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Silva Fennica

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Silva Fennica, joka vuosina 1926–66 ilmestyi sarjajulkaisuna (niteet 1–120), on vuoden 1967 alusta lähtien neljännesvuosittain ilmestyvä aikakauskirja. Suomen Metsätieteellinen Seura julkaisee myös *Acta Forestalia Fennica*-sarjaa vuodesta 1913 (nide 1) lähtien.

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WOOD ANATOMY AND PHYSICAL PROPERTIES OF THE WOOD AND BARK IN BETULA NANA GROWING IN FINLAND

K. M. BHAT and MATTI KÄRKKÄINEN

Seloste

SUOMALAISEN VAIVAISKOIVUN PUUAINEEN ANATOMIA SEKÄ PUUN JA KUOREN FYSIKAALISIA JA ANATOMISIA OMINAISUUKSIA

Saapunut toimitukselle 15. 2. 1982

Eighty *Betula nana* samples were collected from three swamp sites situated in various part of Finland. A butt portion was cut from each dwarf shrub and measured in the laboratory. The average number of growth rings was 12 and the average diameter of the sprouts 6 mm.

The basic density of the wood was 457 kg/m^3, that of the bark 544 kg/m^3, and that of unbarked shoots 485 kg/m^3. The moisture content of oven-dry weight was 62 % in wood and 91 % in bark. The proportion of bark was high, 32 . . . 38 % of weight or volume.

The vessel elements were short compared with other birch species, 0,25 mm. Their average tangential diameter was 37 μm. The proportion of vessels was low, 15 %. On the other hand the proportion of rays was high, 15 %. Thus the proportion of fibres was 70 %. The fibres were short, 0,43 mm, and comparatively thin.

1. INTRODUCTION

Dwarf birch, *Betula nana* L., is a small bush or dwarf shrub common in Finland and other northern countries. Actually it is an arctic species common even in Greenland (e.g. Miller 1975). In Finland it has no significance in forestry, but in the northernmost part of the country it is an important mediator of energy. In southern Finland it grows mainly on peatland, and on some types of swamps it is very typical (dwarf shrub pine swamps) (see Eurola 1962, p. 55).

In cytotaxonomy, *B. nana* is diploid (2n=28) like *B. pendula* and deviating from *B. pubescens* (2n=56). However, the crossings with other birch species are common (e.g. Kihlman 1890, p. 162, Kallio 1978, Kallio and Mäkinen 1978, Sulkinoja et al. 1981).

The physiology, especially photosynthesis and respiration, of the species growing in the Nordic countries and the Alps has been studied thoroughly (Ungerson and Scherdin 1964, 1965). The anatomy of *B. nana* growing in the Soviet Union was described by Barykina and Kudrjašev (1973) and of that growing in Greenland by Miller (1975). However, as no anatomic data are available on *B. nana* growing in Finland, this study was undertaken. As there is no information on the physical properties of the wood and bark, some physical features were included in the study.

This is the last paper of the present birch series (Bhat 1980a, b, Bhat and Kärkkäinen 1980, 1981a, b, c, d, Bhat et al. 1981). The material of this study was collected by Kärkkäinen with the assistance of Pekka Saranpää. The laboratory work and computations were done by Leena Kunnari, the drawings by Leena Muronranta, and typing by Aune Rytkönen. The English language was checked by L. A. Keyworth. The anatomical part of the study was written by Bhat and the other parts by Kärkkäinen. Valuable comments were made by Juhani Salmi and Terho Valanne.

2. MATERIAL AND METHODS

Three dwarf shrub pine swamp stands were selected from various parts of the country for the study (Fig. 1). The swamps were in natural condition although some dust fertilization and draining effect was possible due to nearby roads.

The samples were collected during the growing season at the end of June and beginning of July. 23 . . . 30 shoots of *Betula nana* were cut from each location. They represented various height classes of the shrubs. The total number of samples was 80. A 10 cm long butt portion was cut from each shoot for the laboratory measurements. Thus the results refer only to the butt parts of the plants.

