of stem, mm
y_2 = thickness of longest living branch of stem, mm
x_1 = age of stem, years
x_2 = breast height diameter of stem, cm

The thickness of the branch is dependent on the height and diameter of the stem, but it is especially dependent on the diameter growth rate of the tree. The increase in the diameter growth rate of the tree promotes the diameter growth of the branches proportionately. It has already been stated that the growth rate of the stem is an important factor when explaining the fluctuations of the thickness and length of the largest branches of the stem (Uusvaara 1974). A young tree may thus have thicker branches than considerably older stems, and on an average, the branches are even thinner the older the stem of a certain diameter is.

As the tree gets older the branches that are thickest get higher and higher on the stem and, at a certain age, the thickness of the branches culminates and starts, conversely, to decrease in conjunction with the self-pruning of the stem. The turning point seems to be at around the age of 60, after which the diameter growth of the branch stops. At the beginning of the rotation of the stand, the diameter growth of the branches is quickest, so that at this stage the most important silvicultural measures are those that retard the growth of the branches located at the butt of the stem also.

The thickness of the branches in the stem, from the first complete branch whorl upwards is presented in Figure 4. The branches of the naturally regenerated pines are thinner than those of the plantation-grown pines, especially in the lower part of the stem, but

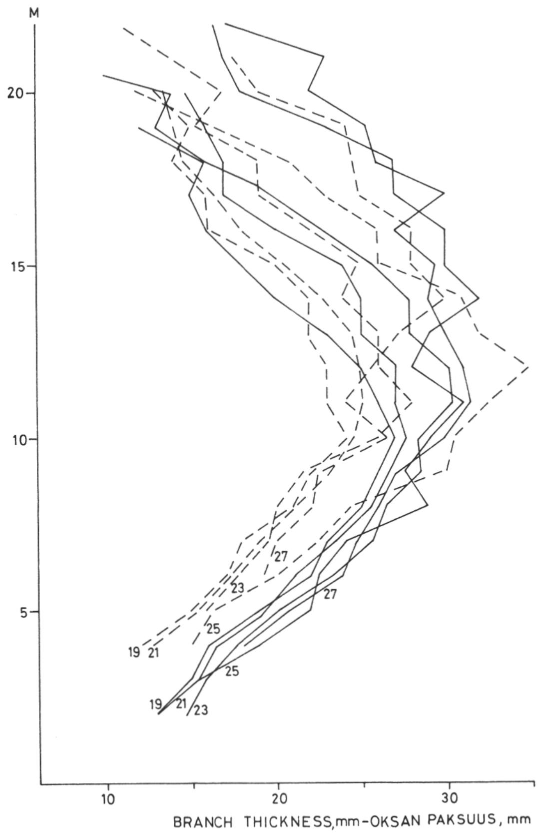


Fig. 4. Thickness of the branches of pine stems at different heights by diameter class starting from the first branch whorl. Broken line = natural pine stands.

Kuva 4. Mäntyrunkojen oksien paksuus eri korkeuksilla ensimmäisestä oksakiehkurasta lähtien läpimittaluokittain. Katkoviiva = luonnonmänniköt.

in the upper part the differences in the thickness of the branches vanish gradually. The thickest branches of the stem are located in stems of small diameters in the middle of the stem or a little below that, but their location rises as the diameter of the stem increases. In Figure 4 it can also be seen that the trees with the largest diameters are not necessarily the ones that have the thickest branches when all of the branches in the stem are examined. At the butt, up to approximately the middle of the stem, the differences are, however, clear in that the stems in the largest diameter classes also have the thickest branches. The thickest branches in naturally regenerated stems are situated somewhat higher than in plantation-grown stems, which is obviously a result of the quicker self-pruning of the branches in the lower part of the natural stems. Also the shape of the crown may have an effect on the location of the thickest branches, that is, the thickest branches of broad-crowned trees are located lower than those of narrow-crowned trees.

The self-pruning of the stem and the thickness of the branches are also dependent on the growth rate of the tree. The older the stem of a certain thickness is, however, the better the quality usually is up to a certain age limit. As the growth speed slows down, even the thinnest branches cannot heal over any longer and self-pruning also weakens (Heiskanen 1965, Uusvaara 1974, Kellomäki and Tuimala 1981).

This matter is described by the following tabulation, which shows that the thickness of the thickest dry branch of the stem will decrease as the breast height diameter of plantation-grown stems of a certain age decreases:

Age, a	Breast height diameter, cm						
	29	27	25	23	21	19	17
	Thickness of branch, mm						
≦ 45	37	42	36	33	31	31	23
46—65	36	32	36	29	29	25	25
≧ 66	49	29	33	27	23	..	..

In natural stands the development of the thickness of the thickest dry branch of the stem was as follows:

Age, a	Breast height diameter, cm						
	29	27	25	23	21	19	17
	Thickness of branch, mm						
≦ 45	35	35	33	31	30	..	..
46—65	34	32	31	34	25	26	..
≧ 66	31	28	27	27	22	21	..

From the viewpoint of the quality of the stem, however, the thickness of the branches in the butt log area has the greatest importance, for the quality of the log is mainly determined on the basis of the branches. On the other hand, the thickness of the branches under discussion also describes, although somewhat poorly, the branchiness and quality of the other logs of the stem. If the branches are thick, they do not fall off as easily as they grow old, and the sawn goods that will later be produced from the stem will have dry or even decayed branches in them.

To describe the thickest branches in the butt area of the stem the thickest still visible branch in standing trees was measured within the butt log area as was the thickest dry branch of prepared logs, in addition to the mean thickness of the branches that had not yet healed over. The branches observed in the butt log area were all dead. In the butt logs prepared from pines of plantation origin, however, 10 per cent were totally branchless, the corresponding figure for natural stands was 21 per cent.

Table 8 presents the number and mean thickness of the branches of the butt log as well as the thickness of the largest branch in accordance with the real quality class. A general trend of development is that the thickness of the branch increases as the quality of the log decreases, and the differences in the diameter of the thickest branches between various classes increase as we move towards the weaker qualities. In logs from plantation-grown stands, the branches are thicker than in corresponding quality classes of natural pine logs. The mean diameter of the branches fluctuates between logs of different qualities less than the thickness of the thickest branches does. Also the number of the branches increases as the quality of the log decreases, which is because logs of poorer quality come from stands younger than average. The thickness of the branch both on the stem and on the butt log is greatly dependent on the thickness growth rate of the stem (Figures 7 and 8, page 27).

The following tabulation shows the mean diameter of the thickest branches of standing trees measured within the butt log area, when the log has been classified solely on the grounds of its branchiness as well as in accordance with the real quality class, including defects on the stem (c.f. Table 8).

	Branchiness class								Real quality class							
	1		2		3		Cull		1		2		3		Cull	
	Thickest dry branch, mm															
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Plantation-grown stands	12	3	20	4	30	6	56	9	12	3	20	4	29	6	31	11
Natural stands	11	3	18	6	25	5	34	6	10	3	17	6	24	7	25	9

The results show in this context also that the differences between the diameters of the branches of good and poor logs increase as the quality of the logs decrease. In plantation-grown stands as well as in forests that have regenerated naturally, the differences be-

Table 8. The thickest knot, the mean knot diameter and number of butt logs of the quality classes.
Taulukko 8. Laatuluokaltaan erilaisten tyvitukkien paksuin oksa, oksien keskiläpimitta ja lukumäärä.

Quality class *Laatuluokka*	Thickest branch, mm *Paksuin oksa, mm*		Average diameter, mm *Keskiläpimitta, mm*		Number of branches *Oksia, kpl*	
	Plantations — *Viljelymänniköt*					
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
1	17	4	11	2	9	8
2	19	4	16	9	21	16
3	30	5	17	6	36	16
Cull *Hylky*	33	15	—	—	36	10
	Natural stands — *Luonnonmänniköt*					
1	7	2	7	2	1	4
2	16	5	11	4	21	14
3	29	4	14	2	28	11
Cull *Hylky*	44	20	—	—	44	4

tween the diameters of branches of logs are greatest in the poorest quality classes.

The branchiness and the importance of branches on the quality can also be described by means of the branch angle, the number and length of branches as well as by the percentage of the cross cut surface area of the branch stubs expressed in terms of the total stem area. The branch angle also describes the thickness of the branch, which usually increases as the branch angle decreases. The size of the branch angle is also different in the butt and crown parts of the stem, that is, the angle widens as the tree grows older (Mayer 1961). It is generally considered that the branch angle is a strongly hereditary characteristic (Schöpf 1954). Together with the natural self-pruning of the stems and the aspect of age, the importance of the branch angle as a quality character, however, lessens.

It has also been established that the number of branches in a branch whorl is strongly regulated by hereditary factors (Eklundh Ehrenberg 1963, Rautiainen 1971). The number of the branches is, however, also strongly dependent on stand density, i.e. on light conditions (Flower-Ellis et al. 1976, Kellomäki 1980). The number of branches in a whorl usually varies minimally (Varmola 1980), for which reason the importance of the trait as a quality factor is not very great.

Kellomäki and Tuimala (1981) have studied the correlation between the diameter of the branch and the density of young stands and have found out that as the stand density in young pine stands exceeds the limit of 2 000 to 3 000 stems, branch thickness do not any longer clearly decrease. Thickness decreased and self-pruning was improved as stand density increased. It looked, however, as though self-pruning was conversely weakened in especially dense stands. Persson (1977) has also observed that there is a similar correlation between the density of a stand and the branch diameter. He discovered that the width of the annual ring increases and the distance to the lowest dry branches decreases as the planting density decreases.

The growth rate during the early years of a stand can be seen when examining the thickness of the branches, often still in saw timber stands. According to Heiskanen (1965), the largest branch on a pine butt log distinctly thickened as the annual ring widened around the pith. When the width of the annual ring on a *Myrtillus* site type was 3 mm, the thickness of a branch was, on an average, about 20 mm when measured from pine butt logs. Nylinder (1958) measured a thickness of 22 mm for a pine branch at the height of 3 m, when the width of the annual ring was 4 mm. Heiskanen (1954b) discovered a correlation between the width of the annual ring and the largest branch in sawn goods. An annual ring of 1.4 mm corresponded, on an average, to a branch thickness of 25 mm in sawn timber pieces.

33. The quality of the butt log

Figure 5 presents the distribution in quality classes of the butt logs of classified standing trees. This distribution is based solely on the branchiness of the butt log part of the stem on the one hand, and on all defects on the other. When the butt log was classified solely on grounds of the branchiness classes, and only branches and branch knots were considered, the butt log fell into the third quality class almost as often as into the second quality class, but it was, however, rarely rejected. The most typical features in the quality distribution of butt logs from plantation-grown stands were the scarcity of first quality class logs (13 per cent) and the prevalence of third quality class logs (42 per cent). In natural stands, the share of the first quality class was considerable (35 per cent), but the second quality class was the commonest. The first and second classes together accounted for almost 85 per cent of all natural butt logs. The examination of the share of the first and second quality classes is significant, because the best quality classes of logs produce, to a considerable degree, the best u/s qualities of sawn goods, albeit mostly thirds and fourths (Siimes 1962, Orvér 1970b).

Although branchiness is a determining factor when estimating the quality of the log, visually observable stem defects and internal defects of the timber are also of considerable importance. Some of the defects are caused by genetic characteristics and others are caused by various environmental factors and external causes of damage. These include snow, which causes the crowns of the trees to break, especially in young, fast growing seedling stands (c.f. Uusvaara 1974, page 51). In plantation-grown stands, unsuccessful planting often leads to the sweep of the butts or even the higher section of the stem. This is called, in conjunction with plantation inventories, the tilting phenomenon (Huuri 1976). Huuri (1979a, 1979b) ascertains that the tilting phenomenon even in its slightest form is so common in plantation-grown stands that this type of pine stand can easily be distinguished from sown or naturally regenerated thinned stands by the abundancy

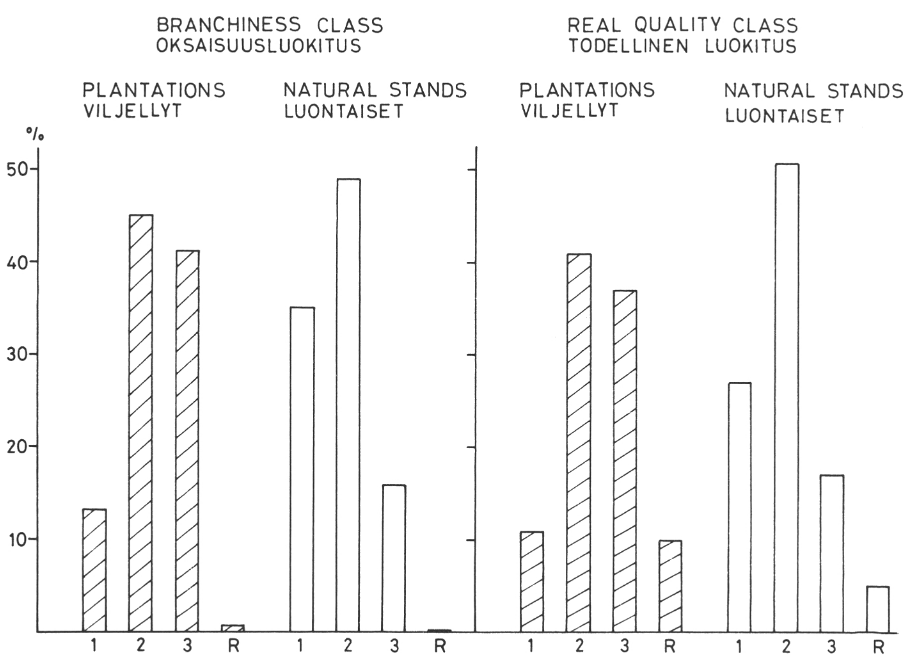


Fig. 5. Distribution of standing tree butt logs into quality classes on the basis of branchiness and real grading class. R = cull.
Kuva 5. Pystypuiden tyvitukkiosan jakautuminen laatuluokkiin oksaisuuden ja todellisen luokituksen perusteella. R = hylky.

of bent stems (c.f. Uusvaara 1981b).

In this study, however, only a fraction of the material came from plantation-grown stands, so that the crooks at the butt of the log or the sweeps of the stem must have some other major cause. One explanation for the occurrence of sweeps may be that the seeding tufts are thinned too late. Sweeps occur more often in plantation-grown stands than in natural stands, but the difference in the occurrance rate of this defect is not as great as when making comparisons between the prevalence of crooks (Table 9). The average sweep of plantation-grown logs which had been prepared for sawing was 18 mm for the length of the log and the greatest sweep measured 90 mm. The corresponding figures for natural pine logs were 14 and 50 mm. The original number of stems in the stand is a factor of considerable effect on the number of defects, for in the management of the stand an attempt is always made in the first place to remove defective stems. Because the starting density of natural stands is great, a sufficient number of defect-free stems can usually be left during the thinning process. This being the case, the larger percentage of defects in plantation-grown stands need not only be related to the susceptibility of the stems to various defects.

In plantation-grown stands, sweeps occur almost solely on the stems, whereas crooks are somewhat more common in the butt area than in the upper sections of the stem. A similar result can be seen also in Table 10, which gives only the observations made in the butt log area. The table would seem to indicate that in the context of test sawings more logs with sweeps but less logs with crooks have been produced from both

Table 9. Frequency of stem defects in standing trees.
Taulukko 9. Pystypuista havaittujen runkovikojen yleisyys.

Origin *Alkuperä*	Defect-free stems *Virheettömät rungot*	Defect in butt *Vika tyvessä*	Defect in stem *Vika rungossa*
	Crook, % — *Mutka, %*		
Plantations — *Viljelymänniköt*	50	27	23
Natural stands — *Luonnonmänniköt*	63	21	16
	Vertical branch, % — *Pystyoksa, %*		
Plantations — *Viljelymänniköt*	88	4	9
Natural stands — *Luonnonmänniköt*	97	—	3
	Sweep, % — *Lenkous, %*		
Plantations — *Viljelymänniköt*	44	1	55
Natural stands — *Luonnonmänniköt*	52	1	47

Table 10. Frequency of defects in butt logs.
Taulukko 10. Tyvitukeista havaittujen vikojen yleisyys.

