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DISTINGUISHING BETWEEN BETULA PENDULA ROTH. AND BETULA PUBESCENS EHRH. ON THE BASIS OF WOOD ANATOMY

K. M. BHAT and MATTI KÄRKKÄINEN

SELOSTE:

RAUDUS- JA HIESKOIVUN EROTTAMINEN PUUAINEEN ANATOMIAN PERUSTEELLA

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It was concluded on the basis of the anatomical investigation of four mature trees that *Betula pendula* can be distinguished from *B. pubescens* using the number of bars per scalariform perforation plate as an identification factor. If the average number of bars is more than 17,6, the sample is probably from *B. pubescens,* and if less, from *B. pendula.* The accuracy can be slightly improved by using the vessel frequency as another factor.

1. INTRODUCTION

Silver birch *(Betula pendula* Roth.) and white birch *(B. pubescens* Ehrh.) are the two main birch species in Finland to provide the raw material to wood based industries. They are distinguished in the forest on the basis of leaf shape in the summertime and by surface characteristics of twigs and the type of bark on the butt portion of stem when leaves are shed (Kujala 1946, Uoti *et al.* 1980, p. 40). In spite of the occurrence of natural crossings between the two species, the identification does not seem to be difficult in the forest.

On the other hand, identification would be a difficult task following cross-cutting and barking of bolts. In the specific problem of distinguishing the two species earlier studies indicate the following differences.

a) Fibres are longer in *Betula pubescens* than in *B. pendula* (Kujala 1946, Ollinmaa 1955, Bruun and Slungaard 1959). However, this difference cannot be used as a distinguishing factor in the identification because of the within tree variation in fibre length. It has been observed that fibre length clearly increases on moving from the pith to the surface although variation between heights is negligible (Kujala 1946).

b) Vessels are smaller and more rounded in shape in *Betula pendula* compared to those of *B. pubescens* (Kujala 1946, Ollinmaa 1955). However, these differences appear to be so small that their diagonostic value is questionable. The shape of birch vessels also varies a great deal within the growth rings (Süss and Müller-Stoll 1970).

c) Another important difference is in the basic density. Wood of *Betula pendula* is heavier than that of *B. pubescens* (Runqvist and Thunel 1945, Kujala 1946, Hakkila 1966). The density difference is also reflected in strength properties (Kujala 1946, Jalava 1945, p. 39). These differences also do not appear to be of any practical value in identification.

Although difficult to carry out, identification made on the basis of wood material would be important in many mill studies. It is commonly believed that the veneer of *B. pubescens* is smoother than that of *B. pendula* (Appelroth 1946). In addition, the knots of *B. pendula* are often larger and more defective than those of *B. pubescens* (Runqvist and Thunell 1945, Kujala 1946), possibly on certain types of site only (Heiskanen 1957, p. 31). The differences in the characteristics of the knots can be partly due to the weaker growth of *B. pubescens* with the result that it becomes suppressed in mixed birch stands (Sarvas 1949). – However, all the other properties favour *B. pendula:* the stem is straighter, grows better, and contains less rotten knots (Sarvas 1951, Heiskanen 1957). It is widely recommended as a veneer species. However, in extensive mill studies made in Finland the birch species have been treated together owing to the difficulties in identification (e.g. Meriluoto 1965, Heiskanen 1966, Kärkkäinen 1978).

In order to be able to study the real differences between species a method is required for the identification that is based on the wood material. If this is not possible, the identification must be made in the forest and the various raw material lots kept separate for mill studies. This increases the study costs.

The purpose of this study is to throw light on the possible differences in wood anatomy between the two birch species and to analyze the possibilities of utilizing these differences in identification.

Of the authors, Bhat carried out the laboratory work and Kärkkäinen wrote the original manuscript. It has been checked by both authors. The material was collected by Pertti Laakso, the computations were made by Tarja Björklund, and the typewriting by Aune Rytkönen. The English text was checked by John Derome.