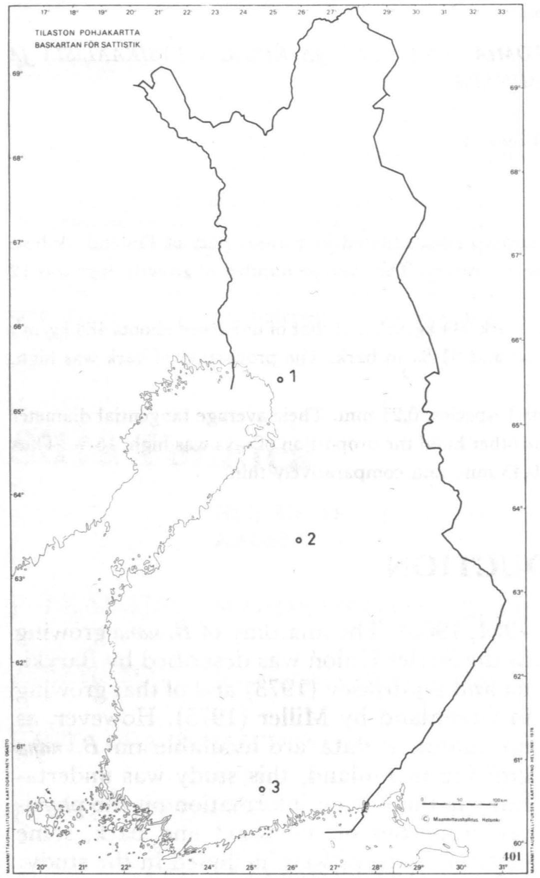

Fig. Location of the sample areas.
Kuva 1. Näytealueiden sijainti.

In the laboratory the basic densities of the bark and wood were determined. The water displacement method was used for the volume determination (Olesen 1971). The volume of the unbarked sample was measured first and then, after removing the bark, the volume of wood. The difference was the volume of bark. The weights of wood and bark were taken before and after drying, and the moisture contents of the components were obtained in this way. The bark percentage was computed both on a weight and a volume basis.

Using a sliding microtome, all the 80 samples were sectioned in transverse, radial and tangential planes. The sections were stained with safranin and mounted in glycerine for the microscopic study. Growth rings were counted under the microscope to determine the age of the sample shoots. Ring width was measured with an ocular micrometer. From each locality 6 samples were examined for anatomical characteristics. Thirty observations were made on each sample. Thus 180 observations were considered for each anatomical feature.

For the measurement of percentage of tissues, the technique reported earlier (Bhat and Kärkkäinen 1981a) was used. In addition, macerations were performed on two samples from each locality to determine the length of the fibres and vessel elements. Using an ocular micrometer, 30 measurements were made from each sample.

3. RESULTS AND DISCUSSION

31. Physical properties

The average number of growth rings was only 12 in the samples, and the average diameter of the sprouts about 6 mm. Thus the material was quite young compared with mature wood of other Finnish birch species, *Betula pubescens, B. pendula* and *B. tortuosa*. However, the samples investigated were mature in the sense that they were cut from the butt of the dwarf shrubs, and even the oldest samples were under 20 years. No older plant was found. It is possible that *B. nana* is comparatively short-lived.

In view of the low age, the basic densities of wood and bark in Table 1 are relatively high. Compared with mature wood of other birch species, however, the densities are a little lower (Hakkila 1966, Bhat and Kärkkäinen 1981c). As in birch species as a rule, the basic density of bark was higher than that of comparable stemwood (Tamminen 1970, Gislerud 1974, Lönnberg 1975, Bhat and Kärkkäinen 1981c).

The moisture content was low in wood, 62,1 %, and extremely high in bark, 90,6 %. The comparable saturation degrees (moisture content of the maximum possible) were 40,3 % and 76,1 %, respectively. The results are typical for the growing season: the moisture content of wood is lower in the growing season than in dormancy, but that of bark is higher (Srivastava 1964, p. 251, Sachsse 1969, 1971, Phillips and Schroeder 1973).

The bark percentages measured from oven-dry and green weight and from volume were all high. Due to differences in the moisture content and basic density of wood and bark the lowest percentages were in the volume and highest in the green weight. The percentages were of the same magnitude as in one-year shoots of *B. pubescens* (Bhat et al. 1981).

In some cases there was variation between the three sample areas. On the other hand, the age or diameter of the sample affected the properties. These comparisons are made in Figs. 2 . . . 9.

