*SILVA FENNICA VOL.* 15, 1981 *N:o* 2: 148–155

# WOOD ANATOMY AND PHYSICAL PROPERTIES OF WOOD AND BARK IN *BETULA TORTUOSA* LEDEB.

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*SELOSTE:*

*TUNTURIKOIVUN PUUAINEEN ANATOMIA SEKÄ PUUN JA KUOREN FYSIKAALISIA JA ANATOMISIA OMINAISUUKSIA*

Saapunut toimitukselle 1980-11-21

Ten mountain birches (*Betula tortuosa* Ledeb.) aged on an average 39 years were sampled in northern Lapland and some properties were measured from breast height. The average green density of wood was 859 kg/m³ and that of bark 971 kg/m³. The basic densities were 520 and 559 kg/m³, respectively. These basic densities are higher than those in *B. pubescens* Ehrh. or *B. pendula* Roth.

The basic density increased only a little from the pith to the surface. The number of bars in the perforation plates of the vessels increased considerably in the same direction. The average number of bars was 17.3, which is half way between *B. pubescens* and *B. pendula*.

## 1. INTRODUCTION

Mountain birch, *Betula tortuosa* Ledeb., is a small tree or bush very common in the northernmost part of Finland and neighbouring areas (HÄMET-AHTI 1963, KALLIO and MÄKINEN 1978). As its growth is extremely low, the stem small and crooked and the mode of growth often polycormic, its role in forestry is negligible. However, the species has a great local importance. The wood is used as fuel, especially so in the past (HEIKINHEIMO 1921, MIKOLA 1942, KALLIOLA 1941). Besides this, the semi-domesticated reindeer uses mountain birch in the summer as the protein content of the buds and leaves is high (HAUKIOJA and HEINO 1974). For the whole ecosystem, mountain birch is the most important mediator of energy. Numerous invertebrate species use the leaves (HAUKIOJA et al. 1973, KOPONEN 1973 a, b). Massive destruction has occurred. For example, in 1965–1966 *Oporinia autumnata* (Mkh.) (Lep., Geometridae) destroyed over 500 000 ha of mountain birch forest in Lapland, some areas so totally that they may remain treeless (NUORTEVÄ 1966, KALLIO and LEHTONEN 1973).

In taxonomy, the status of mountain birch is questionable. The chromosome number is 56 or the same as in *B. pubescens* Ehrh. Very often the mountain birch is regarded as a subspecies or a form of the latter. This view is held traditionally in forestry (e.g. KUJALA 1929, 1946). Some features are different, however, as VAARAMA and VALANNE (1973) have described. For photographs, see LEHTONEN (1979).



To the best of the authors' knowledge, there are no data whatsoever on the anatomy and physical properties of the wood of mountain birch. Therefore, this study was undertaken to investigate these characteristics of the species.

The material was kindly collected by Tore Högnäs from the National Board of Forestry. The laboratory work was performed for the most part by K. M. Bhat and partly by Matti Rytkönen. The computations were made by Raili Voipio and Tarja Björklund, drawings by Tarja Björklund and Leena Muronranta, and the manuscript was typed by Raija Siekkinen. The original manuscript was written by Matti Kärkkäinen and checked by both authors. The language was revised by L. A. Keyworth. Valuable comments were made by Paavo Kallio and Jyrki Raulo.

## 2. MATERIAL

Ten trees of mountain birch were cut in September, 1980, from the mountain area of Inari. The age of the trees at breast height (1,3 m from the ground) varied between 24 and 53 years, average 39 years. The mean diameter under bark was only 53 mm. Thus, the average ring width was as small as 0,7 mm.

In the laboratory, the green and basic density of bark and wood and their moisture content was measured from the disks. Besides this, a narrow strip was cut through the centre of each disk. The strip was cut into pieces, the number of which was between 2 and 5 from pith to the surface. The basic density and the distance from the pith to the outermost border was measured from each piece.

In addition to this, five sample blocks were prepared from the pith outwards in each disk for anatomical studies. All the sample blocks were sectioned on a radial plane using a sliding microtome for counting the number of bars in the perforation plates. Fifty observations were made on each sample making a total of 2500 observations.