Origin *Alkuperä*	Defect-free stems *Virheettömät rungot*	Defect in butt *Vika tyvessä*	Defect in top end *Vika latvassa*
	Crook, % — *Mutka, %*		
Plantations — *Viljelymänniköt*	61	28	11
Natural stands — *Luonnonmänniköt*	77	16	7
	Vertical branch, % — *Pystyoksa, %*		
Plantations — *Viljelymänniköt*	90	7	3
Natural stands — *Luonnonmänniköt*	95	—	5
	Sweep, % — *Lenkous, %*		
Plantations — *Viljelymänniköt*	33	7	60
Natural stands — *Luonnonmänniköt*	44	2	54

Table 11. Frequency of defects in logs of the quality classes.
Taulukko 11. Vikojen yleisyys eri laatuluokan tukeissa.

Quality class *Laatuluokka*	Plantations — *Viljelymänniköt* Defect-free stems *Virheettömät rungot*	Defect in butt *Vika tyvessä*	Defect in stem *Vika rungossa*	Natural stands — *Luonnonmänniköt* Defect-free stems *Virheettömät rungot*	Defect in butt *Vika tyvessä*	Defect in stem *Vika rungossa*
			Crook, % — *Mutka, %*			
1	66	11	23	72	14	13
2	45	33	22	61	23	17
3	47	21	32	69	12	20
			Sweep, % — *Lenkous, %*			
1	60	—	39	57	—	42
2	46	2	53	49	1	50
3	39	1	60	57	5	38
			Vertical branch, % — *Pystyoksa, %*			
1	98	2	—	97	—	2
2	93	3	4	96	—	3
3	82	2	17	92	2	6

plantation-grown and natural stands than is the average number in the study material. On the other hand, this can be explained partly by the fact that the sweeps in the stems are, however, often situated above the butt log area.

When using the real quality classification, in which defects in the stem are also taken into account, there is a major shift in plantation-grown stands from the third into the reject class, but in natural stands again from the first into the second class and respectively from the second into the third class. In plantation-grown the defects seem to concentrate in stems with lots of branches, which means that a log with a maximum number of branches often falls into the reject class (Table 11). The share of the first class remains, on the other hand, almost unchanged. In natural stands again the differences between the numbers of defects in good and poor butt logs seem not to be as great. Both in plantation-grown and natural stands, stem defects decrease the share of the best, first and second quality classes by an average of about 10 per cent.

Figure 6 presents the real quality classes for butt logs of sample trees in plantation-grown and natural stands. The comparison between Figures 5 and 6 shows that although the saw logs of plantation origin included to a certain extent more third class logs on an average than the stands in the sample plots, the quality classes of the sample logs agreed, on an average, fairly well with the quality distribution of the butt logs of standing trees.

In examination of the log masses to be sawn, it is usually noticeable that the quality

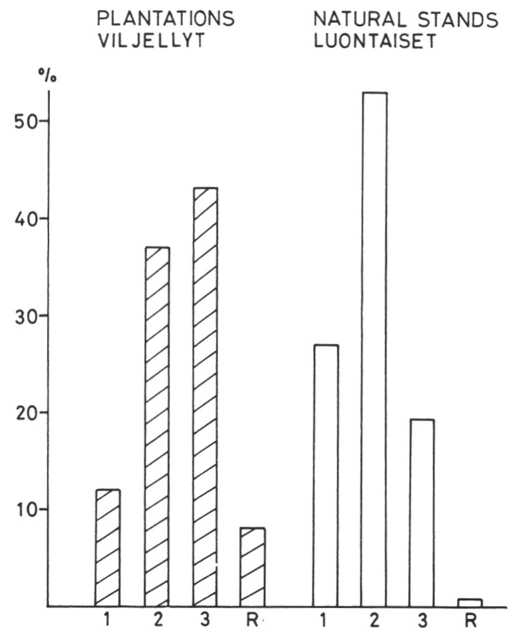


Fig. 6. Distribution of butt logs into quality classes according to real grading class. R = cull.
Kuva 6. Tyvitukkien jakautuminen laatuluokkiin todellisen luokituksen mukaan. R = hylky.

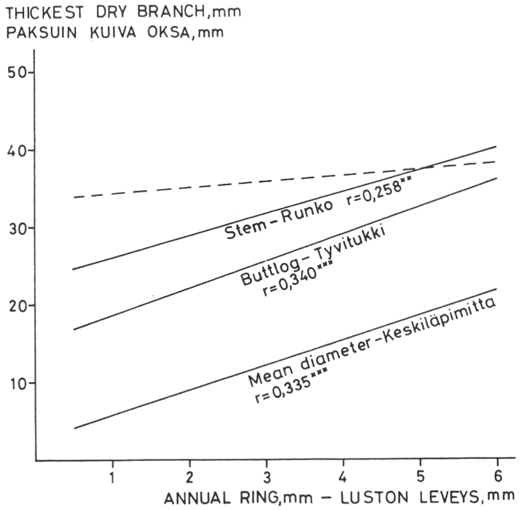


Fig. 7. Correlation between the diameter of the thickest stem branches and butt log knots and annual ring width near the pith. Plantation-grown pine stands. Broken line = the thickest dry branch of a stem in planted pine stands.

Kuva 7. Rungon ja tyvitukin paksuimpien oksien läpimitan riippuvuus luston leveydestä ytimen ympäristössä. Viljelymänniköt. Katkoviiva = rungon paksuin kuiva oksa istutusmänniköissä.

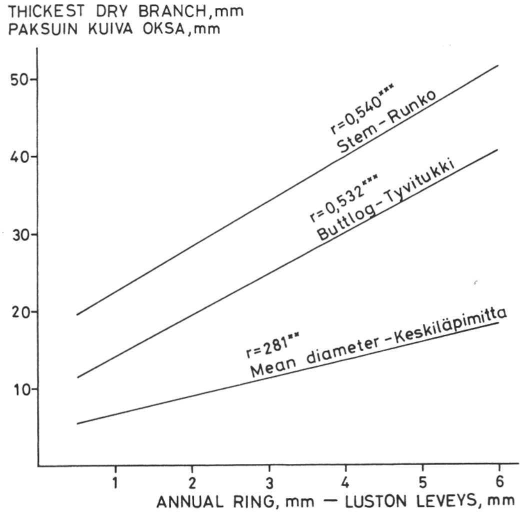


Fig. 8. Correlation between the diameter of the thickest stem branches and butt log knots and annual ring width near the pith. Natural pine stands.

Kuva 8. Rungon ja tyvitukin paksuimpien oksien läpimitan riippuvuus luston leveydestä ytimen ympäristössä. Luonnonmänniköt.

of the log increases i.e., the share of the first and second quality classes rises as the top diameter of the log grows up to a certain point, after which the quality decreases (Heiskanen and Asikainen 1969). The increase in quality is a natural result of the increasing size of the stems which is accompanied by the healing over of the branch-stumps (c.f. Kärkkäinen 1980a). Poor-quality, large-sized logs come from two sources: firstly from relatively young, fast-grown, poorly self-pruned young stems, and secondly from over-aged stems. In terms of the quality of plantation pines, the best logs are obtained from stems that are older and larger than the average. These stems often come from the second or third crown classes and are slower growing and have better self-pruning qualities (Table 6). In any case, the effect of a retarded growth rate on the decreasing of the quality can clearly be seen, especially by examining the thickest branches of the log stem and the butt log and the widths of the annual rings, especially in the vicinity of the pith (Figures 7 and 8, Table 6).

In natural stands the trend is similar, but the differences in the age and size of stems producing good and poor quality logs were smaller. Therefore, in natural stands also younger and smaller-sized stems can be of good quality (Table 7).

On the basis of the information given in the tables an observation can be made that the quality of the log decreases also as the annual rings widen in the area around the pith. There is no such clear dependence between the width of the annual ring close to the sapwood and the quality, especially in natural stands. As far as the other descriptive quality traits of the timber are concerned a rise in the basic density will somewhat improve the quality of the log, but not as clearly as the late wood percentage.

The increase in the width of the annual ring, or the thickness growth rate, has an effect on the decrease in the quality of the timber. This can clearly be seen in Figures 9 and 10, where the correlation between the average quality index of a log and the width of the annual ring at the butt of the log is presented. The quality of the log decreases, or the quality index rises significantly as the width of the annual ring grows in the area around the pith, whereas the correlation between the annual rings of the sapwood area

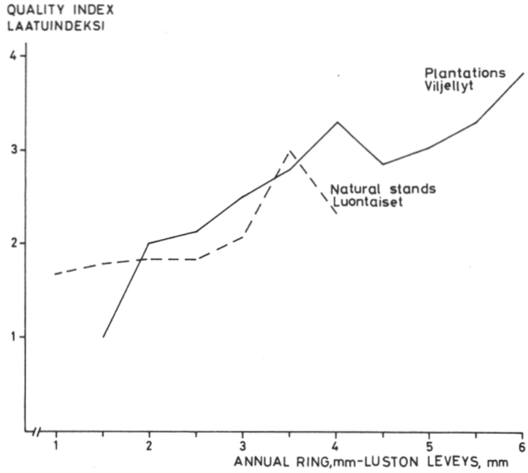


Fig. 9. Correlation between the quality index of the butt log and annual ring width near the pith.
Kuva 9. Tyvitukin laatuindeksin riippuvuus luston leveydestä ytimen ympäristössä.

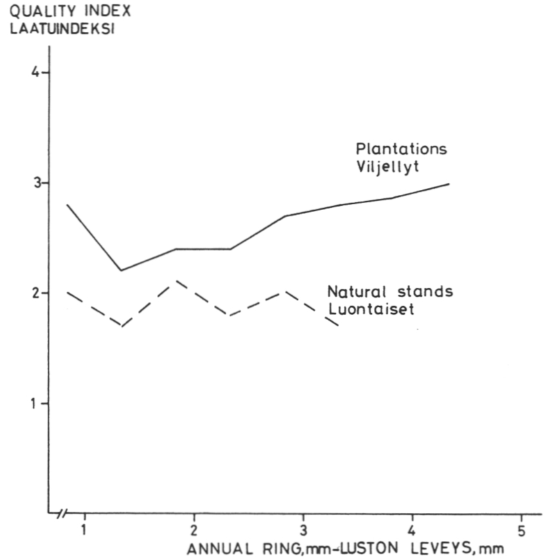


Fig. 10. Correlation between the quality index of the butt log and annual ring width in the outer parts of the log.
Kuva 10. Tyvitukin laatuindeksin riippuvuus luston leveydestä puun pintaosissa.

of the tree and the quality of the log is clearly weaker. In natural stands the changes in the widths of the annual rings in the sapwood area do not, on the other hand, any longer affect the quality of the log. This is mainly because the width of the annual ring does not change to any great extent when going from the vicinity of the pith towards the sapwood area of the tree (Table 7). The results of Heiskanen (1965) concerning the width of the annual ring and the quality of the log are very much similar. He states, however, that the narrowing of thick annual rings has a stronger effect on quality than any changes in narrow annual rings have. Partly because of this, the most noticeable changes in the quality of the timber take place between the thickness of three and two millimetres of the annual ring (Heiskanen 1962). From the viewpoint of the quality of pine log, Siimes (1962) found a factor more important than general branchiness: the largest branch, which grows in almost a straight line as the width of the annual ring grows (c.f. Figures 7 and 8).

The decrease in log quality as it is related to the increasing rate of growth is, in plantation-grown stems, partially attributable to the forest site type. If the age factor is eliminated, the log quality is lowest in the stands growing on the best, and conversely on the poorest sites.

4. THE RESULTS OF THE TEST SAWINGS

41. The quality of the sawn goods

411. Classification in accordance with exportable sawn goods

The share of the u/s quality increases and the share of the weaker qualities decreases as the diameter of the log grows (Heiskanen and Asikainen 1969). In natural stands the improvement of the quality is obviously quicker than in plantation-grown stands. The outcome is a natural result of the healing over of the branches and the decrease and disappearance of the defects of the log caused by the increase in age and the larger size of the tree. Obviously, however, too large a size would again cause a decrease in the quality after a certain diameter class, for very large-sized logs often come from stems that have grown quicker than the average and thus are of poorer quality. This is also suggested by the results Kärkkäinen (1980b) obtained from test sawings of pine logs of a certain area. Some of the large-sized stems may, however, come from over-aged stems, which naturally have more defects than usual; in these stems the various structural defects and damages heal over very slowly.

The foregoing conclusion may, however, be more likely, for already on the grounds of the earlier results in this study and on the basis of the results by Heiskanen (1965) and Uusvaara (1974), medium-sized stems are usually the best in the stand in terms of quality. In plantation-grown stands truly oversized trees are generally very rare for because of the quick growth applicable rotations can be thought to be shorter than usual.

The ratio between the large size of the log and the quality of the sawn goods is also different for logs of various quality classes. Although the rather limited material did not provide good possibilities to examine the matter, it did seem that the improvement of the quality together with the large size was quicker, the better the quality class of the log. In schaalboards especially the thickness and the quality of branches play an important role. The matter can be made clear by the following tabulation based on material from plantations. The tabulation presents the correlation between the classification of sawn goods and the top diameter of the butt log in the second and third quality classes.

Top diameter, cm	Quality class of log: 2				3			
	u/s	V	VI	Cull	u/s	V	VI	Cull
	Centre goods, per cent							
14	32	38	26	5	4	51	38	4
18	39	35	26	..	10	46	42	2
22	40	40	17	5	6	68	26	..
26	44	45	6	..	..	..	..	..
	Boards, per cent							
14	3	17	75	4	..	..	..	..
18	7	24	66	3	..	12	88	..
22	5	28	67	..	10	10	84	7
26	..	..	..	..	..	..	..	..

The matter can also be studied by examining what kinds of sawn goods are obtained from logs of various qualities that have been visually classified on the basis of external characteristics. Test sawings have shown that, on the basis of these traits, it is possible to predict with some accuracy the quality distribution of sawing results (Siimes 1962). Generally speaking, logs that have high grade marks mostly yield high-quality sawn goods.

A log that looks good may, however, also give poor-quality sawn goods, but correspondingly bad logs hardly ever give good quality sawn goods. If the quality of a log is judged only on the strength of external factors, it is possible to get very different quality distributions from logs of a certain quality class, when they are test sawn.

According to Figure 11 a plantation-grown pine log of a certain grade class yielded less u/s quality sawn goods, but more lower-quality sawn goods than did a

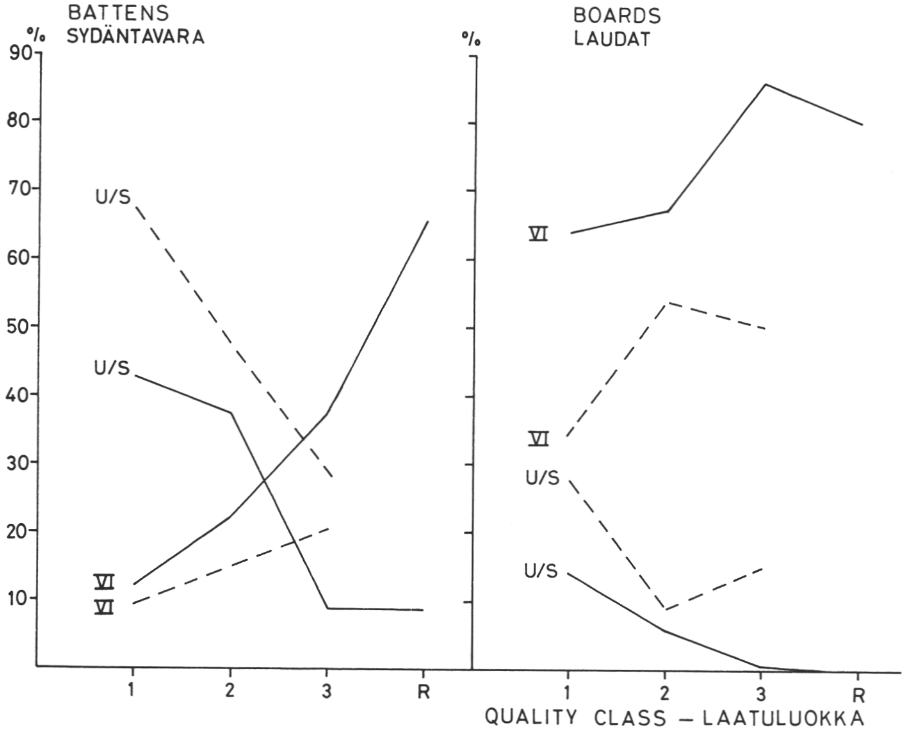


Fig. 11. Correlation between the u/s and sixth grade percentages of sawn goods and the log quality class. Broken line — natural pine stands. R = cull.
Kuva 11. Sahatavaran u/s- ja sekstaprosentin riippuvuus tukin laatuluokasta. Katkoviiva = luonnonmänniköt. R = hylky.

log of natural origin of the same grade. The shares of quality classes have been calculated from the volume of the sawn goods. The better the quality of the logs, the greater the differences are. The differences in the volume of the u/s quality within battens were greater than the corresponding quality differences obtained for boards. The proportional shares of fifths in various quality classes remain, on the other hand, rather small. Stems from plantation-grown stands thus seem to form an exceptional saw log group. The saw timber quality of this group is, according to quality class regulations, inconsistent with the quality of the processed product. The log grading of plantations becomes more biased the higher the age of a stand is, and on the other hand, the faster the growth rate and the lower the quality have been in its early years. The butt logs certainly have a special position in this respect, if compared with other logs from the stem. The internal quality of butt logs is much more easily observable on the basis of external distinguishing traits.