The effect of geographical location on the basic density of the wood was small. The basic density decreased with the increasing diameter, but only to a limited extent (Fig. 2). This decrease possibly reflects the effect of growth rate. For bark the effect was the reverse, and there were clear differences bet-

Table 1. Means and standard deviations of some physical characteristics of *Betula nana* (n = 80).
Taulukko 1. Vaivaiskoivun fysikaalisten tunnusten keskiarvoja ja standardipoikkeamia (n = 80).

Feature – *Ominaisuus*	$\bar{x}$	s
Basic density of wood, kg/m^3 *Puun kuiva-tuoretiheys, kg/m^3*	456,7	27,1
Basic density of bark, kg/m^3 *Kuoren kuiva-tuoretiheys, kg/m^3*	544,3	32,1
Basic density of wood and bark, kg/m^3 *Kuorellisen puun kuiva-tuoretiheys, kg/m^3*	485,0	23,6
Wood moisture content of oven-dry weight, % *Puuaineen kosteussuhde, %*	62,1	7,8
Bark moisture content of oven-dry weight, % *Kuoren kosteussuhde, %*	90,6	9,2
Bark percentage of oven-dry weight *Kuoren osuus kuivasta massasta, %*	35,5	5,8
Bark percentage of green weight *Kuoren osuus tuoreesta massasta, %*	38,2	6,3
Bark percentage of volume *Kuoren osuus tilavuudesta, %*	31,5	4,8

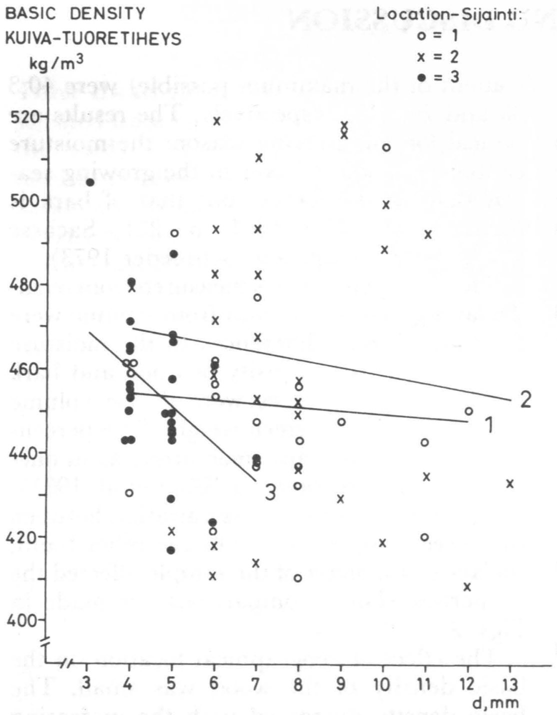

Fig. 2. Basic density of wood in the areas according to the diameter over bark.

Kuva 2. Puuaineen kuiva-tuoretiheys eri alueilla kuorellisen läpimitan mukaan.

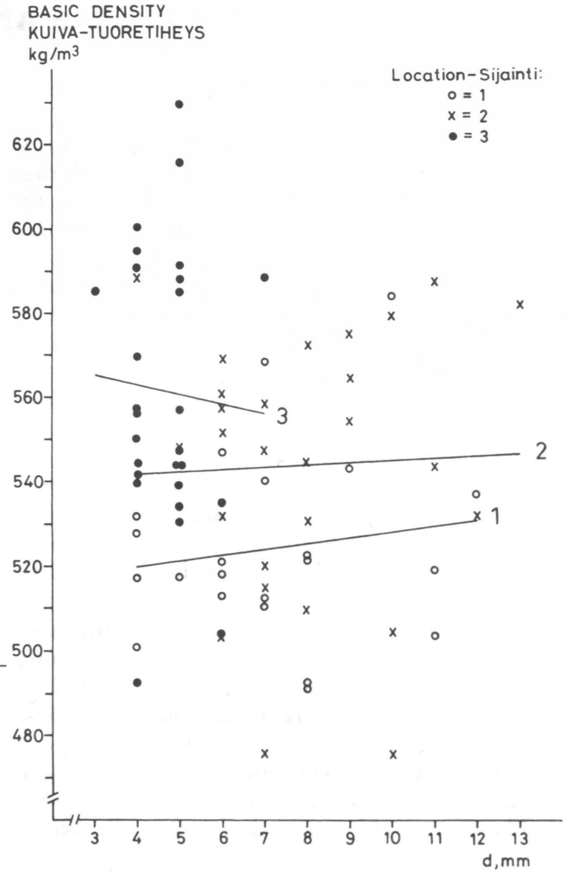

Fig. 3. Basic density of bark in the areas according to the diameter over bark.