2. MATERIAL

Two stems of *B. pendula* and two of *B. pubescens,* aged 45 . . . 56 years, were cut in the forest of the Ruotsinkylä Experiment Station near Helsinki. Disks were taken at stump level and from heights of 4, 8, and 12 m above the ground. Part of the material was used in another study (Bhat 1980). In the present study, a 2 cm wide strip from the pith to surface was taken from each disk and cut into pieces. There were 8 growth rings on the average in each piece. A total of 45 pieces were taken from *B. pendula* and 43 from *B. pubescens.*

The number of growth rings as well as the distance from the pith to the outer border of the sample were determined from each piece. In addition, about 50 measurements were made on each piece in order to determine the average tangential vessel diameter, vessel frequency per square millimeter, number of bars in each perforation plate of vessels, and ray frequency per linear millimeter in the tangential direction. Furthermore, ray height and width in μm and in number of cells were measured on 15 pieces of both tree species.

The average values and standard deviations were calculated for each piece. In the statistical analysis, the average values of pieces were used as observations.

The total number of measurements made on each variable, was about 2 250 for *B. pendula* and 2 150 for *B. pubescens.*

3. RESULTS AND DISCUSSION

The results for averages and standard deviations calculated from the averages for individual pieces are presented in Table 1.

According to the results, the vessels are smaller in *Betula pendula*, but are more frequent. Similarly, the height of rays is smaller, but they are more frequent per linear tangential mm of cross-section. However, all these features are so similar in the two species that their usage in identification work is questionable. The small differences are possibly reflected in the partly conflicting results obtained in other studies. The results of this study are in agreement with those obtained by OLLINMAA (1955) in that the vessels are smaller and the rays more frequent in *B. pendula* than in *B. pubescens*. However, the results concerning vessel frequency and ray height are not in agreement. The numerical values also differ a great deal. In his study, the average tangential vessel diameter in the butt part of stem was 48 μm in *B. pendula* and 53 μm in *B. pubescens*. The corresponding ray heights were 209 μm and 194 μm, respectively. These values are clearly lower than those obtained in this study. The results are not discouraging, however, as the material of OLLINMAA (1955) consisted of only one *B. pendula* and one *B. pubescens* tree. He also referred to the differences in site.

The only characteristic which seems to offer any promise is the number of bars in the scalariform perforation plates of vessels. In *Betula pubescens*, the number of bars is about 50 per cent greater than in *B. pendula*. The reason cannot be the larger vessels of the former as the ratio between the number of bars and the diameter of vessels in μm showed the same tendency. In *Betula pendula*, the ratio was on the average 0,21 (s = 0,04) and in *B. pubescens* 0,29 (s = 0,04).

If a characteristic is chosen as an identification factor, it should vary as little as possible within a tree. If it varies, some

Table 1. Averages and standard deviations of some variables of wood anatomy in *Betula pendula* and *Betula pubescens*.
Taulukko 1. Raudus- ja hieskoivun eräiden puuanatomisten tunnusten keskiarvot ja hajonnat.

Variable *Muuttuja*	*Betula pendula* *Rauduskoivu* $\bar{x}$	s	*Betula pubescens* *Hieskoivu* $\bar{x}$	s	t-value *t-arvo*
Tangential vessel diameter, μm .... *Tangentiaalinen putkilon läpimitta, μm*	69,7	12,1	74,3	11,1	2,0*
Vessel frequency, no/mm² .... *Putkiloita, kpl/mm²*	75,2	42,8	72,1	41,5	0,4
Number of bars in perforation plate .... *Aukonvälejä perforaatiolevyssä*	14,0	1,4	21,3	2,0	21,1***
Ray frequency per tangential linear mm .... *Ydinsäteitä tangentiaalista mm kohti*	12,7	2,6	11,6	2,1	2,3*
Ray height, μm .... *Ydinsäteen korkeus, μm*	267,6	32,0	288,6	40,0	1,6
Ray height, cells .... *Ydinsäteen korkeus soluina*	14,7	1,7	14,7	2,1	0
Ray width, μm .... *Ydinsäteen leveys, μm*	22,1	2,8	19,7	1,5	2,9*
Ray width, cells .... *Ydinsäteen leveys soluina*	2,5	0,2	2,2	0,2	4,1***

Table 2. Regression equations $y = a + b_1x_1 + b_2x_1^2 + b_3x_1x_2 + b_5x_2^2$ for *Betula pendula* and *B. pubescens*
Taulukko 2. Raudus- ja hieskoivun regressioyhtälöt $y = a + b_1x_1 + b_2x_1^2 + b_3x_1x_2 + b_4x_2 + b_5x_2^2$