The internal distribution of the u/s quality class has not, however, been taken into account in the calculations that have so far been made. The internal distribution of the u/s quality class is in some cases an important factor in the sawn goods trade, although the subgroups of the class have usually been similarly priced. In natural pines, the best quality class logs produce mostly thirds and the second quality class logs produce mostly fourths (Heiskanen and Siimes 1959). Thus the u/s distributions obtained are not fully comparable with each other. One can presume that the u/s quality obtained from plantation-grown logs contains mostly weaker thirds and fourths, and this is thus correlative to the sawn goods from, primarily, the second quality saw logs of natural stand origin.

The quality of the sawn goods is mainly determined on the basis of branchiness, which is the most important of the structural defects in sawn goods. Heiskanen (1954a) has shown in his study that of the factors that determine the quality of the log, the share of branchiness is 81 per cent, with the remaining share made up of defects such as sweeps and crooks. In the study by Heiskanen and Siimes (1959) it was established that in all diameter and branchiness classes of the logs it was chiefly branchiness that dropped some of the sawn goods into sixths. The above-mentioned studies refer, however, only to natural stands. New studies seem to indicate that the significance of stem deformation as a factor affecting the quality of pine will increase in the future (Uusvaara 1981a, 1981b, Varmola 1980).

Branchiness can be expressed in terms of branch quality, branch size and number and their location in sawn goods. Quality differences between sawn goods from plantation-grown and natural stands can thus be examined solely on the basis of branchiness, in which case production faults, the next noteworthy quality factor, are not taken into account.

The most significant difference when comparing sawn goods originating from plantation-grown and natural stands is the small number of u/s-quality in sawn goods processed from butt logs from plantation-grown stands, whereas it is the main quality in sawn goods from natural stands (Figure 12). Centre goods of the best quality class are obtained from plantation-grown material almost 30 per cent less than from natural stands, when calculated from the volume of the sawn goods, but in boards the difference is still greater. The result reflects not only the smaller size of the branches in natural stands, but also their better ability to heal over. On the other hand, the share of the fifths and especially of the sixths within centre goods is greater in sawn goods from plantation-grown stems than in sawn goods from natural stands. The differences between the materials from both origins decreased when examining the boards.

When the quality of sawn goods is examined in accordance with the real quality classification, which takes other structural defects of the timber and the defects caused by the sawing technique into consideration, the quality distribution was the same as above. Specifically the share of the best quality in sawn goods of plantation origin is

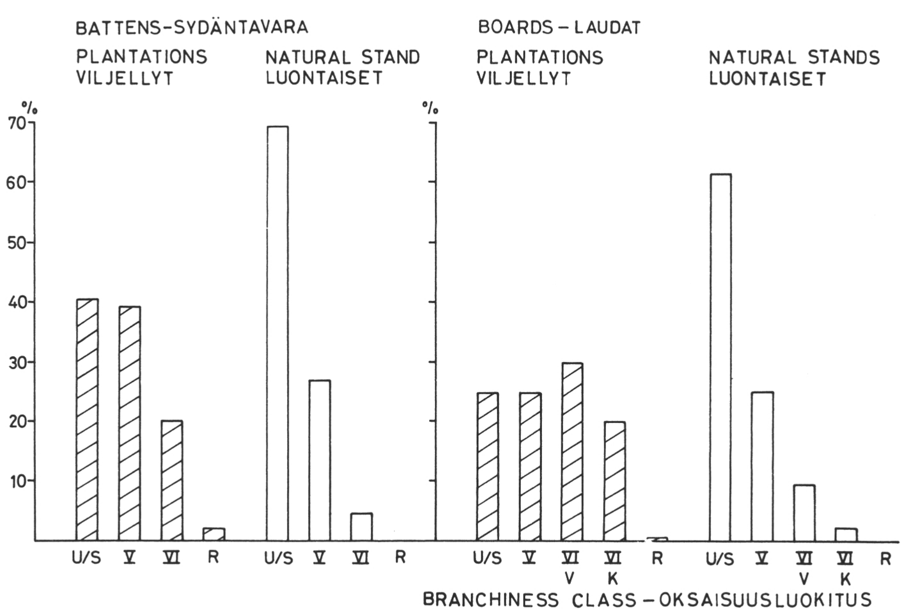


Fig. 12. Distribution of sawn goods into quality classes according to knottiness. Unshaded columns = natural pine stands. R = cull, V = export quality, K = domestic quality.
Kuva 12. Sahatavaran jakautuminen laatuluokkiin oksaisuuden mukaan. Yhtenäiset pylväät = luonnonmänniköt. R = hylky, V = vientilaatu, K = kotimaan laatu.

smaller, and on the other hand, the sixths and, in battens, also the fifths have a larger share than sawn goods processed from natural logs (Figure 13). The share of lower qualities in sawn boards and especially quality schaalboards processed from natural pine, increases rapidly as the share of the u/s board decreases. The greatest differences between the sawn goods of two different groups of study material could thus be found between the u/s qualities and the poorer-quality schaalboards (Figure 13).

When using portable circular saw, Granvik (1967) got the following quality distribution for centre goods: u/s 32.8 per cent, fifths 12.1 per cent, sixths 24.7 per cent and culls 2.3 per cent, when the yield was 72.3 per cent. The distribution corresponds well to the sawn goods classification reached in this study for natural stems.

Except for the fact that the internal distribution within the u/s quality has not been taken into account, differences in the size distribution make it somewhat more difficult to make comparisons between the two study materials. Because the material from the plantation-grown stands included somewhat more small-sized and more large-sized logs than the material from natural stands (Figure 26), the sawn goods prepared from plantation-grown logs were possibly somewhat more waney edged. The difference cannot, however, be very great.

Naturally the wane was overwhelmingly the most common reason for the decrease in the quality of the sawn pieces. The following tabulation shows that of the quality defects proper, branchiness was in one way or the other the main cause for the lower quality in sawn goods from plantation-grown pines. The group "wane and others" stands for a combination of defects, in which branchiness, in addition to the wane, was most often the main cause for lower quality.

Reason for lowered quality	Plantation-grown stands		Natural stands	
	Battens	Boards	Battens	Boards
	Per cent			
Wane	25.4	44.0	38.5	70.1
Wane and others	15.2	23.6	11.9	12.1
Decayed branch	3.0	0.5	1.5	0.3
Encased knot	1.5	0.8	0.0	0.0
Dry branch	0.0	0.5	0.0	0.6
Size of branch	3.0	3.3	1.5	0.9
Edge knot	17.8	6.3	19.3	5.6
General branchiness	33.3	20.1	20.7	8.9
Other	0.9	1.0	6.7	1.7

The development of the annual ring at the butt end of the butt log earlier had some importance as a quality classification criterion in practical measurements of timber. The location of the point of observation was chosen because of the convenience with which it was possible to determine the width of the annual ring, without cutting the tree. By using this method, it was also possible to determine the growth rate and vigour right from the beginning of growth. Although the thick branches of the stem would have had time to heal over into the tree out of sight, the thickness of the annual rings around the pith, when cut at the butt level, hint at the tree's growth rate during early years.

It was established above that even if plantation logs and natural logs received the same grading, plantation logs produced lower quality sawn goods than natural logs. Undoubtedly, this is in most cases attributable to the slower initial growth in natural seedling stands and a result of slow growth especially in the butt section of the stem. The difference is not fully explained by this, however, because even if the growth rate was the same, or the width of the annual ring around the pith was the same, a better quality distribution was obtained for natural stems (Figures 14 and 15). This is obviously partly because the distance 75 mm, used in counting the annual ring width, is too long (Laadukkaan mäntysahapuun . . . 1984). Differences were obviously caused also by hereditary factors in addition to various environmental factors.

The effect of the thickness of the annual ring on the quality distribution of battens and planks is the same in stands of both origins. The u/s percentage of centre goods is highest in sawn goods of plantation-grown stand origin at a growth ring width of about two millimetres and in sawn goods from natural stands at that of about one millimetre, after which the quality decreases rapidly. When the width of the annual rings around the pith rises to 3.5 mm, there are hardly any u/s sawn goods to be obtained. Also with exceptionally low widths of the annual ring (0.5 to 1.5 mm), the share of the u/s quality decreases. The growth rate around the pith of plantation-grown stems also seems to have a similar effect on the development of the quality of the boards, whereas in natural stands the quality of schaalboards rises when the thickness development is fast in

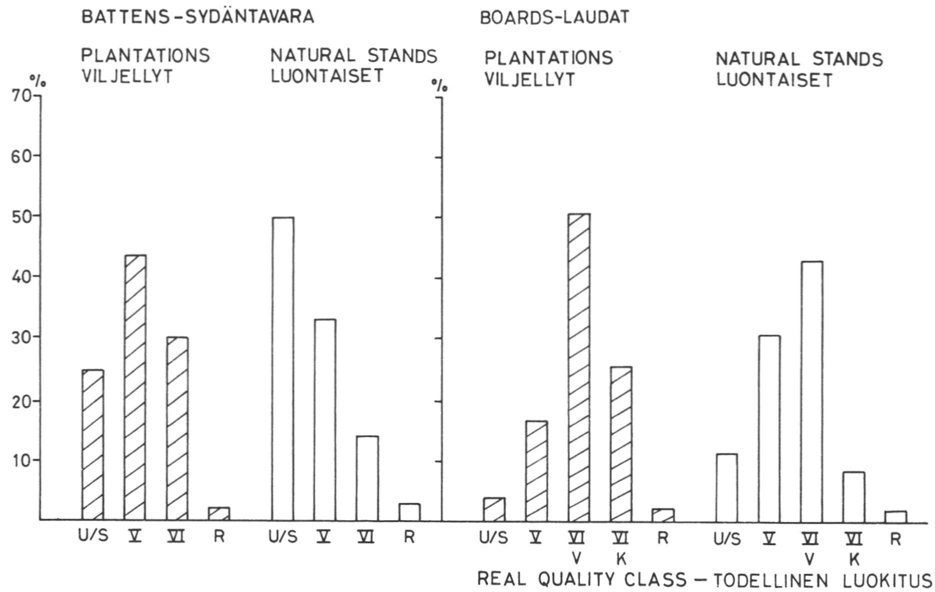


Fig. 13. Distribution of sawn goods into quality classes according to real quality grading. Unshaded columns = natural pine stands. R = cull, V = export quality, K = domestic quality.

Kuva 13. Sahatavaran jakautuminen laatuluokkiin todellisen luokituksen mukaan. Yhtenäiset pylväät = luonnonmänniköt. R = hylky, V = vientilaatu, K = kotimaan laatu.

the early years of the tree's growth.

A similar connection is also to be seen in natural stands between the width of the annual rings of the sapwood of the log and the quality of the boards. The effect of thickness of the annual ring on the quality of sawn goods has been similar in buttlogs taken by sampling on some sawmills in Southern Finland (Laadukkaan mäntysahapuun . . . 1984). The quality distribution of the boards is at its best when the width of the annual ring in the sapwood is about 3 mm. The reason for this is that in the sapwood the widening of the annual ring and the increase in the growth rate imply better healing over of the branch-stumps and an increase in the quality. Generally there is no longer any noticeable strong correlation between the width of the annual ring in the sapwood of the stems and the quality of sawn goods (Figures 16 and 17). Also when examining the annual rings in the sapwood the same phenomenon as above will be observed; when the width of the annual ring is the same, natural pines give more valuable sawn goods than plantation-grown stems.

Observation of the basic density of timber and the quality of sawn goods has its own interest, for it is a known fact that there is a clear correlation between the high density of the timber and its mechanical strength (Siimes 1967). In natural stands, the wood density in the stem rises with age (Hakkila 1966), but the correlation is weaker in plantation-grown stands (Uusvaara 1974). According to this study as well there is no great difference between the basic density of the timber generated during the early years of plantation-grown stands and the timber of the sapwood areas (Table 6). The width of the annual ring of natural stems around the pith is, on an average, the same as in the sapwood of the timber, although the basic density does rise rather significantly towards the sapwood. The fluctuations of the basic density of the timber do not, in this context, have any connection with the width of the annual ring. Even the stress grading of sawn goods does not seem to greatly depend on the basic density (Figures 18 and 19). In plantation-grown stands a weak rise in the share of the best sawn good qualities is nevertheless noticed, as the basic density rises in inner part of the timber.

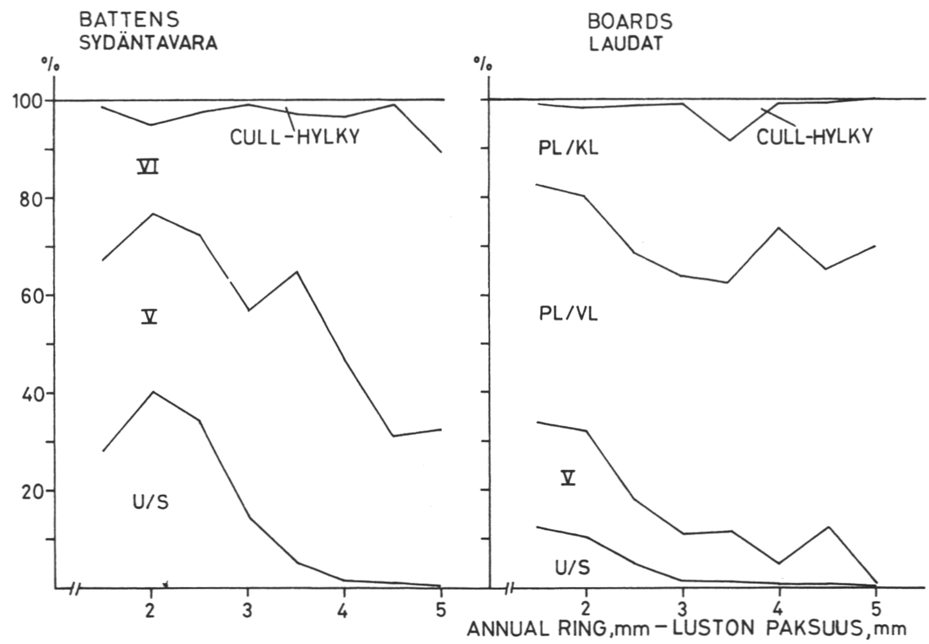


Fig. 14. Correlation between the sawn goods quality distribution and the annual ring width near the pith. Pine plantations. PL/VL = side board export quality, PL/KL = side board domestic quality.

Kuva 14. Sahatavaran laatujakauman riippuvuus luston leveydestä ytimen ympäristössä. Viljelymänniköt. PL/VL = pintalauta vientilaatu, PL/KL = pintalauta kotimaan laatu.