Kuva 3. Kuoren kuiva-tuoretiheys eri alueilla kuorellisen läpimitan mukaan.

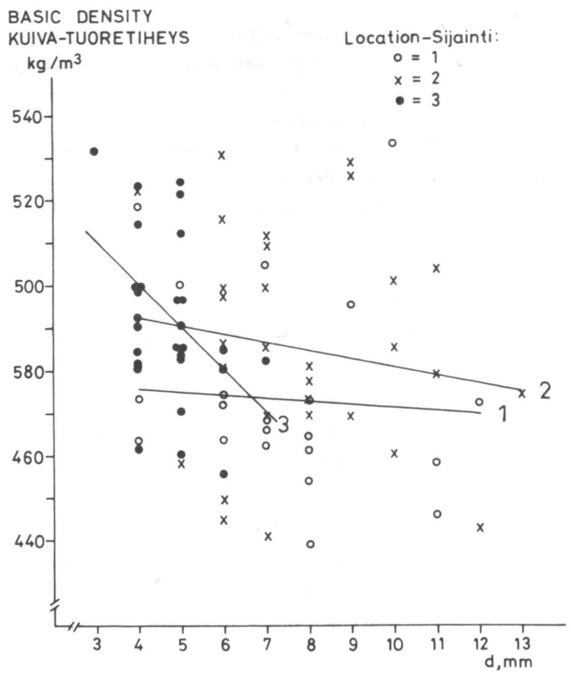

Fig. 4. Basic density of wood and bark of unbarked samples in the areas according to the diameter over bark.

Kuva 4. Kuorellisen puun kuiva-tuoretiheys eri alueilla kuorellisen läpimitan mukaan.

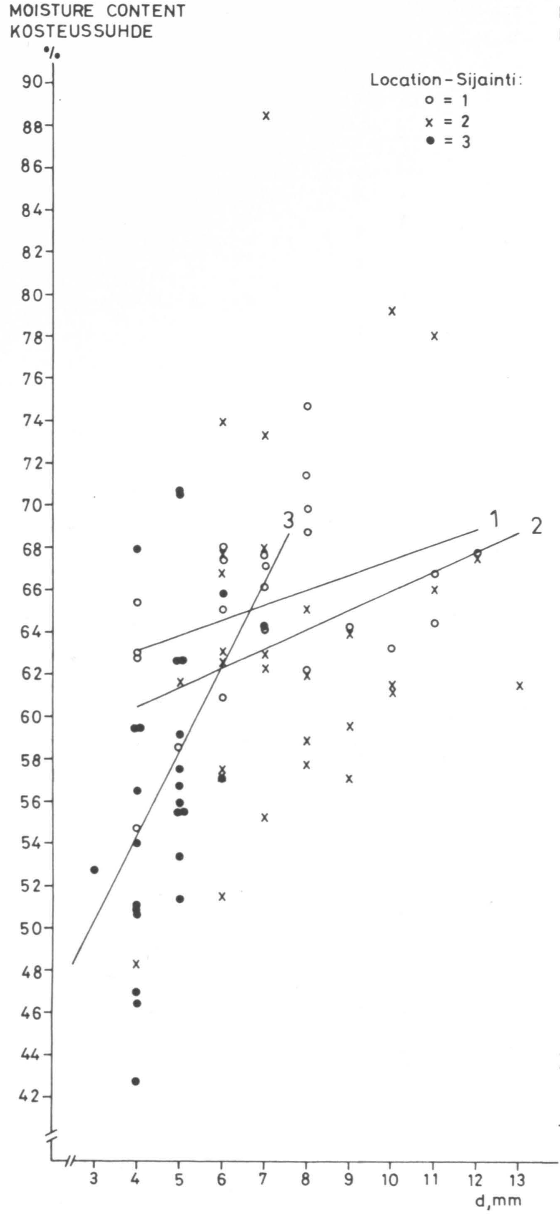

Fig. 5. Moisture content (oven-dry weight) of wood in the areas according to the diameter over bark.