Selitys: — *Explanation:*
y_1 = Vessel diameter, μm — *Putkilon läpimitta, μm*
y_2 = Vessel frequency, no/mm² — *Putkiloita, kpl/mm²*
y_3 = Number of bars per perforation plate — *Aukonvälejä perforaatiolevyssä*
y_4 = Ray frequency per tangential linear mm — *Ydinsäteitä tangentiaalista mm kohti*
a = Constant — *Vakio*
x_1 = Distance from pith to the outer border of sample, mm — *Etäisyys ytimestä näytteen ulkoreunaan, mm*
x_2 = Height from stump, m — *Etäisyys kannosta, m*
R^2 = Degree of determination, % — *Selitysaste, %*
F = F-value — *F-arvo*
$S_{y.x}$ = Standard error of regression estimate — *Jäännöshajonta*
t = t-value — *t-arvo*

Variable *Muuttuja*	Dependent variable — *Selitettävä tekijä* y_1	y_2 Regression coefficient — *Regressiokerroin*	y_3	y_4
	Betula pendula — Rauduskoivu			
a	30,8	128,3	13,7	19,5
x_1	1,072	— 2,399	0,02402	— 0,1267
t	7,2	4,8	0,9	4,0
x_1^2	— 0,005499	0,01251	— 0,000156	0,000557
t	5,5	3,7	0,8	2,6
x_1x_2	— 0,03186	0,007303	0,002769	— 0,000423
t	2,8	0,2	1,3	0,2
x_2	3,662	6,514	— 0,06435	— 1,052
t	3,7	1,9	0,3	5,0
x_2^2	— 0,1676	— 0,2720	— 0,01181	0,06627
t	2,6	1,2	1,0	4,9
R^2, %	75,8	77,8	35,1	76,0
F (5,39)	24	27	4	25
$S_{y.x}$	6,3	21,4	1,2	1,3
	Betula pubescens — Hieskoivu			
a	41,7	116,0	21,2	16,9
x_1	0,9847	— 2,569	— 0,04842	— 0,1333
t	7,4	6,3	1,0	3,6
x_1^2	— 0,005369	0,01697	0,000689	0,000754
t	4,8	5,0	1,7	2,4
x_1x_2	— 0,01866	— 0,04430	0,008184	0,000679
t	2,1	1,6	2,5	0,3
x_2	2,237	7,630	— 0,2258	— 0,6417
t	3,1	3,5	0,9	3,2
x_2^2	— 0,09982	— 0,1333	0,002433	0,03564
t	2,1	0,9	0,1	2,7
R^2, %	86,1	90,7	41,8	68,7
F (5,37)	46	72	5	16
$S_{y.x}$	4,4	13,5	1,6	1,2

Table 3. Regression equations $y = a + b_1x_3 + b_2x_3^2 + b_3x_3x_2 + b_4x_2 + b_5x_2^2$ for *Betula pendula* and *B. pubescens.*

Taulukko 3. Raudus- ja hieskoivun regressioyhtälöt $y = a + b_1x_3 + b_2x_3^2 + b_3x_3x_2 + b_4x_2 + b_5x_2^2$

Explanation — *Selitys:*

x_3 = Number of growth rings from pith — *Vuosilustoja ytimestä*

Others, see Table 2 — *Muut, ks. taulukko 2.*

Variable *Muuttuja*	Dependent variable — *Selitettävä tekijä* y_1	y_2	y_3	y_4
	Regression coefficient — *Regressiokerroin*			
	Betula pendula — Rauduskoivu			
a	31,4	139,3	13,2	20,6
x_3	2,264	− 6,798	0,1118	− 0,3986
t	6,0	5,3	1,6	5,4
x^2_3	− 0,02373	0,09115	− 0,001934	0,004640
t	3,8	4,2	1,7	3,8
x_3x_2	− 0,07174	0,05679	0,004094	0,004238
t	3,0	0,7	0,9	0,9
x_2	3,319	7,590	− 0,04774	− 1,004
t	3,4	2,3	0,3	5,2
x_2^2	− 0,1368	− 0,3922	− 0,01079	0,05695
t	2,1	1,8	0,9	4,5
R^2, %	75,6	77,3	36,7	79,1
F	24	27	5	30
$S_{y.x}$	6,4	21,7	1,2	1,3
	Betula pubescens — Hieskoivu			
a	40,4	121,2	20,6	17,8
x_3	2,063	− 5,573	− 0,03033	−0,3359
t	6,7	6,4	0,3	5,3
x_3^2	− 0,02296	0,07689	0,001729	0,004153
t	4,3	5,0	1,0	3,8
x_3x_2	− 0,04060	− 0,08454	0,007539	0,002164
t	2,2	1,6	1,2	0,6
x_2	1,851	8,894	− 0,1466	− 0,5688
t	2,2	3,6	0,5	3,2
x_2^2	− 0,05990	− 0,2560	0,005688	0,02732
t	1,0	1,6	0,3	2,3
R^2, %	80,7	88,6	29,9	76,0
F	31	57	3	23
$S_{y.x}$	5,2	15,0	1,8	1,1