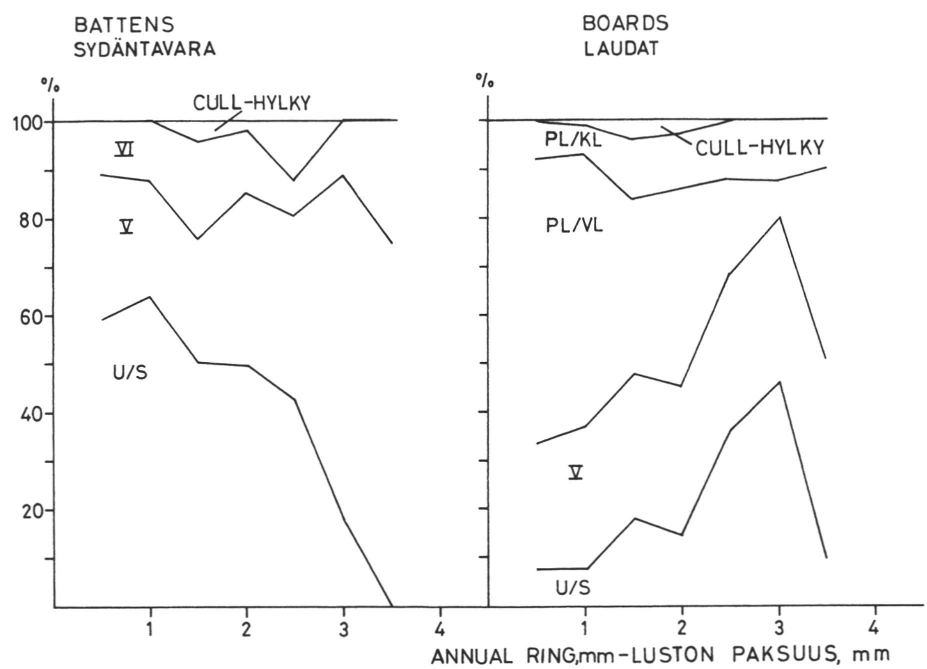


Fig. 15. Correlation between the sawn goods quality distribution and the annual ring width near the pith. Natural pine stands. PL/VL = side board export quality, PL/KL = side board domestic quality.

Kuva 15. Sahatavaran laatujakauman riippuvuus luston leveydestä ytimen ympäristössä. Luonnonmänniköt. PL/VL = pintalauta vientilaatu, PL/KL = pintalauta kotimaan laatu.

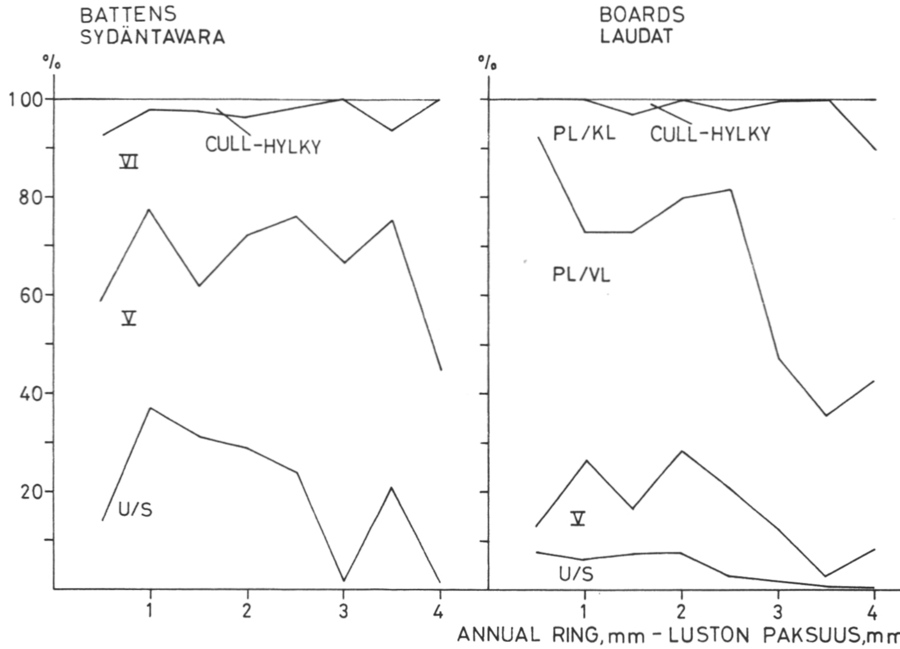


Fig. 16. Correlation between the sawn goods quality distribution and annual ring width in the outer parts of the log. Pine plantations. PL/VL = side board export quality, PL/KL = side board domestic quality.

Kuva 16. Sahatavaran laatujakauman riippuvuus luston leveydestä tukin pintaosissa. Viljelymänniköt. PL/VL = pintalauta vientilaatu, PL/KL = pintalauta kotimaan laatu.

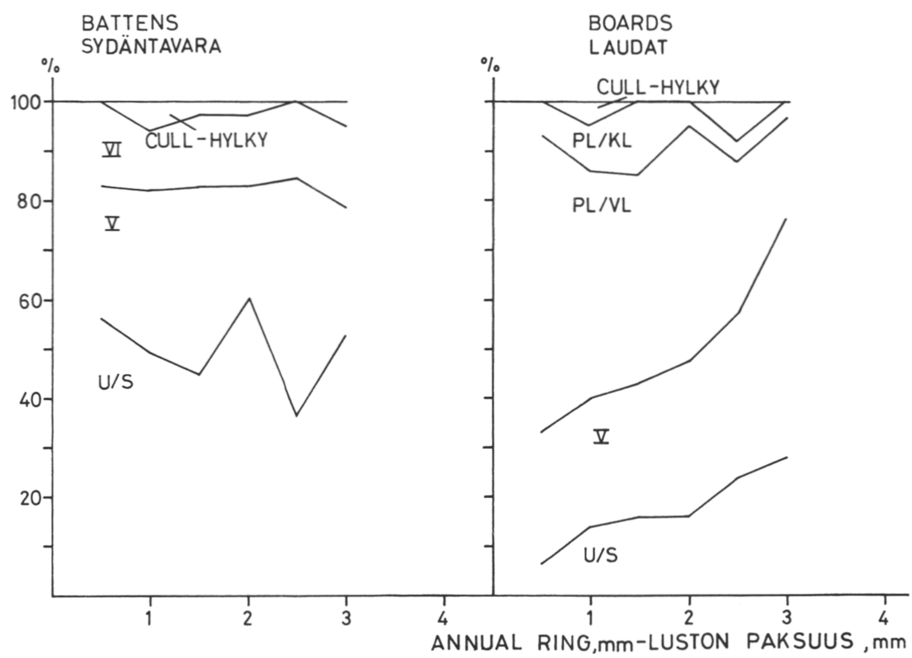


Fig. 17. Correlation between the sawn goods quality distribution and the annual ring width in the outer parts of the log. Natural pine stands. PL/VL = side board export quality, PL/KL = side board domestic quality.

Kuva 17. Sahatavaran laatujakauman riippuvuus luston leveydestä tukin pintaosissa. Luonnonmänniköt. PL/VL = pintalauta vientilaatu, PL/KL = pintalauta kotimaan laatu.

In an earlier study by the same author, the relations between the various traits that describe timber quality were focused upon. An attempt was made to describe the quality of timber by means of certain independent variables (Uusvaara 1974). In addition to traits which describe tree dimensions, the growth rate proved to be a good independent variable of quality fluctuations. The width of the annual ring was not, at that time, a very useful trait, because it was based on the average annual increment.

The values of the butt log and stem can generally be described by the quantity of u/s sawn goods derived from the butt log, because the u/s share coming from other parts of the stem is very small in comparison. The best variable for the u/s percentage of sawn goods from plantation-grown stands proved to be the height of the lowest full whorl of branches from the ground, the *Myrtillus* type dummy variable and the diameter of the longest living branch. The forest site type thus had some importance as a factor affecting quality.

In natural stands the best independent variables for the quantity of u/s sawn goods were the width of the annual ring at the butt of the stem and the height of the lowest branch whorl. The fluctuation of the u/s percentage of sawn goods obtained from butt logs can be best explained by the following equations:

Plantation-grown stands

$$y = 30.278 - 6.941_{x_{14}} + 0.544_{x_{20}} - 11.698_{x_{38}}$$

		Variable	T value
R^2	= 37.2	x_{38}	—3.2
F	= 23.4	x_{20}	6.0
DF	= 158	x_{14}	—2.9
y	= u/s-percentage of sawn goods		

Natural stands

$$y = 20.357 - 0.325_{x_{20}} - 0.020_{(x_{25})^2} + 0.036_{(x_{26})^2}$$

		Variable	T value
R^2	= 20.8	x_{20}	3.0
F	= 10.6	x_{25}	—2.2
DF	= 121	x_{26}	3.8
y	= u/s-percentage of sawn goods		

The correlations of the equations, 37.2 and 20.8 per cent, remained rather low, which may be due to the nature of the dependent variable and the effect of the sawing technique on the quality. The drawback of using the u/s-percentage of sawn goods as an dependent variable is that the price relations of the sawn timber qualities are unknown. The above-mentioned variables, in addition to some of the best correlating variables were the following:

Plantation-grown stands		Natural stands	
Variable	r	Variable	r
x_{16}	—0.155	x_{14}/x_7	0.159
x_{17}	—0.141	x_{23}	—0.141
x_{22}	0.134	x_{33}	—0.141
x_{25}	—0.129	x_{36}	—0.132
$(x_{25})^2$	—0.128	$(x_{23})^2$	—0.125

Other variables with the best correlation were the following:

Plantation-grown stands		Natural stands	
Variable	r	Variable	r
x_2	—0.142	$(x_{28})^2$	0.170
x_{24}	—0.111	x_{28}	0.166
x_2/x_{30}	0.101	$(x_{23})^2$	0.122

According to Heiskanen (1965), the narrower the annual ring around the pith is, the longer the share of u/s timber is and the shorter the share of fifths is in stems of all diameter classes. The share of u/s class in very slowly-grown trees is rather short, and it lengthens as the annual ring widens and shortens again in most fast-grown trees. Sparsely-grown stands therefore generally cause a decrease in the quality of the sawing yield. According to Heiskanen (1954b), the average quality of the sawing yield is less than 4.0, when the width of the annual ring narrows to 2.4 mm; in other words, stems which grow more quickly than those mentioned above produce mostly fifth- and sixth-grade sawn goods. The quality index 4.0 in the above-mentioned study refers to the subgroup of fourths of the u/s class. Thus the logs of the first quality class should not include logs with annual rings wider than mentioned above. On the basis of the studies, it was concluded that, for the sake of quality timber, and in order not to exceed the annual ring width of 2.4 mm, preference should be given to increasing the stand density until the butt diameter is from 8 to 10 cm.

Kärkkäinen (1980a, 1980b) tried to estimate the value of the sawing yield of a marked stand on the basis of various measurable external factors of the stems. The best independent variables for the u/s percentage are the lowest dry branch, the crown ratio and the quality class of the butt log. It was established that the value of logs can be estimated by means of two measurable quan-

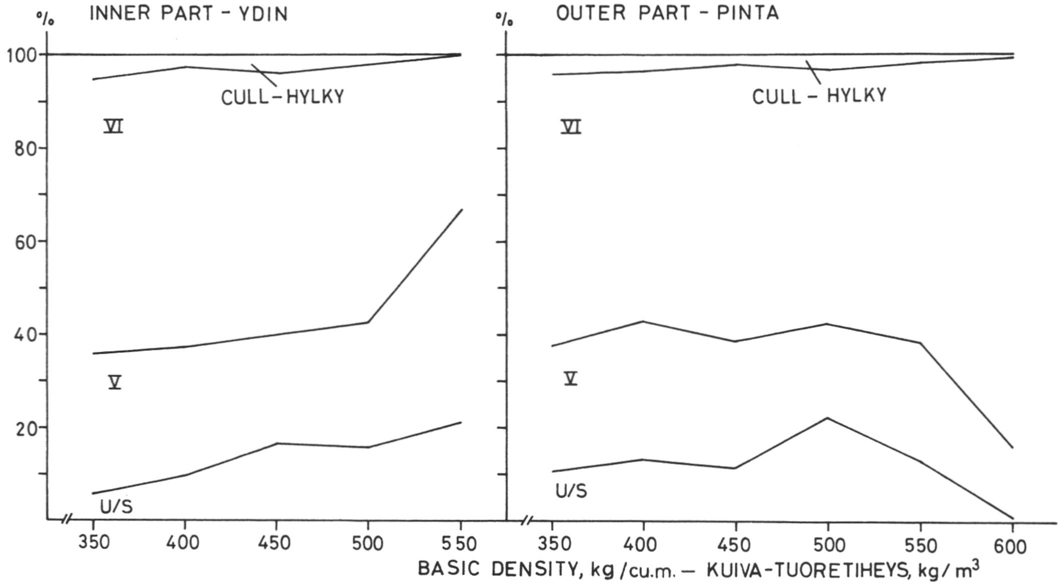


Fig. 18. Correlation between the sawn goods quality distribution and the basic density of the log. Pine plantations.
Kuva 18. Sahatavaran laatujakauman riippuvuus tukin kuiva-tuoretiheydestä. Viljelymänniköt.

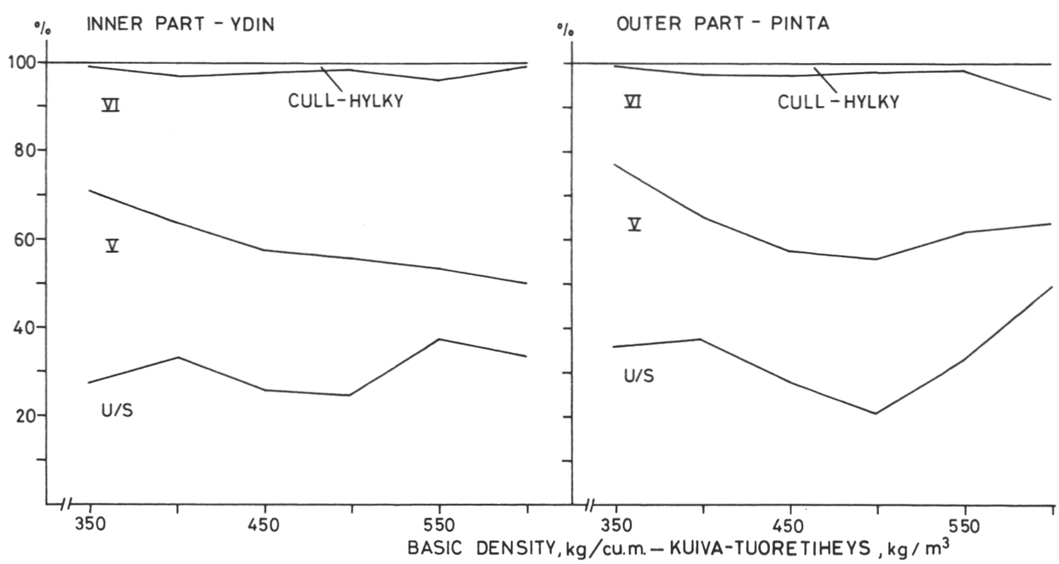


Fig. 19. Correlation between the sawn goods quality distribution and the basic density of the log. Natural pine stands.
Kuva 19. Sahatavaran laatujakauman riippuvuus tukin kuiva-tuoretiheydestä. Luonnonmänniköt.

tities, namely the breast height diameter of the stem and the height of the lowest dry branch from the ground. Persson (1976) analysed the importance of various variables descriptive of quality from the viewpoint of the quality index of the centre goods taken from butt logs from planted stands, and discovered that the planting density and the width of the annual ring at the distance of 2 to 4 cm from the pith give the strongest correlations. Also the branch diameter had a good correlation coefficient in the analysis. When studying the effect of the original planting density on the quality distribution of sawn goods it was discovered that the planting density of 0.75 m gives about 45 per cent of the u/s quality, whereas the planting distance of 3.0 m gave no u/s quality at all (Persson 1976). In planted stands no u/s quality was produced either when using the planting density of 1.5 m, whereas the corresponding density in sown areas produced about 35 per cent of the u/s sawn goods.