Ten samples, each representing one tree, were sectioned in transverse and tangential planes and stained with safranin to study the anatomy.

## 3. RESULTS AND DISCUSSION

### 3.1 Density and moisture content

The green density of the wood material was quite low, on average 859 kg/m³ (s = 35,3). As a rule, the green density of unbarked or barked industrial birch is over 900 kg/m³ in both northern and southern Finland (HEISKANEN 1959, PETERSON and WINQVIST 1960, TUOVINEN 1965, NISULA 1961, 1967, FINNE 1972). The green density of the bark was 971 kg/m³ (s = 37,4). This figure seems to be exceptionally high (e.g. TAMMINEN 1970 and LÖNNBERG 1975 obtained about 900 kg/m³).

The basic density of the wood of mountain birch seems to be higher than that of two other birch species *Betula pubescens* and *B. pendula*. The average for the wood material was 520 kg/m³ (s = 27,2) which is about 5 per cent higher than in the industrial raw material in southern Finland (HAKKILA 1966). The basic density of the bark, too, was high, 559 kg/m³ (s = 24,9). The basic density of bark in other birch species is also higher than that of comparable stemwood (TAMMINEN 1970, GISLERUD 1974, LÖNNBERG 1975). However, it should be noted that in birch branches the basic density of bark is lower than that of wood and is under 500 kg/m³ (GISLERUD 1974, KÄRKKÄINEN 1976).

In mountain birch the presence of bark increases the common basic density of wood and bark. The effect is distinct as the proportion of bark is very high. The average percentage for mountain birch was 22,4 (s = 6,1) calculated from the oven-dry weight of wood and bark. This is more than has been found in other birch species of comparable size (SIMOLA 1977).

The average moisture content was 65,4 per cent of dry weight (s = 6,6) for wood and 74,0 (s = 8,8) for bark.