Kuva 5. Puuaineen kosteussuhde eri alueilla kuorellisen läpimitan mukaan.

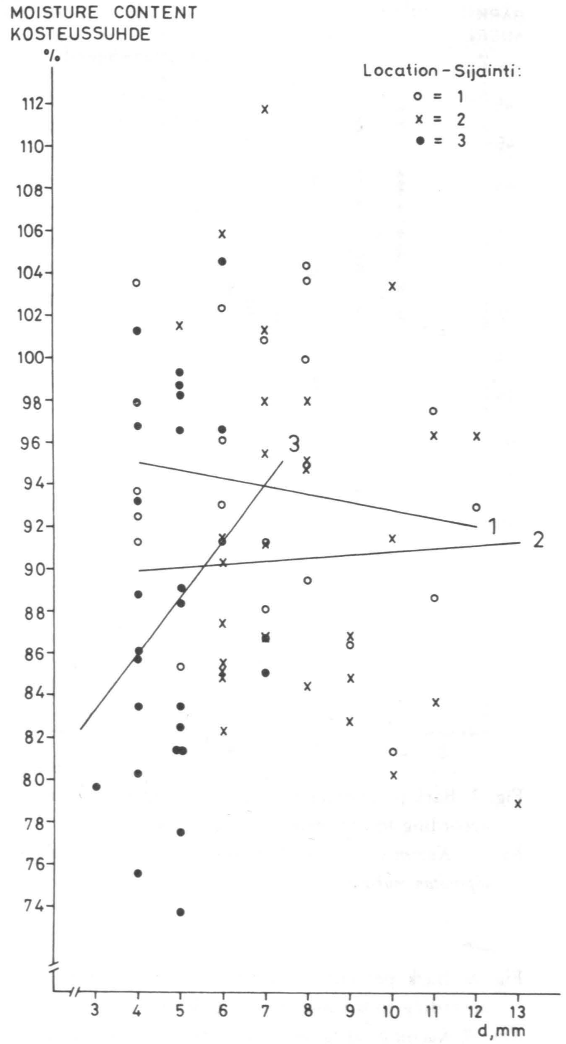

Fig. 6. Moisture content (oven-dry weight) of bark in the areas according to the diameter over bark.

Kuva 6. Kuoren kosteussuhde eri alueilla kuorellisen läpimitan mukaan.

ween the locations: the basic density of the bark increased from the north to the south (Fig. 3). The unbarked samples did not differ much (Fig. 4).

The moisture content of wood increased distinctly with diameter. The differences between locations were small, although the rate of increase was highest in the southernmost site (Fig. 5). The bark material showed no consistent behaviour, but the increase with diameter was clear in the south (Fig. 6).

The bark percentages decreased as the

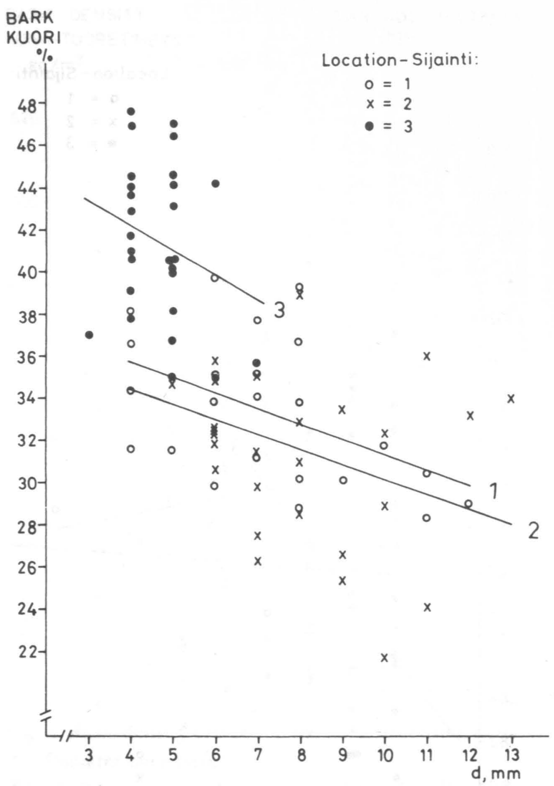

Fig. 7. Bark percentage of oven-dry weight in the areas according to the diameter over bark.