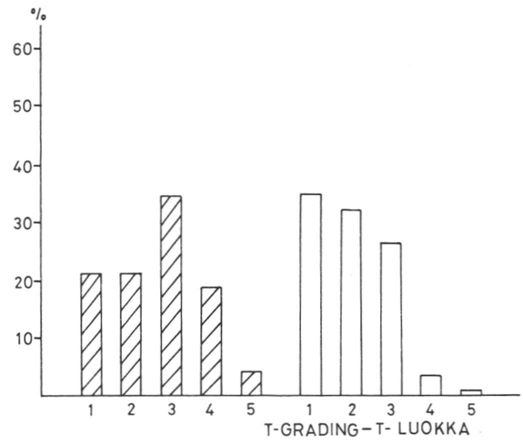


Fig. 20. Distribution of sawn goods into strength classes according to knottiness. Visual stress grading. (1=T40, 2=T30, 3=T24, 4=T18, 5=cull). Unshaded columns = natural pine stands.

Kuva 20. Sahatavaran jakautuminen lujuusluokkiin oksaisuuden perusteella. Silmävarainen arviointi. (1=T40, 2=T30, 3=T24, 4=T18, 5=hylky). Yhtenäiset pylväät = luonnonmänniköt.

412. Stress-grading

The task of stress-grading is to divide the sawn timber into different stress grades using visual or mechanical classification. Stress-grading mostly concerns construction lumber, for which certain minimum strength requirements have to be set, especially if it is to be used in bearing structures.

Visual stress-grading was done, in this study, in accordance with the T and LT classifications in the first phase by using the branchiness classification, i.e., only on the basis of the number, size and location of the branches. Branches usually have the strongest effect of all the defects on the mechanical strength characteristics of sawn goods. Figure 20 shows the distribution of sawn goods into stress grades on the basis of visual estimation which took only branches into consideration. The majority of plantation-grown sawn goods fall into stress grade T24. Most of the natural material, however, falls into the best quality class T40. The stress-grading classification of material from plantation-grown stands is, excluding class T24, rather even, whereas with natural material the percentage of various classes decreases progressively towards the lowest quality class.

In real T classification, when all factors affecting the matter are considered, the plantation-grown material still falls clearly into stress-grade T24, whereas the share of the best class simultaneously decreases (Figure 21). Also the stress-grading of sawn goods originating from natural stems changes in the same direction, although the share of pieces within the best classes is still higher than in plantation-grown stem material.

In the LT grading based solely on the observation of branchiness, the material falls, more strongly than in T grading, into the best stress grades LT40 and LT30. This is because T grading puts more emphasis on the size of the face and edge knots (Figure 22). The number of pieces falling into rejects is much greater in real classification in the original as well as the comparison material. This is obviously caused, to a great degree, by the presence of wanes, which in T grading is permitted on the edge of the piece to a maximum of 1/4 of its thickness, but in LT grading only to a maximum of 1/10 of the thickness of the piece (RIL 120, 1978).

Because the mechanized T grading is based on stress values obtained by bending the piece, the method gives faulty results, if the measurement accuracy of the sawn pieces varies. In portable circular sawing especially,

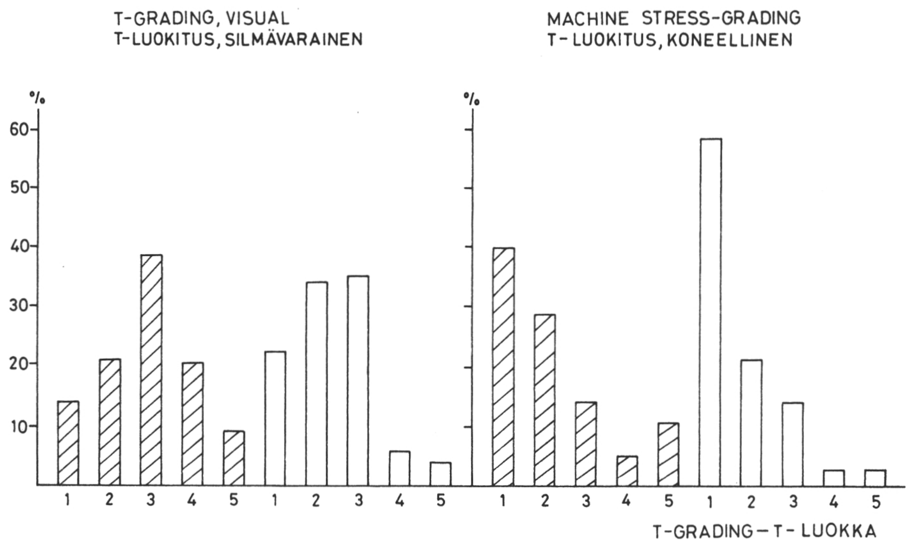


Fig. 21. Distribution of sawn goods into strength classes according to real, visual and machine stress grading (1=T40, 2=T30, 3=T24, 4=T18, 5=cull). Unshaded columns = natural pine stands.

Kuva 21. Sahatavaran jakautuminen lujuusluokkiin todellisen, silmävaraisen ja koneellisen luokituksen perusteella (1=T40, 2=T30, 3=T24, 4=T18, 5=hylky). Yhtenäiset pylväät = luonnonmänniköt.

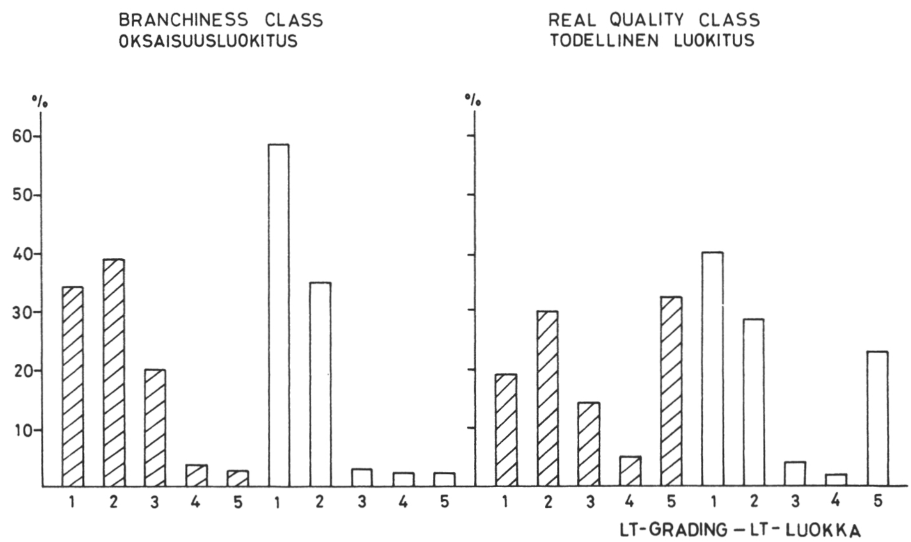


Fig. 22. Distribution of sawn goods into glue-laminated classes according to visual knottiness grading and real grading (1=LT40, 2=LT30, 3=LT24, 4=LT18, 5=cull). Unshaded columns = natural pine stands.

Kuva 22. Sahatavaran jakautuminen lamelliluokkiin silmävaraisen oksaisuusluokituksen ja todellisen luokituksen perusteella (1=LT40, 2=LT30, 3=LT24, 4=LT18, 5=hylky). Yhtenäiset pylväät = luonnonmänniköt.

fluctuations in the thickness of the sawn pieces occur because of weaknesses in the centering of the log. Granvik (1967) mentions that the sawn goods obtained in portable circular sawing are usually thinner at the ends than in the middle, and the inaccuracy of the dimensions is greater in the top end than in the bottom end. Apart from this, the piece is often somewhat wedgelike.

If the oversize exceeded 1 mm, the faulty bending stresses and the stress-grades given by them were corrected in this study by the following formula:

$$k_v = \frac{t_v}{\left(\frac{d_m}{d_n + 1}\right)^3}$$

k_v = correction factor in kp
t_v = bending stress in kp
d_m = measured thickness
d_n = nominal thickness

By planing some of the sawn goods to a fixed thickness and by retaking the stress measurements after this, it was possible to notice that the correction factor resulted, however, in too low a stress-grade in many cases. On the other hand, in some cases the planing decreased the stress-grade of pieces which had not been subject to the class correction.

Figure 21 presents the distribution of material of different origins into stress-grades in mechanized grading, when the values have been rectified by using coefficients, and checked on the basis of the planing tests. The distributions of different classes are very much alike in each of the groups of material, i.e. the slantings of the histogrammes resemble each other. The distributions also differ clearly from the results of the visual classification, which has resulted in a much stricter classification of the sawn goods than mechanized classification. The accuracy of visual estimation is, to some degree, better in sawn goods taken from natural stands, but the method exaggerates the importance of branchiness as a factor that decreases the strength, the better the quality of the sawn goods under inspection is.

The lowest stress-grades for sawn pieces usually are situated at the upper end of the piece (Figures 23 and 24). This is partly due to the basic density of the timber, which is lower in the top of the log than in the butt, and partly to the greater branchiness of the top end of the piece. The method used in this study, in which the sawn piece that was too long was shortened at the top end, may have somewhat reduced the quality differences of sawn goods of different research materials. The basic density of the timber at the top end of centre pieces sawn of plantation-grown

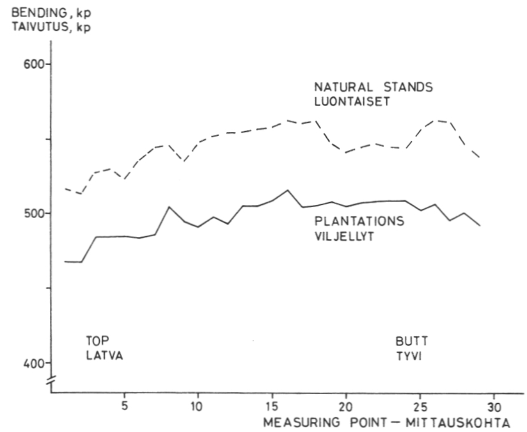


Fig. 23. Variation of the bending strength of scantlings (50 × 100 mm) in different parts of the piece. Stress area 1, bending 1,3 mm.
Kuva 23. Sydäntavarakappaleiden (50 × 100 mm) taivutusvoiman vaihtelu kappaleen eri osissa. Painealue 1, taivutus 1,3 mm.

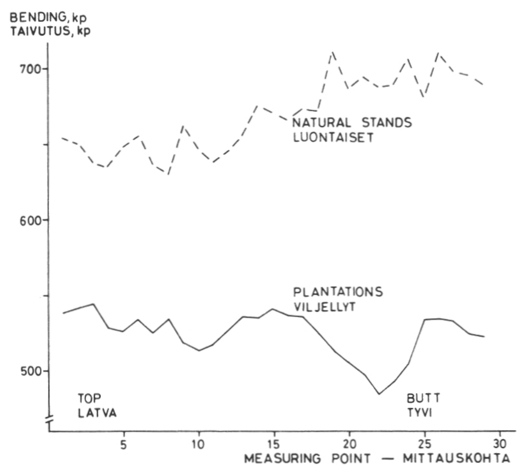


Fig. 24. Variation of the bending strength of scantlings (50 × 100 mm) in different parts of the piece. Stress area 1, bending 1,5 mm.
Kuva 24. Sydäntavarakappaleiden (50 × 100 mm) taivutusvoiman vaihtelu kappaleen eri osissa. Painealue 1, taivutus 1,5 mm.

and natural material was 383 and 406 kg per cu.m and at the butt end 432 and 471 kg per cu.m respectively.

The third factor which affects strength considerably is the width of the annual ring, which will be taken into account in connection with stress-grading. The maximum allowable width of the annual ring in the best classes T40 and LT40 is 30 mm (RIL 120, 1978).

The differences in the strength of material from plantation-grown and natural stands are not great, if sawn goods from logs of the same quality class are compared (Table 12). In examination of the internal division within both origins, one notices that the quality differences of the sawn goods from logs of the first and second quality classes are comparatively small. Strength, on the other hand, is decisively reduced in sawn goods made of third quality class logs. The stress-grading of sawn goods resembles in this respect the quality distribution in which the greatest differences in the u/s percentage were also between the second and third quality classes (Figure 11, page 30).

The reduction of quality is mostly explained on the basis of the increased branchiness of poor quality logs, the width of the annual ring, and the decrease of the basic density of the timber. The effect of the basic density of the timber on the stress-grade distribution of the centre pieces can be seen in Table 13. The share of the best quality classes decreases quickly, as the basic density of the timber decreases (Table 13).

For sawn goods originating from plantation-grown stands Persson (1976) obtained the following percentages which represent the best stress-grade as the planting density of the stands increases.

Planting distance in meters	T 300 in per cent
0.75	42
1.25	22
1.50	15
3.00	—

The lower stand density is when a stand is established, the less mechanical strength sawn goods have. In addition, according to modern standards, even rather dense planted stands yield sawn goods that scarcely meet the high strength requirements.

Persson has also shown, that mechanized T grading often gives clearly higher quality indexes than visual classification. According to him, the difference is mostly due to the large edge knots found in thin pieces. In this case, edge knots are the reasons for sawn goods to be visually classified as rejects, although in mechanized classification they qualify for a better grade class. The higher values obtained in mechanized stress grading than in visual classification may be partly because the pieces have been shortened at the top end, in which case of the worse branch defects have vanished (page 11).

Table 12. Correlation between the T-strength class distribution and the real quality class of the log. R = cull.
Taulukko 12. T-lujuusluokkajakauman riippuvuus tukin todellisesta laatuluokasta. R = hylky.

T-grading class *T-luokka*	Log quality class *Tukin laatuluokka* 1	2	3
	Plantations, % — *Viljelymänniköt, %*		
40	76,9	61,3	20,6
30	7,7	16,1	35,3
24	7,7	16,1	20,6
18	7,7	3,2	2,9
R	..	3,3	20,6
	Natural stands, % — *Luonnonmänniköt, %*		
40	72,2	70,6	23,1
30	16,7	17,7	38,5
24	5,6	8,8	30,8
18	5,6	..	7,7
R	..	2,9	..

Table 13. Correlation between the T-strength class distribution and the basic density of the sawn goods piece. R = cull.
Taulukko 13. T-lujuusluokan riippuvuus sahatavarakappaleen kuiva-tuoretiheydestä. R = hylky.

T-grading class *T-luokka*	Basic density, kg/cu.m *Kuiva-tuoretiheys, kg/m³* 325	375	425	475
	Plantations, % — *Viljelymänniköt, %*			
40	..	18,5	60,5	63,6
30	..	25,9	25,6	18,2
24	20,0	33,3	11,6	..
18	..	11,1	..	..
R	80,0	11,1	2,3	18,2
	Natural stands, % — *Luonnonmänniköt, %*			
40	..	28,6	55,6	81,8
30	..	28,7	25,0	13,6
24	..	28,7	13,9	4,6
18	..	14,3	2,8	..
R	..	..	2,8	..

42. Value of sawn goods

The value of sawn goods will be examined on the basis of the wholesale prices of export sawn goods so that the price of the u/s quality board will be considered as 100 (Sahatavaran . . . 1980). The prices and value relations of sawn goods of different quality classes have been given in Appendix 1. The prices of other quality classes have been calculated in relation to the u/s price and an extra price has been calculated for wide dimensions (Appendix 1). This extra price is based on the price differences for pieces of various widths obtained from the price list.

Table 14 shows the unit prices for sawn goods from plantation-grown and natural stands, grouped according to the quality class of the log. The table shows that the differences between the materials of two different origins are especially great, particularly if boards sawn out of poor quality logs are examined. The differences in the values of centre goods pieces between two different research materials remain smaller. The difference between the first and the second quality class in material from plantation-grown stands is not great, but the value drops quickly, when moving from the second to the third quality class. In natural stands, the differences in value are greatest between sawn timber lots derived from logs of the best quality classes. The differences in the prices of centre goods pieces, boards and sawn goods as a whole between the two materials were, on an average, 7.0, 22.2 and 9.1 per cent respectively, in favour of sawn goods originating in natural stands. The great differences in the value of the boards are due to the price differences of the various qualities of boards. These price differences are also considerably greater in boards than in battens and planks.

The sawn goods yield gained from plantation-grown and natural stands was 51.9 and 52.9 per cent respectively. The figures in question were comparatively high, if compared with percentages of yield found in other studies (e.g., Heiskanen 1976). Kärkkäinen (1980a) obtained an average percentage of yield of 48.7 in test sawings. The smaller yield in plantation-grown stands in this context may reflect that the quality of their timber stock is weaker than in the growing stock in natural stands, especially as far as stem defects are concerned. Sweeps for example, have been shown to lower the yield clearly (Siimes 1957, Asikainen and Panhelainen 1970). The sawn goods yield increases also in both plantation-grown materials and in other comparison materials, as the diameter of the log increases. The yield is, however, two per cent units lower in third class logs than in first class logs.