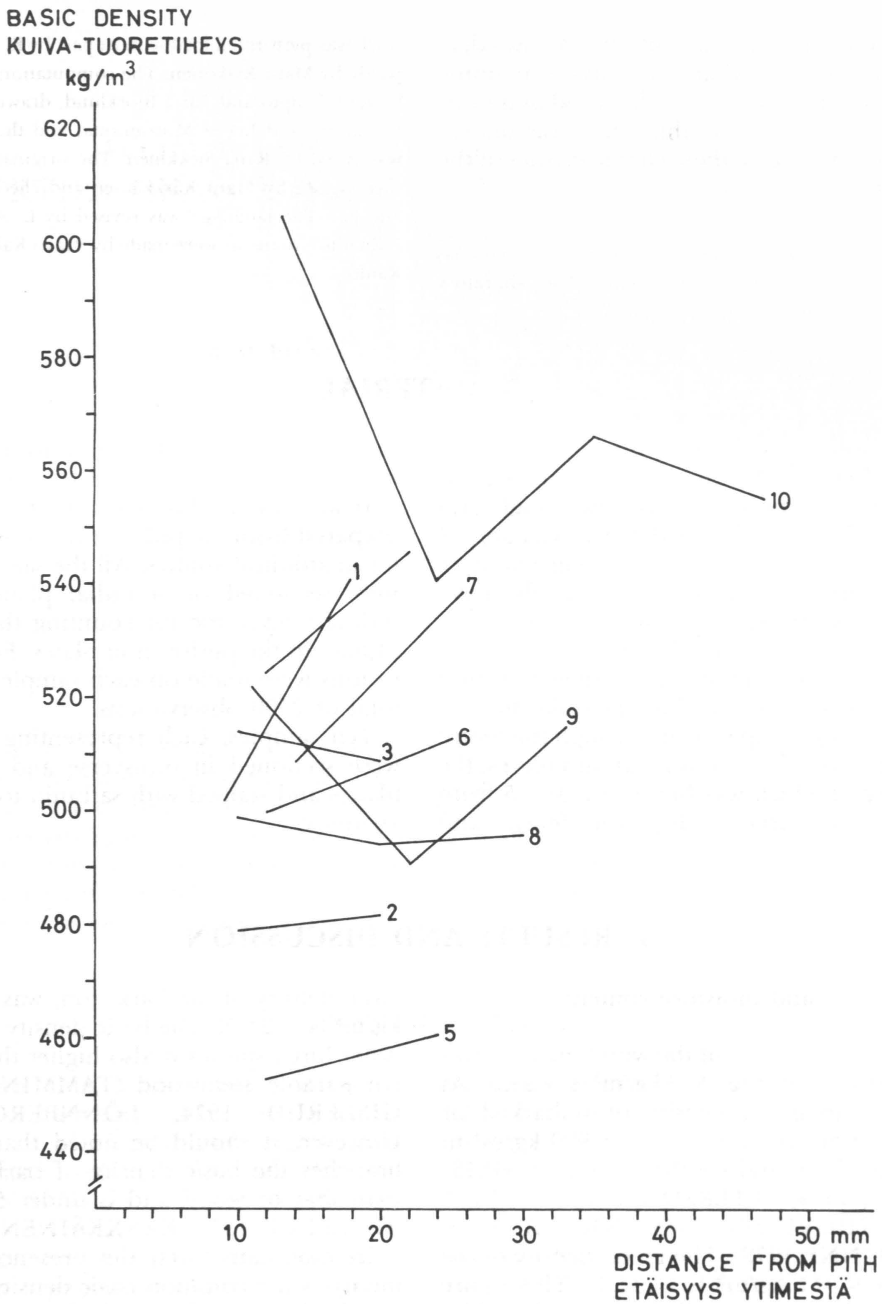


Fig. 1. Basic density of wood according to the distance from the pith to the outermost border of the measured piece. The numbers refer to the sample trees.

*Kuva 1. Puun kuiva-tuoretiheys ytimestä palan ulkoreunaan mitatun etäisyyden mukaan. Numerot tarkoittavat näytepuita.*

The variation of basic density within the disks was analysed. In most trees the density increased from the pith to the surface. However, in some cases the density remained unchanged or even decreased. This can be seen in Figures 1 and 2 where the distance was measured either in years or in millimeters. The rate of increase in basic density seemed to be much slower in this species than in either of the industrial birch species. In the latter the