Kuva 7. Kuoren osuus kuivasta massasta eri alueilla kuorellisen läpimitan mukaan.

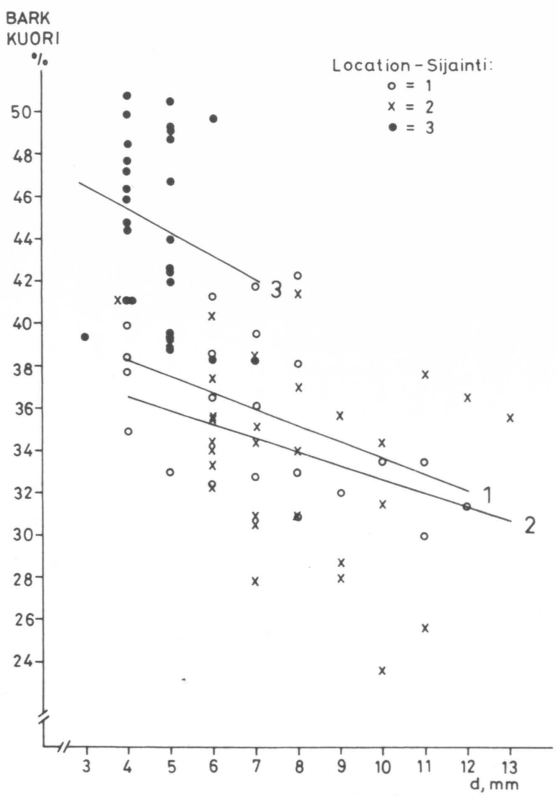

Fig. 8. Bark percentage of green weight in the areas according to the diameter over bark.

Kuva 8. Kuoren osuus tuoreesta massasta eri alueilla kuorellisen läpimitan mukaan.

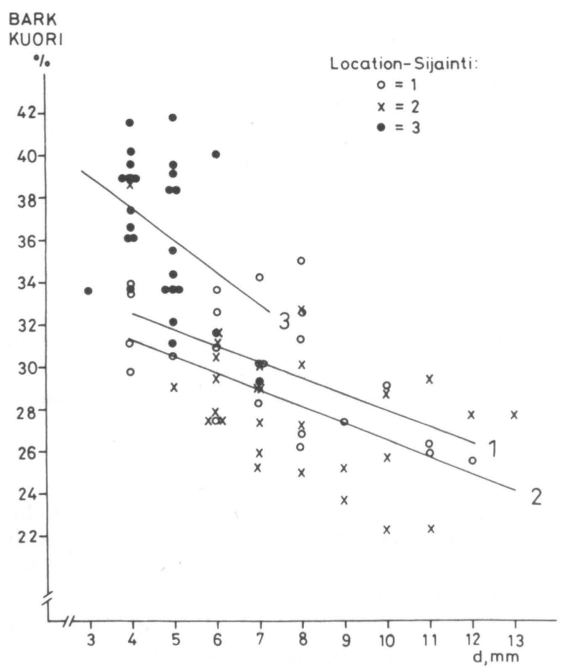

Fig. 9. Bark percentage of volume in the areas according to the diameter over bark.

Kuva 9. Kuoren osuus tilavuudesta eri alueilla kuorellisen läpimitan mukaan.

diameter increased. The proportion of bark was at its highest in the southernmost site. The difference was higher in weight percentage (Figs. 7 and 8) than in volume percentage (Fig. 9) due to differences in the basic density of bark.

The differences between sites were so small that in practice *Betula nana* can be regarded as very homogeneous in Finland. However, no data were available from Lapland.

32. Anatomical features

According to the anatomical measurements (Table 2) the growth rate of *B. nana* is extremely low even allowing for the poor swamp sites. On the other hand, the biomass production can be high per hectare as the number of *B.nana* shoots is large.