information is needed about how it changes from the pith to the surface and from the butt to the top.

The variation of four characteristics was studied in this way. These features were vessel diameter, vessel frequency, number of bars per perforation plate, and ray frequency per tangential linear mm. The following model was chosen for regression analysis.

$$y = a + b_1x_1 + b_2x^2_1 + b_3x_1x_2 + b_4x_2 + b_5x^2_2$$

where y = characteristic to be studied

x_1 = distance from pith

x_2 = height from stump level

Instead of x_1, x_3 = growth rings from pith was also used alternatively.

The results are presented in Tables 2 and 3. It is evident that all the characteristics varied a great deal in both directions with the exception of the number of bars per perforation plate. Only in Table 2 in the case of *Betula pubescens* was one variable statistically significant. However, the overall regressions were significant according to the F-test. In practice the variation in the number of bars is of little importance as can be seen from Figures 1. . . 8. However, if the position of the sample is known, the accuracy of the identification can be improved using Fig. 3 or 7.

It deserves to be mentioned that even in genus *Ilex* the number of bars was rather constant from pith to surface (Baas 1973).

For practical purposes two discriminant functions were calculated in the manner described by Cunia (1973 p. 104).

In the first equation, the only independent variable was the number of bars per perforation plate.

$$y = -1{,}49 + 0{,}1129\ x \qquad R^2 = 82,4\ \%$$

where y = tree species (0 = *B. pendula*, 1 = *B. pubescens)*

x = number of bars per perforation plate

It can be seen from the equation that the limit is 17,6. If there are more bars, the sample is assumed to be from *B. pubescens*, and if less, from *B. pendula*.

If two identification criteria are used, the other one is the vessel frequency. This result was obtained using stepwise regression analysis.

$$y = -1{,}78 + 0{,}1191\ x + 0{,}002403\ z \quad R^2 = 86{,}1\ \%$$

where z= number of vessels per square millimeter and other variables as above.

No other statistically significant variables were obtained.