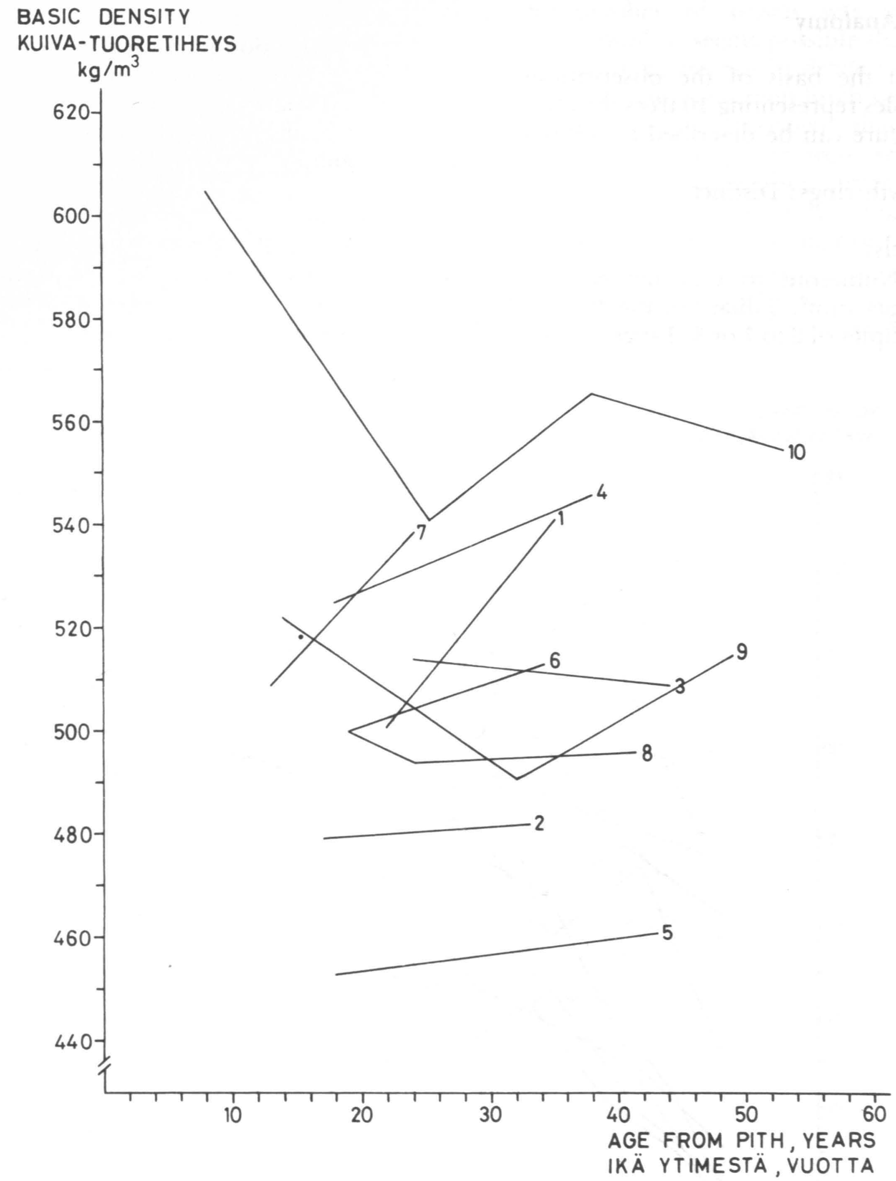


Fig. 2. Basic density of wood according to the age from the pith to the outermost border of the measured piece. The numbers refer to the sample trees.

*Kuva 2. Puun kuiva-tuoretiheys ytimestä palan ulkoreunaan lasketun iän mukaan. Numerot tarkoittavat näytepuita.*

increase from the pith to the surface is normally many tens of kilograms per cubic meter, in some cases even 200 $kg/m^3$ (WALLDEN 1934, JALAVA 1945, KUJALA 1946, HAKKILA 1966, TAMMINEN 1970).

Correlation analysis was used to explain the variation between trees. However, no significant correlation was found between the basic density of wood and some measured variables including the growth rate. Even the variation in the density of bark remained unexplained.

### 3.2. Anatomy

On the basis of the observations of 10 samples representing 10 trees the microscopic structure can be described as follows.

Growth rings: Distinct

Vessels:

Numerous to very numerous, 80–124 per mm². Solitary or mostly radial multiples of 2 to 7 or 8. Tangential vessel diameter up to 70–82 $\mu$m, oval or oblong. Perforation plates scalariform with 7–24 bars. Intervessel pitting minute, 2–3 $\mu$m in tangential diameter, almost alternate. Circular or oval to angular. Frequent gummy infiltrations present.

Parenchyma:

2–3 cells wide, apotracheal, tangential bands delimiting the growth rings.

Fibres:

Angular to oval or circular, tangential

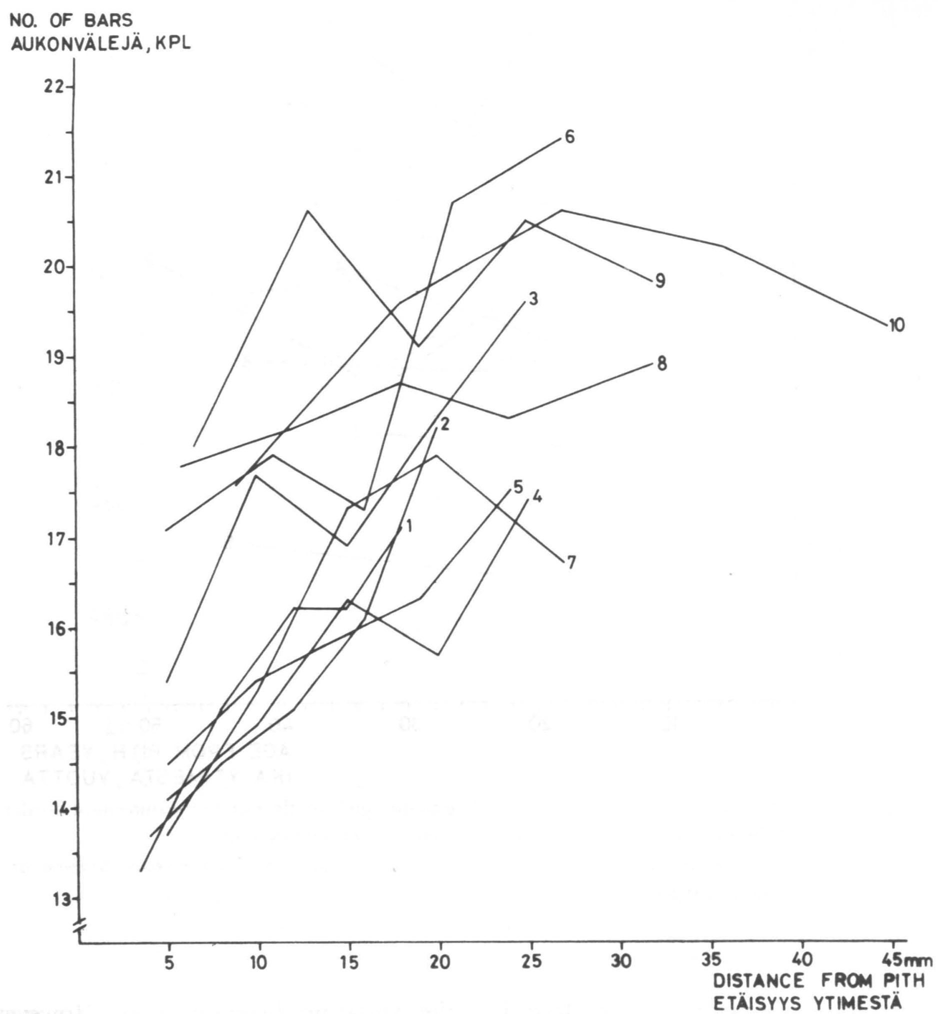


Fig. 3 Number of bars in the perforation plate of the vessels according to the distance from the pith to the outermost border of the measured piece. The numbers refer to the sample trees.

*Kuva 3. Putkilosolujen perforaatiolevyn aukonvälinen lukumäärä ytimestä palan ulkoreunaan mitatun etäisyyden mukaan. Numerot tarkoittavat näytepuita.*



diameter up to 32 $\mu$m. Wall thickness up to 9 or 10 $\mu$m. Non-septate.

Rays:

1, 2 or 3 seriate, almost homogeneous, 9–12 per linear tangential mm. (1) Uniseriate rays up to 8–10 $\mu$m wide and 400 $\mu$m or 19 cells in height. (2) Multiseriate rays up to 3 cells or 28–30 $\mu$m wide and 23 cells or 440 $\mu$m in height.

Pith flecks: Not found.

As the number of vessels was up to 120–130 per mm², it seems possible that the vessels are more numerous in *Betula tortuosa* than in the other two common birch species. Personal observations revealed that the largest vessels of this species were smaller than those of *B. pubescens* but larger than those of *B. pendula*. It is known that for identification purposes the number of bars is a useful anatomical feature of birch (BHAT and KÄRKKÄINEN 1980). The average number of bars was 17,3 (s = 1,68 between stems)