The number of vessels per mm^2 was extremely high compared with other birch species, but the average diameter was much lower. Thus the proportion of vessels was of the same magnitude as in other birch species or smaller (Ollinmaa 1955, Bhat and Kärkkäinen 1981a, c). The vessel elements were short compared with other birch species (Bhat and Kärkkäinen 1981b).

An interesting taxonomic feature is that the number of bars in perforation plates lay between the averages for *B. pendula* and *B. pubescens,* but nearer *B. pendula* (Bhat and Kärkkäinen 1980).

The fibres were very much shorter and their diameter a little smaller than in other birch species (e.g. Bhat 1980b). Thus *B. nana* is not suitable for pulping. However, the proportion of fibres was of the same magnitude (Ollinmaa 1955, Bhat and Kärkkäinen 1981c). In contrast, the number of rays per linear tangential mm and ray per-

Table 2. Means and standard deviations of some quantitative anatomical characteristics of *Betula nana* (n = 80).
Taulukko 2. Vaivaiskoivun anatomisten tunnusten keskiarvot ja standardipoikkeamat (n = 80).

Feature – *Ominaisuus*	$\bar{x}$	s
Ring width, mm *Vuosiluston leveys, mm*	0,252	0,156
Vessel number per mm^2 *Putkiloita mm^2 kohti*	261,1	42,6
Vessel percentage *Putkiloiden osuus, %*	15,4	6,7
Tangential vessel diameter, μm *Putkilon tangentiaalinen läpimitta, μm*	37,1	12,1
Vessel element length, mm *Putkilosolun pituus, mm*	0,289	0,062
Number of bars per perforation plate *Putkilosolun aukonvälejä, kpl*	16,0	3,4
Tangential fibre diameter, μm *Kuidun tangentiaalinen läpimitta, μm*	19,0	1,9
Fibre length, mm *Kuidun pituus, mm*	0,431	0,052
Fibre wall thickness, μm *Kuidun seinämän paksuus, μm*	2,5	0,4
Fibre percentage *Kuitujen osuus, %*	70,0	6,3
Ray number per linear mm *Ydinsäteitä tangentiaalista mm kohti, kpl*	14,5	2,1
Ray percentage *Ydinsäteiden osuus, %*	14,6	1,4

centage were high in comparison with other birch species.

The anatomical description of *B. nana* grown in Finland is:

Growth rings:	Distinct, delimited with 1–2 layered parenchyma. Sometimes not well defined.
Vessels:	Typically diffuse, less commonly semi-ring porous. Very numerous, 140 ... 340 per mm^2, solitary or mostly radial multiples of 2–4 or even up to 10. Sometimes clusters of 2–3 or 4. Tangential diameter 9–45 μm with 3–4 μm thick walls. Vessel element length 160 . . . 410 μm with short tails, at one or both ends. Oval or oblong or sometimes angular. Perforation plates exclusively of scalariform type, with 8–23 bars. Intervessel pitting minute, 2–3 μm in tangential diameter, almost alternate, circular to oval. Tyloses and gummy infiltrations absent.
Parenchyma:	1–2 cells wide apotracheal concentric bands delimiting the growth rings.
Fibres:	Angular to circular, more or less radially aligned in cross section, maximum diameter up to 22 μm, wall thickness 3–5 μm, very short, 290 . . . 650 μm in length, non-septate.
Rays:	1, 2 or 3 seriate, often aggregate rays present, Kribs' type homogeneous I to heterogeneous I, 12–17 per linear mm. (1) Uniseriate rays up to 14 μm wide, up to 460 μm or 26 cells high. (2) Multiseriate rays up to 27 μm or 3 cells wide and up to 440 μm or 22 cells high.
Pith flecks:	Common.

33. Microscopic identification of *B.nana* and other Finnish birch species

On the basis of this paper and others belonging to this birch series the following identification key can be presented. However, its applicability has not been tested against independent materials. In this sense, it can prove to be preliminary.