The yield of sawn goods decreased in this study, as the quality of the log weakened. The correlation between yield and the quality of the log is usually the contrary, that is the yield rises as the branchiness quality class of the log weakens (Kärkkäinen 1980a). This development is obviously a result of the change in stem form which is caused by butt swelling, and the difference in yield is most defined in the stem between butt logs and other logs.

The factors affecting the unit price of sawn goods were tested using the selective regression analysis. The most significant independent variable of the fluctuation of the unit price in plantation-grown stands is the

Table 14. Volume price of sawn goods obtained from logs of different qualities. R = cull.
Taulukko 14. Eri laatuisista tukeista saadun sahatavaran yksikköhinta. R = hylky.

Log quality *Tukin laatu*	Plantations — *Viljelymänniköt* Battens *Sydäntavara*	Boards *Laudat*	Total *Yhteensä*	Natural stands — *Luonnonmänniköt* Battens *Sydäntavara*	Boards *Laudat*	Total *Yhteensä*
1	59.2	52,1	57,6	62,7	60,4	62,0
2	58,3	45,2	55,0	58,5	51,4	56,7
3	54,1	38,7	49,9	57,5	53,8	56,5
R	50,9	36,5	48,1	53,5	44,0	50,8
Average *Keskimäärin*	56,0	42,7	52,8	59,6	54,9	58,3

volume of the log, which alone accounts for 85 per cent of the total fluctuation of the price (c.f. Qy 1974). Other independent variables of the best equation were the quality class of the log, age of the stem and its sweep. The best unit price formula of sawn goods originating from plantation-grown stands had a correlation coefficient of 92 per cent.

$$y = 8.552 - 3.448_{x17} - 0.115_{x31} + 0.254_{x30} + 0.006_{(x2)^2}$$

		Variable	T value
R^2	= 91.7	x_{17}	—4.1
F	= 346.8	x_{31}	—2.8
DF	= 157	x_{30}	14.8
y	= unit price of sawn goods	$(x_2)^2$	2.4

The best independent variables of the unit price of logs from natural stands were, in addition to the volume of the log, the growth of the breast height diameter, the top diameter of the log, the height of the first branch whorl and the width of the annual ring at the butt level. The forest site type also had an effect on the value of the sawn goods, although it was not statistically significant. The best unit price equation had a correlation coefficient of 86 per cent.

$$y = 11.486 + 0.283_{x14} - 2.145_{x18} + 0.129_{x20} + 0.357_{x30} + 98.437_{(x7/x2)^2} - 0.015_{(x25)^2} + 7.593_{x38}$$

		Variable	T value
R^2	= 86.4	x_{14}	2.9
F	= 106.1	x_{18}	—4.1
DF	= 117	x_{20}	3.8
		x_{30}	13.5
y	= unit price of sawn goods	x_7/x_2	4.7
		$x_{(25)}^2$	3.2
		x_{38}	2.4

Other noteworthy factors that affect the price, and their correlation coefficients are listed below.

Plantation-grown stands		Natural stands	
Variable	r	Variable	r
x_{38}	—0.143	x_{10}	0.162
$(x_{28})^2$	—0.143	x_{26}	0.145
x_{37}	0.139	$(x_{26})^2$	0.145
x_{16}	0.130	x_{32}	0.144
x_{28}	—0.126	$(x_{12})^2$	—0.142

The value of sawn goods derived from the butt log are mostly dependent on the size of the log, but also on the factors representative of the growth speed and self-pruning. The importance of the height of the first full branch whorl as an independent variable of quality is natural, especially in young plantations, where self-pruning of the stems has been weak. Kärkkäinen (1980a) found out that the price of sawn goods is dependent on the size of the tree, and on the height of the lowest dry branch from the ground. The results applied to natural stands at the end of their rotation.

The following equations are obtained when the unit price of sawn goods is examined without the effect of the volume of the log.

Plantation-grown stands

$$y = 128.495 - 1.100_{x1} + 0.603_{x3} - 3.452_{x7} - 3.334_{x17} + 0.304_{x26} - 0.144_{x31} - 9.752_{x6/x2} + 0.507_{(x7)^2 \cdot x6} - 72.203_{x2/(x7)^2 \cdot x_6}$$

		Variable	T value
R^2	= 89.9	x_1	—2.1
F	= 150.6	x_3	3.2
DF	= 153	x_7	—4.2
y	= unit price of sawn goods	x_{17}	—3.4
		x_{26}	3.4
		x_{31}	—3.1
		x_6/x_2	—6.5
		$(x_7)^2 \cdot x_6$	9.8
		$x_2/(x_7)^2 \cdot x_6$	—8.2

Natural stands

$$y = 76.034 - 3.894_{x71} - 2.291_{x18} + 0.317_{x22} - 6.433_{x12/x7} + 0.007_{(x14)^2} + 0.368_{(x7)^2} - 54.973_{x2/(x7)^2 \cdot x6}$$

		Variable	T value
R^2	= 80.9	x_{17}	—3.5
F	= 61.5	x_{18}	—2.7
DF	= 116	x_{22}	3.7
y	= unit price of sawn goods	x_{12}/x_7	2.1
		x_{14}	4.8
		$(x_7)^2 \cdot x_6$	6.3
		$x_2/(x_7)^2 \cdot x_6$	—6.2
		x_{38}	2.3

Other variables resulting in the best correlation coefficient were the following.

Plantation-grown stands		Natural stands	
Variable	r	Variable	r
x_{16}	0.147	$(x_{26})^2$	0.159
x_{38}	0.142	x_{31}	—0.157
x_{37}	0.142	x_{26}	0.143
$(x_{26})^2$	—0.126		
$x_8 \cdot x_7$	—0.115		

In a study by Kärkkäinen (1980a) the best independent variables of the unit price of sawn goods in natural stands were the unit price of centre goods and the top diameter of the log under bark. These gave a correlation coefficient of 91.4 per cent. The average unit price for sawn goods in Kärkkäinen's studies (1980a and 1980b) was 56.3 and 60.9. The prices used in his studies differed from those used in this study, and the studies also dealt with the log part of the whole stem. It can therefore be said that the results of the studies in question are not directly comparable with the results of this study. Nevertheless, the unit prices for natural stands in the studies mentioned above were rather high, despite the branchy middle and top logs.

5. DISCUSSION

Some features concerning the way data was collected have already been mentioned in connection with the explanation of the research method. The material was collected from the southern and central parts of the country, consequently the terrain and climatic factors were comparatively uniform. Coastal areas were avoided because of their exceptional wind conditions, which affect the quality of the stem wood. The choice of sample stands and the way of taking samples were affected by the availability and location of suitable plots. A systematic sampling method could not be applied in choosing the material, because old regeneration areas, for which reliable information on their establishment is available, are rather limited on State-owned lands. For this reason, the plots were chosen from among available stands, but in some areas lots were drawn to choose the plots.

The origins of the seeds or the regeneration material of plantation-grown stands were usually local, but little attention was paid to the genetic quality of the seed collection trees when the research stands were established. In most cases the origin of the seed was unknown.

The goal was to find an equal number of plantation-grown and comparison stands on each research location, and an equal total number of stands on different areas. This was not, however, fully successful, for the number of plantations fluctuated from location to location. For the above reasons, the material cannot be considered totally representative, since it was partly necessary to apply subjective method in the choice.

In the method used for locating sample plots within the stand (c.f. page 10) all parts of the stand were possible sample plots, with the exception of central parts of large stands. These sections were few, since most old plantations were small in size. Natural stands were more uneven in this respect.

The trees of the sample plot were numbered both systematically and randomly starting at the edge of the sample plot. Surplus trees at the end were not counted in the measurable material. When trees to be cut were chosen by the drawing of lots these trees were randomly included in the group of sample trees. Younger stands were an exception, because all stems had not yet reached the size requirements for saw logs. In cases like this, it was sometimes necessary to choose the sample trees from among a rather small number of trees.

The number of sample plots and stems can be considered rather large and well distributed, although the material came, to a certain degree, from the Province of Häme, owing to the location of the State-owned lands. The number of stems felled and logs prepared from them is much smaller, i.e. 165 logs from plantation-grown and 150 from natural stands. Because the material is not extensive, it is important that it is as descriptive of the characteristics of the whole basic group as possible. When examining the characteristics of stems large enough to yield logs and the butt logs derived from them one can notice that the breast height diameters of the standing trees in plantation-grown and natural stands were 20.1 and 20.9 cm on an average, and in stock prepared into butt logs 20.3 and 20.2 cm respectively. In both data groups the top diameters of butt logs were 19.1 and 19.5 respectively in standing trees and 19.1 and 18.9 cm in sawn logs. Logs derived from sample trees that were to be cut represented the whole tree population under study well, as far as size is concerned.

The quality distributions of logs in standing trees and in felled sample trees were similar, although a few more poor-quality stems were converted into logs than was the average for the material (page 25). The quality of the stand is also described by the thickest branches of the butt log, which were 23 and 18 mm in standing trees in plantation-grown and natural stands and 25 and 18 mm in logs respectively. As far as both size and quality are concerned the logs and the sawn goods prepared from them corresponded very well to the whole material. Therefore, the material sawn, a total of 300 logs, can be considered sufficient in number. It may be mentioned that in the study by Persson (1976) the material concerning the quality of sawn goods originating from planted stands included a total of 269 logs.

When choosing the material, the goal was to have the correct proportions of various forest site types, to that extent that they are typical of sites for pine. Pine plantations were earlier established more often on good soils, but it is possible that the share of good sites in the material is larger than in reality (page 12). Natural stands were established, owing to the physiological requirements of the stock, mostly on *Vaccinium* site types.

Because a fourth of the plantation-grown stands were clearly situated on more fertile soils than is typical of pine, it was considered appropriate to study the effect of the forest site type on the quality of butt logs and on the quality distribution and value of sawn goods separately. This was done by ignoring all logs originating in the *Oxalis-myrtillus* site type during calculations. Because the natural stands were often older than the plantation-grown stands (page 47), logs derived from stems older than 90 years of age were excluded from the above group, in order to even out the age. The result is the following quality distribution for sawn butt logs, which also gives the change caused by the omission of the best forest site type as compared with the whole of the material.

Quality class of log	Plantation-grown			Natural		
	Whole material	Corrected material	Change	Whole material	Corrected material	Change
	In per cent			In per cent		
1	11.6	8.7	—2.9	17.4	32.4	+5.0
2	36.6	36.5	±0	53.3	50.9	—2.4
3	43.9	48.7	+4.8	18.5	15.7	—2.8
Cull	7.9	6.1	—0.2	0.9	0.7	—0.2

Contrary to expectations, the quality distribution of logs in plantation-grown stands weakened somewhat, while in natural stands the distribution improved after the omission of the logs from the most fertile site. If compared to earlier calculations, the changes were nevertheless small. The fertility of the site did not decrease the quality of the stand to any great extent. One reason for this is that those logs which were removed in the correction came mostly from old plantations which had been too densely established and had been treated with slight thinnings at an early age.

The following tabulation contains the corrected quality distribution of sawn goods in plantation-grown and natural stands.

Quality class of log	Plantation-grown			Natural		
	Whole material	Corrected material	Change	Whole material	Corrected material	Change
	Centre goods in per cent					
u/s	24.2	23.1	—1.1	50.0	48.7	—1.3
V	42.7	45.7	+3.0	32.7	33.9	+1.2
VI	30.3	28.1	—2.2	14.1	14.8	+0.7
Cull	2.8	3.1	+0.3	3.2	2.7	—0.5
	Boards in per cent					
u/s	3.9	3.2	—0.7	15.6	16.5	+0.9
V	16.7	16.5	—0.2	30.3	31.5	+1.2
PL/VL	50.6	61.5	+10.9	42.8	41.3	—1.5
PL/KL	27.0	17.5	—9.5	9.4	8.9	—0.5
Cull	1.8	1.3	—0.5	1.9	1.8	—0.1

On an average the changes brought about by the correction in the quality of the sawn goods remained small. The same observation can be made for the following tabulation which contains the unit prices of sawn goods by log classes.

Quality class of log	Plantation-grown			Natural		
	Whole material	Corrected material	Change	Whole material	Corrected material	Change
	In per cent			In per cent		
1	57.6	53.5	—4.1	62.0	61.9	—0.1
2	55.0	54.7	—0.3	56.6	56.5	—0.1
3	49.9	51.2	+1.3	56.4	57.8	+1.3
Cull	48.1	46.7	—1.4	50.8	50.5	—0.3

After the correction, the differences in the values of centre goods, boards and sawn goods as a whole, originating from plantation-grown and natural stands, are 6.7, 20.3 and 10.0 per cent on an average. If compared with the whole of the material, the difference in the value of centre goods has thus slightly increased and the difference of boards has decreased.

Kärkkäinen and Uusvaara (1982) also found out that in young plantations the influence of the forest site type on the quality of the growing stock is minimal (also Varmola 1980, Uusvaara 1981a and 1981b). In stands of the same density the more fertile nature of the site decreases quality, but the fluctuation of the density of the growing stock between different stands affects the quality more than the site type. In this study,

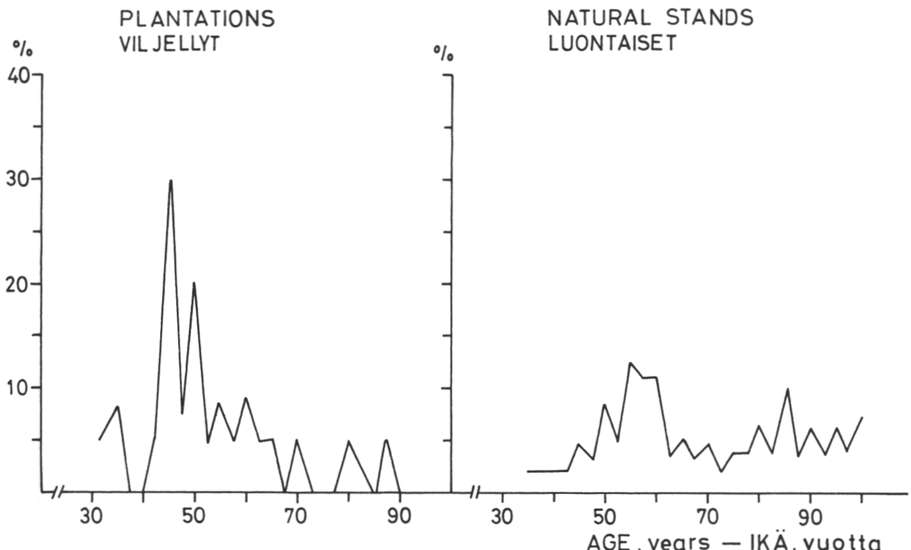


Fig. 25. Age distribution of the material.
Kuva 25. Aineiston ikäjakauma.

the *Myrtillus* site type, which accounted for 28 per cent of the plantation-grown material, seems to have affected the results more than more fertile sites.

The goal was to locate plots within natural stands in each locality where the age and size of the trees would correspond as well as possible to those of the plantation-grown stands chosen for research. This was difficult in many cases, especially because the lack of middle-aged natural stands was obvious. The size and age of the stems within the stand could also fluctuate quite a lot in natural stands. In some cases this was possibly attributable to old methods of stand treatment, e.g., selection cuttings. All stands had, however, always been within the sphere of silviculture, although the efficiency and regularity of the procedures usually seemed to be better in plantation-grown stands. Better information was available on the cuttings, clearings and thinnings carried out in plantation-grown stands than on those carried out in natural stands.

The average age of the plantation-grown stands was lower than that of natural stands, and the distribution of the age classes of both materials differed from each other to some extent (Figure 25). The difference in the average age between plantation-grown and natural stands was also statistically very significant (t=12.0***). There was a strong concentration on the age of 45 in plantation-grown stands, whereas the age classification of natural stands had two clear peaks. The measures of age dispersion were as follows.