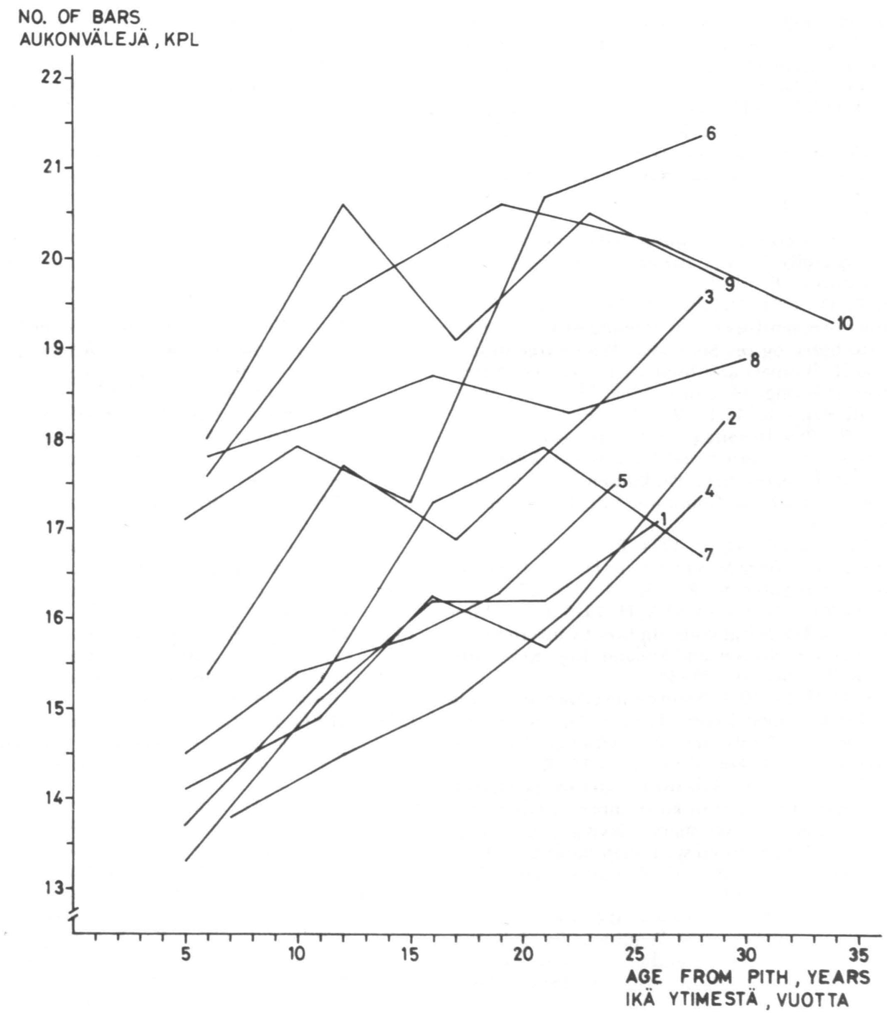


Fig. 4. Number of bars in the perforation plate of the vessels according to the age from the pith to the outermost border of the measured piece. The numbers refer to the sample trees.

*Kuva 4. Putkilosolujen perforaatiolevyn aukonvälinen lukumäärä ytimestä palan ulkoreunaan laskettun iän mukaan. Numerot tarkoittavat näytepuita.*

which is between the average number of bars of *B. pendula* and *B. pubescens.*

The number of bars increased distinctly from the pith outwards. This feature is not distinct in the other two birch species.

The fibre wall of mountain birch seemed to be a little thicker than that of the other two species. This is also reflected in the basic density. The rays did not differ from those of the other birch species.

Pith flecks are very frequent in *B. pendula* and *B. pubescens* (BHAT 1980), but were totally lacking in the samples of mountain birch. This is quite strange in view of the large number of insects which destroy the leaves of this species.

## REFERENCES


BHAT, K. M. 1980. Pith flecks and ray abnormalities in birch wood. Seloste: Koivun puuaineen ruskotäplät ja ydinsäteiden epänormaalisuus. Silva Fenn. 14 (3): 277–285.

– " – & KÄRKKÄINEN, M. 1980. Distinguishing between *Betula pendula* Roth and *Betula pubescens* Ehrh. on the basis of wood anatomy. Seloste: Raudus- ja hieskoivun erottaminen puuaineen anatomian perusteella. Silva Fenn. 14 (3): 294–304.

FINNE, B. 1972. Koivupaperipuun painomittauskokeilu Kemijärvellä II. Metsähallitus, Kehittämisjaosto, Koeselostus 69: 1–4.

GISLERUD, O. 1974. Heltreutnyttelse II. Biomasse og biomasseegenskaper hos tynningsvirke av gran, furu, bjørk og or. Summary: Whole tree utilization II. Biomass and biomass properties of trees from thinnings of spruce, pine, birch and alder. NISK Rapp. 6/74: 1–59.