1. The average number of bars per perforation plate is up to 17, see 2
1. The average number of bars per perforation plate is more than 17, see 3
2. The growth rings are very narrow ($\bar{x}$ = 0,25 mm), no more than 20 in number. The vessels are numerous (x = 260 per mm^2), very small and short ($\bar{x}$ = 37 μm tangential diameter and 0,30 mm length), rays homogeneous to heterogeneous *Betula nana*
2. Growth rings fairly wide, vessels fairly numerous ($\bar{x}$ = 75 per mm^2), medium sized to small and fairly long ($\bar{x}$ = 70 μm tangential diameter and 0,75 mm long), rays almost homogeneous *Betula pendula*
3. Vessels relatively large but few in number, average number of bars per perforation plate is the largest ($\bar{x}$ = 21 *Betula pubescens*
4. Vessels smaller and more numerous (120–130 per mm^3), number of bars smaller (x = 17) *Betula tortuosa*

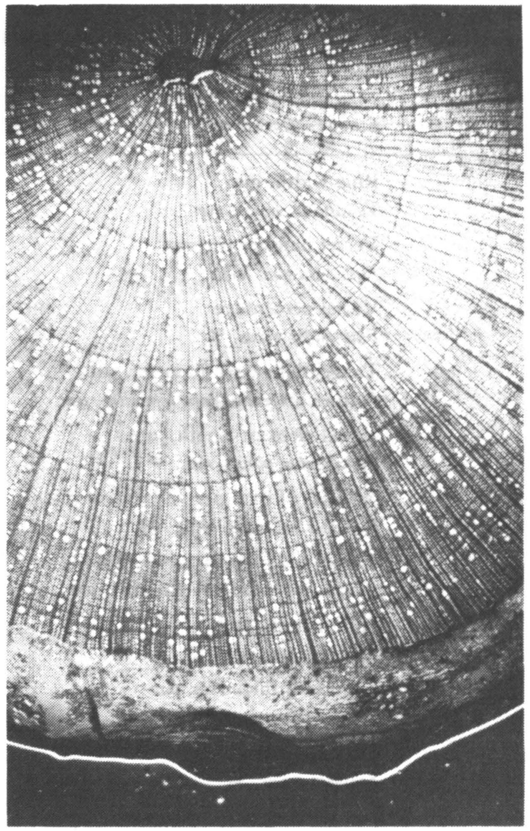

Fig. 10. Transverse section of unbarked *Betula nana*.
Kuva 10. Poikkileikkaus kuorellisesta vaivaiskoivusta.

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SELOSTE

SUOMALAISEN VAIVAISKOIVUN PUUAINEEN ANATOMIA SEKÄ PUUN JA KUOREN FYSIKAALISIA JA ANATOMISIA OMINAISUUKSIA

Koska vaivaiskoivun (*Betula nana* L.) anatomiasta ja fysikaalisista ominaisuuksista on vähän tietoja, kerättiin kasvukauden 1981 aikana kolmelta eri paikkakunnalta (Kuivaniemi, Pyhäjärvi ja Mäntsälä) isovarpuisen rämeen vaivaiskoivuista yhteensä 80 näytettä, jotka otettiin pensaan tyviosasta. Keskimääräinen vuosilustojen lukumäärä oli 12 ja rangan läpimitta 6 mm.

Keskimääräinen puuaineen kuiva-tuoretiheys oli 457 kg/m^3, kuoren 544 kg/m^3 sekä kuorimattoman puun 485 kg/m^3. Kosteussuhde oli puuaineessa 62 % ja kuoressa 91 %. Kuoren osuus oli suuri, 32 . . . 38 % riippuen siitä, laskettiinko kuoren osuus massan vai tilavuuden mukaan.

Anatomisissa ominaisuuksissa oli silmiinpistävin ominaisuus vuosilustojen ohuus: keskiarvo oli 0,25 mm. Putkiloita oli muihin koivulajeihin verrattuna erittäin runsaasti pinta-alayksikköä kohti (keskiarvo 260 kpl/mm^2), mutta ne olivat pieniläpimittaisia (37 μm) ja lyhyitä. Myös kuidut olivat lyhyitä (0,43 mm) ja verraten ohuita. Näin ollen puuaine sopii heikosti sellun valmistukseen.

Putkiloiden osuus puuaineen tilavuudesta, 15 %, on tavanomainen tai sitä alhaisempi eri koivulajien vertailussa. Kuitujen osuus 70 % on tavanomainen. Sitä vastoin ydinsäteitä oli muihin koivulajeihin verrattuna runsaasti, 15 %.