	Plantation-grown stands	Natural stands
x	51	67
Me	49	60
Mo	45	56
S	12.3	17.3
Fluctuation limits	31—87	34—99
N	630	314
Skewnes	1.09	0.36
Peakedness	1.25	—1.15

The difference in the breast height diameters between plantation-grown and natural stems was statistically significant (t = 2.92**). The measures of the dispersion of the breast height diameters were as follows (c.f. Figure 26).

	Plantation-grown stands	Natural stands
x	20.1	20.9
Me	19.5	20.0
Mo	18.0	20.0
S	5.2	5.3
Fluctuation limits	8—37	8—44
N	630	1879
Skewnes	0.55	0.72
Peakedness	0.27	0.90

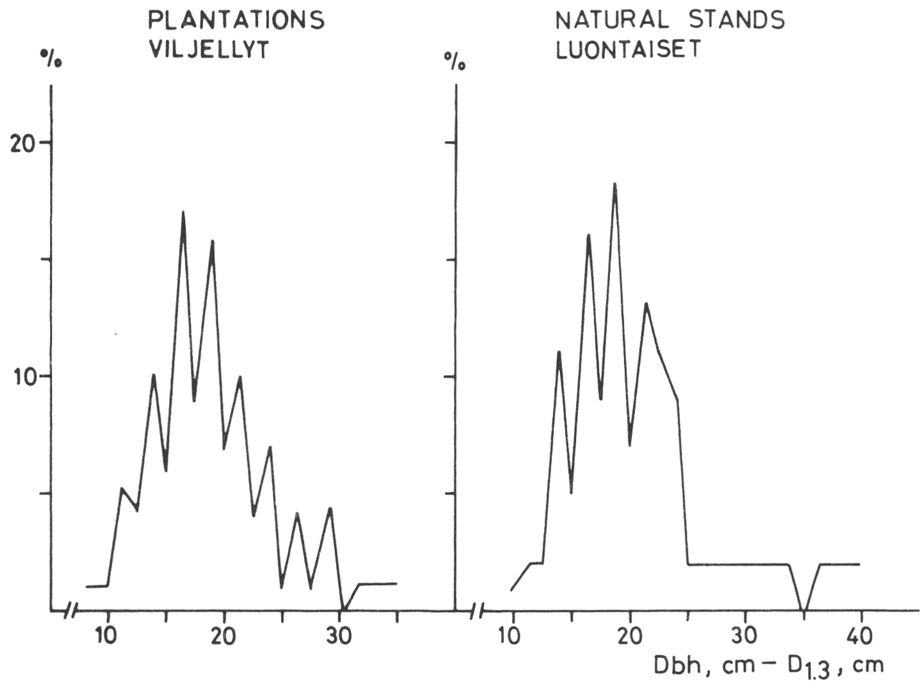


Fig. 26. DBH distribution of the material.
Kuva 26. Aineiston rinnankorkeusläpimitta.

The average volume of the butt log for plantation-grown stands was 148.5 cu.dm and for natural stands 155.6 cu.dm; the difference between the two was statistically important (t=1.20*). The figures for the distribution of the volumes were the following (c.f. Figure 27).

	Plantation-grown stands	Natural stands
x	148.5	155.6
Me	134.8	149.1
Mo	—	—
S	61.2	53.8
Fluctuation limits	60.9—401.5	85.1—442.6
N	162	135
Skewnes	1.36	1.94
Peakedness	1.99	6.22

Natural stems were thus older than plantation-grown stems, but natural butt logs were not, to any significant degree, larger than logs from plantation-grown stands. The result reflects earlier received proof that natural stems are somewhat older but also slower growing than plantation-grown pines, when comparing stems from the same diameter class. This point has had a decisive effect on the better quality of timber of natural stems and the more favourable quality distribution of the sawn goods derived from them.

The above results show that timber derived from plantation-grown stands is, taking all criteria under observation into account, of poorer quality than the timber from natural stands, when considering the timber from the viewpoint of its utilization value. The differences can be explained, only for a small part, on the basis of the weaknesses of the research material.

When evaluating the results and their importance, with consideration to the quality of the plantation-grown stands established recently, attention must be paid to the fact that old plantation-grown stands, which were the origin of the material in this study, were mostly established by sowing, whereas at present the main regeneration method is planting. The results cannot therefore be applied as such to the evaluation of the quality of the present planted stands. Nevertheless, there are plenty of similarities between old and young plantation stands, be-

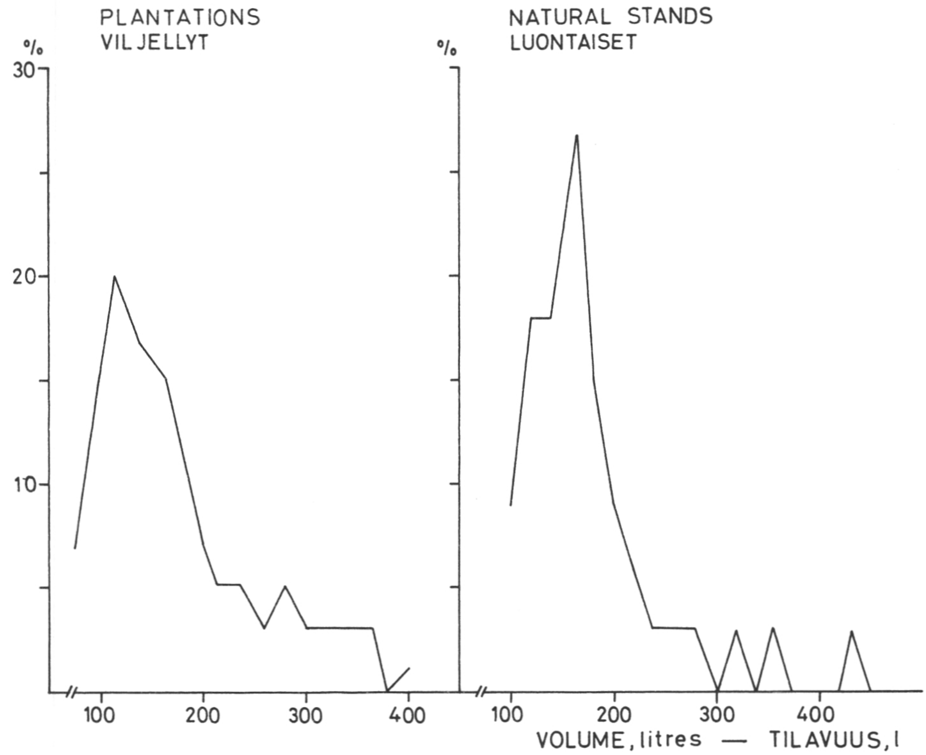


Fig. 27. Volume distribution of the butt logs of the material.
Kuva 27. Aineistoon kuuluneiden tyvitukkien tilavuusjakauma.

cause neither of them is of local progeny. In both regeneration methods the number of regeneration sites and the early development of the seedling stands are approximately the same. Among other things, on the basis of the small planting densities used today in plantations, it is possible to estimate that the quality of our plantation stands will decrease drastically in comparison with the quality of older stands.

LITERATURE

Arnkil, J. 1978. Sahatukin laatu unohdettu asia. Metsä ja Puu 10: 23—24.

Asikainen, K. 1980. Tukin laadun vaikutus sahaustulokseen. Sahapuupäivät 31. 1.—1. 2. 1980. Moniste. 11 p.

— & Panhelainen, A. 1970. Tukin lenkouden vaikutus sahaustulokseen. Paperi ja Puu 52(4a): 219—230.

Dahlen, L. & Warg, A. 1978. Värdering av stämplingsposter. Summary: Valuation of timber stands marked for felling. Rapp. Instn. Virkeslära Sveriges Lantbruksuniv. 105: 1—32.

Definitioner, metoder m.m. vid vedundersökningar. 1980. Andersson, E. & Tuimala, A. (eds.) Upps. 4: 1—139.

Eklundh Ehrenberg, C. 1963. Genetic variation in progeny tests of Scots pine (Pinus silvestris L.). Sammanfattning: Ärftlig variation in avkommeförsök med tall. Stud. For. Suec. 10: 1—135.

Erteld, W. 1967. Crown characteristics as indicators of growth potential in young pine stands at various spacings. Sozial Fortsw., Berl. 17(8): 236—239. (Ref. Forestry Abstracts 1968: 566).

Flower-Ellis, J., Albrektsson, A. & Olsson, L. 1976. Structure and growth of some young Scots pine stands: (1) dimensional and numerical relationships. Swedish coniferous forest project. Techn. rep. 3: 1—98.

Granvik, B-A. 1967. Havusahatavaran valmistus kenttäpyörösahalla. Työtieteellinen tutkimus. Summary: On the preparation of coniferous sawn goods using circular saws. Acta For. Fenn. 84(3): 1—162.

Hakkila, P. 1966. Investigations on the basic density of Finnish pine, spruce and birch wood. Lyhennelmä: Tutkimuksia männyn, kuusen ja koivun puuaineen tiheydestä. Commun. Inst. For. Fenn. 61(5): 1—98.

— & Uusvaara, O. 1968. On the basic density of plantation-grown Norway spruce. Lyhennelmä: Viljelykuusikoitten puuaineen tiheydestä. Commun. Inst. For. Fenn. 66(6): 1—23.

Heikinheimo, O. 1953. Puun rungon luontaisesta karsiutumisesta. Summary: On natural pruning of tree stems. Commun. Inst. For. Fenn. 41(5): 1—39.

Heiskanen, V. 1954a. Tutkimuksia mäntytukkipuiden laatuluokitustavoista ja niiden tarkkuudesta. Summary: Investigations into pine tree grading methods and their accuracy. Commun. Inst. For. Fenn. 44(1): 1—132.

— 1954b. Vuosiluston paksuuden ja sahatukkien laadun välisestä riippuvuudesta. Summary: On the interdependence of annual ring width and sawlog quality. Commun. Inst. For. Fenn. 44(5): 1—28.

— 1962. Mäntysahatukkien laatuluokituksen tarkkuudesta. Summary: Accuracy of the grading of pine sawlogs. Commun. Inst. For. Fenn. 55(16): 1—15.

— 1965. Puiden paksuuden ja nuoruuden kehityksen sekä oksaisuuden ja sahapuulaadun välisistä suhteista männiköissä. Summary: On the relations between the development of the early age and thickness of trees and their branchiness in pine stands. Acta For. Fenn. 80(2): 1—62.

— 1971. Tyvitukkien ja muiden tukkien koesahauksia Pohjois-Suomessa. Summary: Test sawings of butt logs and top logs in Northern Finland. Folia For. 116: 1—23.

— 1976. Havusahatukkeja koskevia arvolaskelmia vv. 1974—1975. Summary: Value calculations for softwood sawlogs in 1974—1975. Folia For. 251: 1—64.

— & Asikainen, K. 1969. Havusahatukkien järeyden mukaiset arvosuhteet ja hinnoitteluperusteet. Summary: The value relationships and pricing principles of coniferous sawlogs on the basis of their diameter. Commun. Inst. For. Fenn. 69(3): 1—122.

— & Siimes, F. E. 1959. Tutkimus mäntysahatukkien laatuluokituksesta. Paperi ja Puu 41(8): 359—368.

Huuri, O. 1976. Kallistumisilmiö istutusmänniköissä. Tiedustelun tuloksia. Summary: Tilting of planted pines; survey results. Folia For. 265: 1—22.

— 1979a. Havaintoja Etelä-Suomen piirikunnan istutusmänniköiden tilasta. Esitelmä. 20 p.

— 1979b. Havaintoja Pohjanmaan piirikunnan istutusmänniköiden tilasta v. 1979. Esitelmä. 33 p.

Isomäki, A. 1978. Kiertoaika metsätaloudessa. Metsä ja Puu 8: 27—30.

Kaila, S. 1979. Tuloksellinen metsänviljely. Helsinki. 125 p.

Kalela, E. 1945. Metsät ja metsien hoito. 1. painos. Porvoo-Helsinki. 368 p.

Kallio, K. 1960. Etelä-Suomen kylvömänniköiden rakenteesta ja kehityksestä. Summary: On the structure and development on pine stands established by sowing in the south of Finland. Acta For. Fenn. 71(3): 1—78.

Kellomäki, S. 1980. Growth dynamics of young Scots pine crowns. Seloste: Nuorten mäntyjen latvusten kasvun dynamiikka. Commun. Inst. For. Fenn. 98(4): 1—50.

— 1981. Effect of within-stand light conditions on the share of stem, branch and needle growth in a twenty-year-old Scots pine stand. Seloste: Metsikön valaistusolojen vaikutus rungon, oksien ja neulasten kasvun osuuksiin eräässä kaksikymmenvuotiaassa männikössä. Silva Fennica 15(2): 130—139.