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.

HAUKIOJA, E. & HEINO, J. 1974. Birch comsumption by reindeer (*Rangifer tarandus*) in Finnish Lapland. Rep. Kevo Subarctic Res. Sta. 11: 22–25.

– " – , KOPONEN, S. & OJALA, H. 1973. Local differences in birch leaf consumption by invertebrates in northern Norway and Finland. Rep. Kevo Subarctic Res. Sta. 10: 29–33.

HEIKINHEIMO, O. 1921. Suomen metsänrajametsät ja niiden vastainen käyttö. Referat: Die Waldgrenzwälder Finnlands und ihre künftige Nutzung. Commun. Inst. For. Fenn. 4: 1–71, Ref. 1–20.

HEISKANEN, V. 1959. Halkaistun, aisatun ja kuorellisen koivupinotavaran kuivuminen ja säilyminen metsävarastossa. Summary: Drying and storage decays of forest-stored split, strip-barked, and unbarked birch cordwood. Commun. Inst. For. Fenn. 50 (7): 1–63.

HÄMET-AHTI, L. 1963. Zonation of the mountain birch forests in northernmost Fennoscandia. Selostus: Pohjoisimman Fennoscandian tunturikoivikkojen vyöhykkeisyydestä. Ann. Bot. Soc. Fenn. 'Vanamo' 34 (4): 1–127.

JALAVA, M. 1945. Suomalaisen männyn, kuusen, koivun ja haavan lujuusominaisuuksista. Summary: Strength properties of Finnish pine, spruce, birch and aspen. Commun. Inst. For. Fenn. 33 (3): 1–66.

KALLIO, P. & LEHTONEN, J. 1973. Birch forest damage caused by *Oporinia autumnata* (Bkh.) in 1965–66 in Utsjoki, N. Finland. Rep. Kevo Subarctic Res. Sta. 10: 55–69.

– " – & MÄKINEN, Y. 1978. Vascular flora of Inari Lapland. 4. Betulaceae. Rep. Kevo Subarctic Res. Sta. 14: 38–63.

KALLIOLA, R. 1941. Tunturimittari (*Oporinia autumnata*), subalpiinisten koivikkoiden tuholainen. Luonnon Ystävä 45 (2): 53–60.

KOPONEN, S. 1973 a. On the mining insects of the mountain birch in northernmost Fennoscandia. Rep. Kevo Subarctic Res. Sta. 10: 14–19.

– " – 1973 b. Herbivorous invertebrates of the mountain birch at Kevo, Finnish Lapland. Rep. Kevo Subarctic Res. Sta. 10: 20–28.

KUJALA, V. 1929. Untersuchungen über Waldtypen in Petsamo und in angrenzenden Teilen von Inari-Lappland. Selostus: Tutkimuksia Petsamon ja siihen rajoittuvien Inarin Lapin osien metsätyypeistä. Commun. Inst. For. Fenn. 13: 1–125.

– " – 1946. Koivututkimuksia. Summary: Some recent research data on birches. Commun. Inst. For. Fenn. 34 (1): 1–36.

KÄRKKÄINEN, M. 1976. Puun ja kuoren tiheys ja kosteus sekä kuoren osuus koivun, kuusen ja männyn oksissa. Summary: Density and moisture content of wood and bark, and bark percentage in the branches of birch, Norway spruce, and Scots pine. Silva Fenn. 10 (3): 212–236.

LEHTONEN, J. 1979. Lapin koivutuho – luonnollinen ekokatastrofi. Summary: Ravaged birch trees in Lapland – a natural ecological disaster. Suomen Luonto 38 (6): 264–267.

LÖNNBERG, B. 1975. Short-rotation hardwood species as whole-tree raw material for pulp and paper. 2. Wood raw material. Paperi ja Puu 57 (8): 507–516.

MIKOLA, P. 1942. Koivun vesomisesta ja sen metsänhoidollisesta merkityksestä. Referat: Über die Ausschlagbildung bei der Birke und ihre forstliche Bedeutung. Acta For. Fenn. 50 (3): 1–102.

NISULA, P. 1961. Havaintoja koivupaperipuun ja havuohutpuun todellisen puumäärän määrittämisestä punnitsemalla. Summary: Observations concerning the determination of the true wood quality of birch pulpwood and small-diameter softwood by weighing. Pienpuualan Toimik. Tied. 51: 1–20.

– " – 1967. Tutkimuksia vaneritukkien ja sorvipölkkyjen kuutio- ja painosuhteista. Summary: Studies on the relationships between the volume and weight in veneer logs and bolts for rotary cutting. Commun. Inst. For. Fenn. 63 (1): 1–87.

NUORTEVA, P. 1966. Leaf development and leaf pathogens on subarctic birches after a calamity of *Oporinia autumnata* (Bkh.) (*Lep., Geometridae*). Ann. Zool. Fenn. 3 (4): 270–286.

PETERSON, O. & WINQVIST, T. 1960. Vikt- och fuktighetsvariationer hos björk under olika årstider. Summary: Seasonal changes in weight and moisture content of birch. Rapp. Uppsats. Instn. Virkeslära Skogshögsk. 28: 1–60.

SIMOLA, P. 1977. Pienikokoisen lehtipuuston biomassa. Summary: The biomass of small-sized hardwood trees. Folia For. 302: 1–16.

TAMMINEN, Z. 1970. Fuktighet, volymvikt mm. hos ved och bark. III Björk. Summary: Moisture content, density and other properties of wood and bark. III Birch. Rapp. Instn. Virkeslära Skogshögsk. 63: 1–99.

TUOVINEN, A. 1965. Koivupaperipuun pinomittaustutkimus Kemijärvi Oy:ssä. Summary: Study on the weight scaling of birch pulpwood at Kemijärvi Oy. Metsäteho Tied. 245: 1–45.

VAARAMA, A. & Valanne, T. 1973. On the taxonomy, biology and origin of *Betula tortuosa* Ledeb. Rep. Kevo Subarctic Res. Sta. 10: 70–84.

WALLDÉN, P. 1934. Tutkimuksia koivupuun anatoomisen rakenteen ja teknillisten ominaisuuksien keskinäisestä riippuvaisuudesta solumittauksien perusteella. Referat: Untersuchungen über die Abhängigkeit der technischen Eigenschaften vom anatomischen Bau des Birkenholzes nach Zellenmessungen. Acta For. Fenn. 40 (14): 1–39.



### *SELOSTE:*

### *TUNTURIKOIVUN PUUAINEEN ANATOMIA SEKÄ PUUN JA KUOREN FYSIKAALISIA JA ANATOMISIA OMINAISUUKSIA*

Inarin tunturiseuduilta kaadettiin kymmenen keskiiältään 39 a olevaa tunturikoivua, joiden rinnantasalta otetuista kiekoista mitattiin eräitä fysikaalisia ja anatomisia ominaisuuksia. Tuoretiheys oli puuaineessa alhainen, 859 kg/m$^3$. Kuoren tuoretiheys oli vastaavasti 971 kg/m$^3$. Vastaavat kuiva-tuoretiheydet olivat 520 ja 559 kg/m$^3$. Näin ollen tunturikoivun tiheys on suurempi kuin raudus- tai hieskoivun. Myös kuoren osuus on epätavallisen korkea, keskimäärin 22,4 %, vaikka huomioon otetaankin puiden pieni koko.

Kuiva-tuoretiheys lisääntyi vain vähän ytimestä pintaan päin toisin kuin raudus- ja hieskoivulla, joilla muutos on suuri. Putkiloiden perforaatiolevyjen aukonvälien lukumäärä kasvoi sitä vastoin selvästi samassa suunnassa toisin kuin muilla koivulajeilla. Keskimääräinen aukonvälien lukumäärä oli 17,3. Kun hieskoivulla aukonvälejä on aiemman tutkimuksen mukaan keskimäärin noin 21 ja rauduskoivulla 14, tunturikoivu on suunnilleen näiden koivulajien puolivälissä.