— & Tuimala, A. 1981. Puuston tiheyden vaikutus

puun oksikkuuteen taimisto- ja riukuvaiheen männiköissä. Summary: Effect of stand density on branchiness of young Scots pines. Folia For. 478: 1—27.
Koivisto, V. 1980. Minkä laatuista puuta tulisi kasvattaa. Metsä ja Puu 3: 23—25.
Kärkkäinen, M. 1978. Laatupuun kasvattaminen — unohtunut tehtävä. Metsänhoitaja 7: 10—12.
— 1980a. Mäntytukkirunkojen laatuluokitus. Summary: Grading of pine sawlog stems. Commun. Inst. For. Fenn. 96(5): 1—152.
— 1980b. Tuloksia Rauman alueen mäntytukkien sahauksesta. Summary: Results of sawing pine logs in Rauma region, western Finland. Commun. Inst. For. Fenn. 96(7): 1—43.
— 1981. Onko männyn pystykarsinnalla tulevaisuutta. Teho 1: 20—22.
— & Salmi, J. 1981. Länsi-Uudenmaan rannikon mäntytukkien ominaisuudet. Summary: Properties of pine logs in coastal sawmill in southern Finland. Folia For. 458: 1—20.
— & Uusvaara, O. 1982. Nuorten mäntyjen laatuun vaikuttavia tekijöitä. Abstract: Factors affecting the quality of young pines. Folia For. 515: 1—28.
Laadukkaan mäntysahapuun kasvatus (Growing of good quality sawn timber of pine). 1984. Suomen Sahanomistajayhdistys. 43 p.
Laitakari, E. 1937. Laatupuun kasvattamisesta. Silva Fennica 39: 259—270.
Leikola, M., Metsämuuronen, M., Räsänen, P. & Taimisto, E. 1977. Männyn viljelytaimistojen kehitys Lounais-Suomessa vv. 1967—1975. Summary: The development of Scots pine plantations in south-western Finland in 1967—1975. Folia For. 312: 1—27.
Mathieu, J. 1967. Einfluss von Pflanzenverband und Herkunft auf das Wachstum der Kiefer im Versuch Bremervörde. Göttingen. 117 p.
Mayer, H. 1961. Waldbauliche Güteansprache und morphologische Qualitätsmerkmale in Fohren-Dickungen zwischen Alpen und Donau. Forstwiss. Cbl. 809(10): 294—316.
Nilsson, B. 1968. Studier av några kvalitetsegenskapers genetiska variation hos tall (Pinus silvestris L). Summary: Studies of the genetical variation of some quality characters in Scots pine (Pinus silvestris L.). Rapp. Uppsats. Instn. Skogsgenet. Skogshögsk. 3: 1—117.
Nylinder, P. 1958. Synpunkter på produktionens kvalitet. Skogen 45(4): 100—102.
Nyyssönen, A. 1954. Hakkauksilla käsiteltyjen männiköiden rakenteesta ja kehityksestä. Summary: On the structure and development of Finnish pine stands treated with different cuttings. Acta For. Fenn. 60(4): 1—194.
Näslund, M. 1944. Diskussionsinlägg i anslutning till föredraget "Erfarenheter av skogsodling". Sveriges SkogsvFörb. Tidskr. 42(2): 108—116.
Ohjekirje metsittämisestä ja metsän uudistamisesta. 1978. Metsähallitus Mh. 130. 71 p.
Oksanen, A. 1978. Laatuluokitus mukaan tukkien hinnoitteluun. Metsä ja Puu 10: 26—27.
Orvér, M. 1970a. Klassificering av tallsågtimmer med objektivt mätbara faktorer. Summary: Grading of Scots pine saw timber using objectively measurable factors. Rapp. Instn. Virkeslära Skogshögsk. 65: 1—138.
— 1970b. Sågutfallets volym och värde hos tall vid olika råvarukvaliteter och varierande postningar. Summary: Lumber yield and value for Scots pine at different log qualities and gang saw set-ups. Rapp. Instn. Virkeslära Skogshögsk. 66: 1—54.
Persson, A. 1975. Ved och pappersmassa från gran och tall i olika förband. Summary: Wood and pulp of Norway spruce and Scots pine at various spacings. Rapp. Uppsats. Instn. Skogsprod. Skogshögsk. 37: 1—145.
— 1976. Förbandets inverkan på tallens sågtimmerkvalitet. Summary: The influence of spacing on the quality of sawn timber from Scots pine. Rapp. Uppsats. Instn. Skogsprod. Skogshögsk. 42: 1—122.
— 1977. Kvalitetsutveckling inom yngre förbandsförsök med tall. Summary: Quality development in young spacing trials with Scots pine. Rapp. Uppsats. Instn. Skogsprod. Skogshögsk. 45: 1—152.
Qy, . 1974. Verdien av forskjellige kvaliteter og dimensjoner av grantømmor ved skurlastproduksjon. Summary: The value for different log qualities and dimensions of Norway spruce in sawmilling. Medd. Norsk. Inst. Skogforskn. 31(7): 275—325.
Rautiainen, P. 1971. Ympäristö- ja perintötekijöiden vaikutus männyn ilmiasuun Pohjois-Karjalan piirimetsälautakunnan siemenviljelyksessä Tohmajärvellä. Summary: The effect of environmental and genetical factors on the phenotype of pine in seed orchard in North Karelia. Silva Fenn. 5(4): 336—349.
Rautiainen, O. & Räsänen, P. 1980. Männyn ja kuusen viljelytaimistojen kehitys Itä-Savossa 1968—1976. Summary: Development of Scots pine and Norway spruce plantations in Itä-Savo in 1968—1976. Folia For. 426: 1—24.
Raveala, A. 1979. Uusitut puunormit ja lujuuslajittelu. Suomen Puutalous 2: 11.
RIL 120. 1978. Puurakenteiden suunnitteluohjeet. Rakennusinsinööriliitto.
Räsänen, P. 1981. Metsäpuiden taimikasvatus ja metsänviljely. Helsingin yliopisto. Metsänhoitotieteen laitos. Tiedonantoja 29: 1—99.
Sahatavaran tukku- ja vähittäismyyntihinnasto. 1980. Suomen Sahat r.y. 30: 1—12. Helsinki.
Sarvas, R. 1956. Metsänhoidon tekniikka. Metsäkäsikirja 1: 498—564. Rauma.
Schöpf, I. 1954. Untersuchungen über Astbildung und Astreinigung der Selber Kiefer. Forstwiss. Cbl. 73(9/10): 275—290.
Siimes, F. 1957. Tukkien lenkouden vaikutus sahaustulokseen. Paperi ja Puu 39(3): 93—98.
— 1962. Tukkien koon, muodon ja laadun sekä sahausasetteen vaikutus sahaustulokseen. Paperi ja Puu 44(1): 3—16.
— 1967. The effect of specific gravity, moisture content, temperature and heating time on the tension and compression strength and elasticity properties perpendicular to the grain of Finnish pine, spruce and birch wood and the significance of these factors on the checking of timber at kiln drying. Julk. Valt. Tekn. Tutkimusl. 84: 1—86.
Takala, P. 1978. Metsänviljely. In: Tapion Taskukirja. 1978. 18. p. 124—136.
Uusitalo, M. (toim.) 1979. Metsätilastollinen vuosikirja 1977—1978. Yearbook of Forest Statistics 1977—1978. Official Statistics of Finland XVII S: 10. Folia For. 375: 1—197.
Uusvaara, O. 1974. Wood quality in plantation-

grown Scots pine. Lyhennelmä: Puun laadusta viljelymänniköissä. Commun. Inst. For. Fenn. 80 (2): 1—105.
— 1979. Viljelymänniköt — uhka sahapuun laadulle. Metsänhoitaja 2: 12—14.
— 1980a. Karsimalla ei korjata taimikkovaiheen virheitä. Metsäliiton Viesti 2: 24—25.
— 1980b. Karsimallako puun laatua parantamaan. Metsä ja Puu 1: 28—29.
— 1981a. Istutusmänniköiden laatu — kasvava ongelma. Metsä ja Puu 1: 4—5.
— 1981b. Lenkous vaivaa istutusmänniköissä. Metsälehti 5.
— 1981c. Minkä laatuista puutavaraa istutusmänniköistämme. Suomen Puutalous 2: 26—28.
— 1981d. Saammeko tulevaisuudessa hyvälaatuista sahapuuta. Sahamies 1: 8—10.
Varmola, M. 1980. Männyn istutustaimistojen ulkoinen laatu. Summary: The external quality of pine plantations. Folia For. 451: 1—21.
Vientisahatavaran lajitteluohjeet. 1979. Suomen Sahateollisuusmiesten Yhdistys. Helsinki. 50 p.
Vuokila, Y. 1972. Taimiston käsittely puuntuotannolliselta kannalta. Summary: Treatment of seedling stands from the viewpoint of production. Folia For. 141: 1—36.
— 1977. Harsintaharvennus puuntuotantoon vaikuttavana tekijänä. Summary: Selective thinning from above as a factor of growth and yield. Folia For. 298: 1—17.
— 1979a. Karsinta tulee taas. Metsänhoitaja 6: 6—7.
— 1979b. Laatunäkökohdat metsänkasvatuksessa. Metsä ja Puu 6—7: 8—9.
— 1980a. Luonnonmetsiemme hyvä laatu — pelkkä näköharhako? Suomen Puutalous 5: 8—9.
— 1980b. Metsänkasvatuksen perusteet ja menetelmät. Porvoo. 256 p.

Total of 83 references

SELOSTE

Tutkimuksen aineisto käsitti 31 etupäässä kylväen perustettua ja 30 luontaisesti syntynyttä mäntykoemetsikköä Etelä- ja Keski-Suomen alueelta. Runkoja mitattiin viljelymänniköistä 630 ja luonnonmänniköistä 1810 kappaletta, joista arvottiin kaadettaviksi vastaavasti 165 ja 150 runkoa. Kaadetuista rungoista mitattiin rungon laatutunnuksia kuten eri oksaisuusvyöhykkeet, oksien paksuus, vikaisuudet ja rungon kapeneminen. Kannon korkeudelta otetuista näytteistä määritettiin puun sisäisiä laatutunnuksia. Tyviosa valmistettiin tukeiksi, koesahattiin ja sahaustulos laatuluokitettiin.

Tutkimuksen tavoitteena oli selvittää koesahausten avulla viljelymäntyrunkojen tyvitukeista saatavan sahatavaran laatu ja arvo sekä niihin vaikuttavat tekijät. Laatua verrattiin vastaavan tyyppisistä luonnonmänniköistä saatuihin tuloksiin.

Tutkimuksen tärkeimmät tulokset olivat seuraavat:

1. Oksattoman rungonosan muodostuminen alkoi viljelymänniköissä myöhemmin kuin luonnomänniköissä ja karsiutuminen oli metsikön iän lisääntyessäkin hitaampaa. Myös suhtessa rungon pituuteen oli virheettömän ja oksakyhmyjä käsittävän rungonosan pituus viljelymänniköissä alhaisempi kuin luonnonmänniköissä, mutta kuivaoksainen rungonosa pidempi ja latvus lyhyempi.

2. Luonnonmäntyrunkojen oksat olivat ohuempia kuin viljelymäntyrunkojen oksat etenkin rungon alaosassa, mutta rungon yläosassa erot osittain hävisivät. Tyvitukkien suurimpien oksien paksuus sekä mitattujen oksien keskipaksuus kasvoivat tukin laadun heiketessä kumpaakin alkuperää olevassa aineistossa. Viljelymäntytukeissa oksat olivat myös keskimäärin paksumpia kuin luonnonmänniköistä valmistetuissa tukeissa.

3. Viljelymänniköistä saadut tyvitukit olivat heikkolaatuisempia kuin luonnonrunkotukit sekä pelkän oksaisuuden että todellisen luokituksen mukaan arvostellen. Tukin laatu heikkeni eli laatuindeksi nousi jyrkästi luston leveyden kasvaessa ytimen ympäristössä. Luston paksuuden ylittäessä noin 3,5 mm:n rajan tukin laatu oli keskimäärin heikompi kuin kolmannen luokan laatuvaatimukset edellyttävät.

4. Saman laatuluokan viljelymäntytukista saatiin vähemmän u/s-luokan mutta enemmän heikompien laatuluokkien sahatavaraa kuin saman arvoiseksi luokitellusta luonnonmäntytukista. Sahatavaran u/s-prosentti laski ja heikompien laatujen osuus nousi luston levetessä ytimen ympäristössä. Kriittinen raja viljelymäntyrunkojen sydäntavarakappaleissa oli luston leveys 3,5 mm, jonka jälkeen ei enää saatu u/s-sahatavaraa.

5. Silmävaraisen lujuusluokituksen mukaan T40-, T30-, T24-, T18-lujuusluokkien osuudet sekä hylkyosuus olivat viljelymänniköistä peräisin olevissa soiroissa ja lankuissa 14, 21, 38, 20 ja 7 % sekä luontaisessa sahatavarassa vastaavasti 22, 35, 35, 5 sekä 3 %.

6. Viljelymäntyrunkojen tyvitukeista sahatut soirot ja lankut, laudat sekä sahatavara yhteensä olivat yksikköhinnaltaan keskimäärin 7,0 22,2 ja 9,1 % alhaisempia kuin vastaavat luonnonmäntytukeista saadut sahatavaralajit. Yksikköhinnan vaihteluita parhaiten selittäviä suureita ja laatutunnuksia olivat tukin tilavuus, u/s-prosentti sekä rungon kasvunopeus. Kun tilavuus jätettiin pois selittävien tekijöiden joukosta, kasvunopeuden, erityisesti ytimen läheisten lustojen leveyden, selitysarvo nousi.

7. Eri alkuperää olevien aineistojen vertailukelpoisuutta vähensi osittain viljelymetsiköiden sijoittuminen keskimääräistä paremmille kasvupaikoille, sekä niiden luontaisia metsiköitä jonkin verran alhaisempi ikä. Runkojen ja tukkien kokojakaumat vastasivat sen sijaan hyvin toisiaan aineistoissa.

UUSVAARA, O. 1985. The quality and value of sawn goods from plantation-grown Scots pine. Seloste: Viljelymänniköistä saadun sahatavaran laatu ja arvo. Commun. Inst. For. Fenn. 130: 1—53.

ODC 832.10 + 851 + 228.7 + 174.7 *Pinus sylvestris*
ISBN 951-40-0697-6
ISSN 0358-9609

UUSVAARA, O. 1985. The quality and value of sawn goods from plantation-grown Scots pine. Seloste: Viljelymänniköistä saadun sahatavaran laatu ja arvo. Commun. Inst. For. Fenn. 130: 1—53.

The material of the study comprised of 31 experimental pine stands established by planting and 30 stands of natural origin in Southern and Central Finland. The butt logs of the stems were test sawn and the quality and grade of sawn goods were determined. Branchiness in particular, but also stem defects made the butt logs and sawing yield of pine plantations poorer in quality than logs from naturally grown trees. The u/s-percentage of sawn goods decreased and the share of poorer qualities increased when the annual ring widened in the vicinity of the pith.

Author's address: The Finnish Forest Research Institute, Unioninkatu 40 A, SF- 00170 Helsinki, Finland.

ODC 832.10 + 851 + 228.7 + 174.7 *Pinus sylvestris*
ISBN 951-40-0697-6
ISSN 0358-9609

UUSVAARA, O. 1985. The quality and value of sawn goods from plantation-grown Scots pine. Seloste: Viljelymänniköistä saadun sahatavaran laatu ja arvo. Commun. Inst. For. Fenn. 130: 1—53.

The material of the study comprised of 31 experimental pine stands established by planting and 30 stands of natural origin in Southern and Central Finland. The butt logs of the stems were test sawn and the quality and grade of sawn goods were determined. Branchiness in particular, but also stem defects made the butt logs and sawing yield of pine plantations poorer in quality than logs from naturally grown trees. The u/s-percentage of sawn goods decreased and the share of poorer qualities increased when the annual ring widened in the vicinity of the pith.

Author's address: The Finnish Forest Research Institute, Unioninkatu 40 A, SF- 00170 Helsinki, Finland.

Tilaan kortin kääntöpuolelle merkitsemäni julkaisut (julkaisun numero mainittava).

Please send me the following publications (put number of the publication on the back of the card).

Nimi
Name ____________________

____

____

Osoite
Address ____________________

____

____

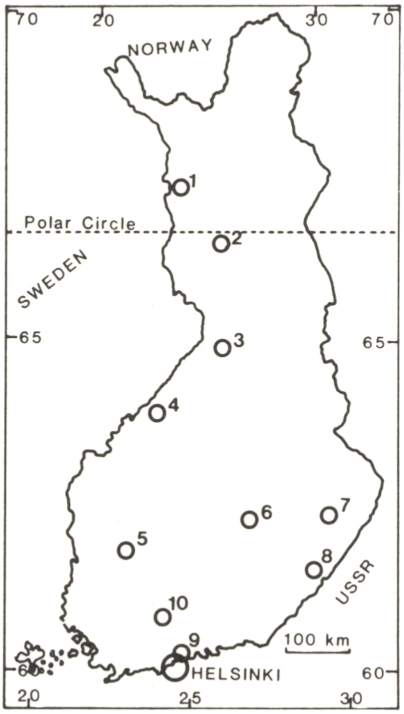
____

Metsäntutkimuslaitos
Kirjasto/*Library*
Unioninkatu 40 A
SF-00170 Helsinki 17
FINLAND

Folia Forestalia

Communicationes Instituti Forestalis Fenniae

Huomautuksia
Remarks



THE FINNISH FOREST RESEARCH INSTITUTE

DEPARTMENTS (Helsinki)

Administration Office
Information Office
Experimental Forest Office
Dept. of Soil Science
Dept. of Peatland Forestry
Dept. of Silviculture
Dept. of Forest Genetics
Dept. of Forest Protection
Dept. of Forest Technology
Dept. of Forest Inventory and Yield
Dept. of Forest Economics
Dept. of Mathematics

RESEARCH STATIONS

1 Kolari
2 Rovaniemi
3 Muhos
4 Kannus
5 Parkano
6 Suonenjoki
7 Joensuu
8 Punkaharju
9 Ruotsinkylä
10 Ojajoki

FACTS ABOUT FINLAND

Total land area: 304 642 km^2 of which 60—70 per cent is forest land.

Mean temperature, °C:	Helsinki	Joensuu	Rovaniemi
January	-6,8	-10,2	-11,0
July	17,1	17,1	15,3
annual	4,4	2,9	0,8
Thermal winter (mean temp. < 0°C):	20.11.—4.4.	5.11.—10.4.	18.10.—21.4.

Most common tree species: Pinus sylvestris, Picea abies, Betula pendula, Betula pubescens

THE FINNISH FOREST RESEARCH INSTITUTE ● METSÄNTUTKIMUSLAITOS

Communicationes Instituti Forestalis Fenniae

127 Tamminen, P. Butt-rot in Norway spruce in southern Finland. Seloste: Kuusen tyvilahoisuus Etelä-Suomessa.

128 Saarenmaa, H. Within-tree population dynamics models for integrated management of *Tomicus piniperda* (Coleoptera, Scolytidae). Seloste: Pystynävertäjän lisääntymiskauden populaatiodynamiikkamallit tuhojen integroitua hallintaa varten.

129 Sepponen, P. The ecological classification of sorted forest soils of varying genesis in northern Finland. Seloste: Syntytavaltaan erilaisten lajittuneiden kangasmetsämaiden ekologinen luokittelu Pohjois-Suomessa.

130 Uusvaara, O. The quality and value of sawn goods from plantation-grown Scots pine. Seloste: Viljelymänniköistä saadun sahatavaran laatu ja arvo.

ISBN 951-40-0697-6
ISSN 0358-9609