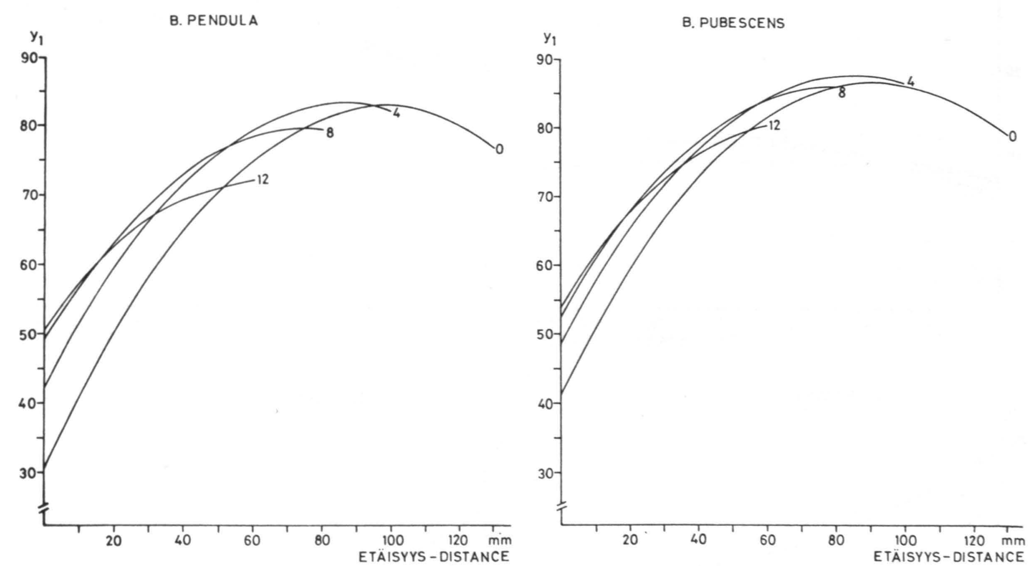
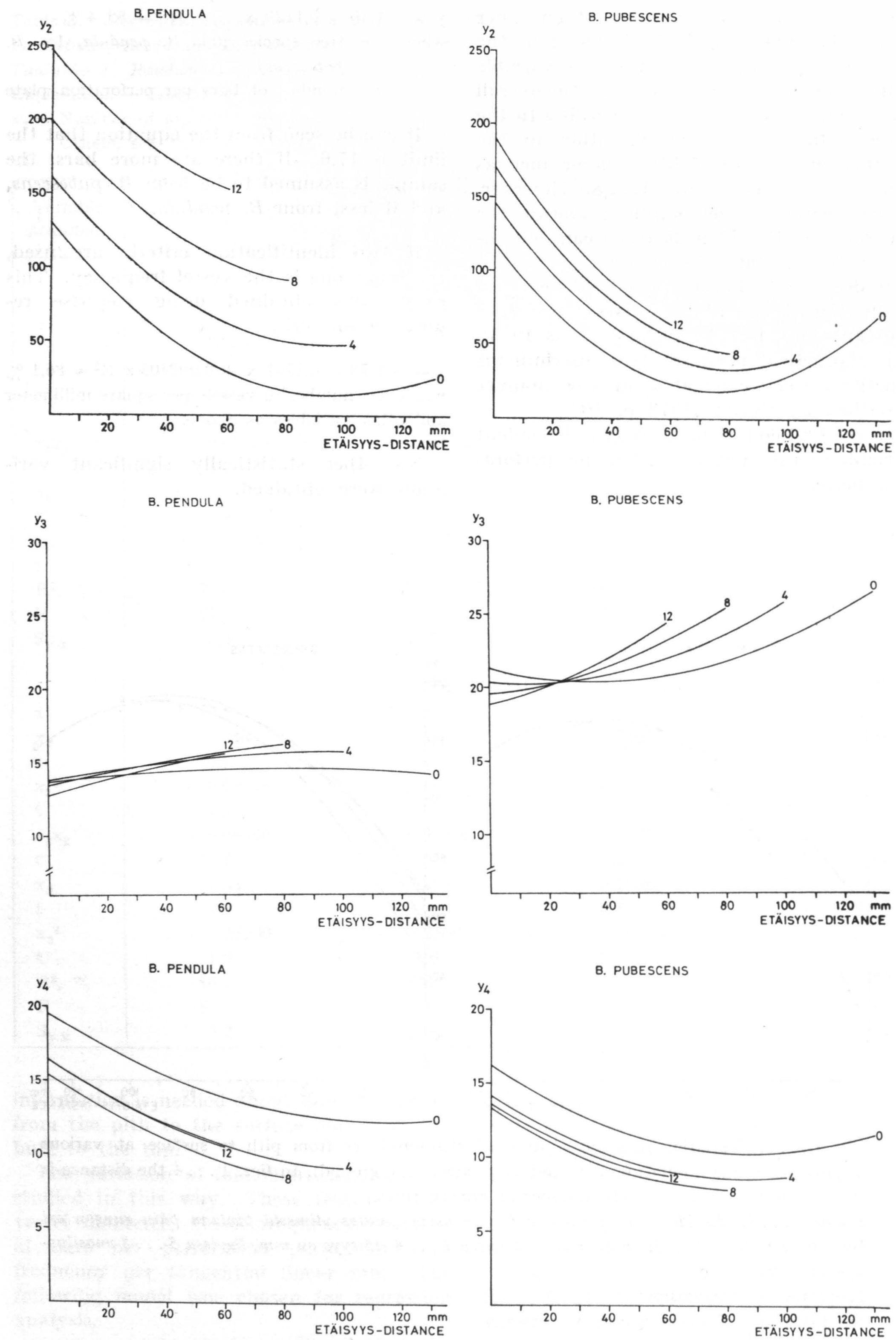


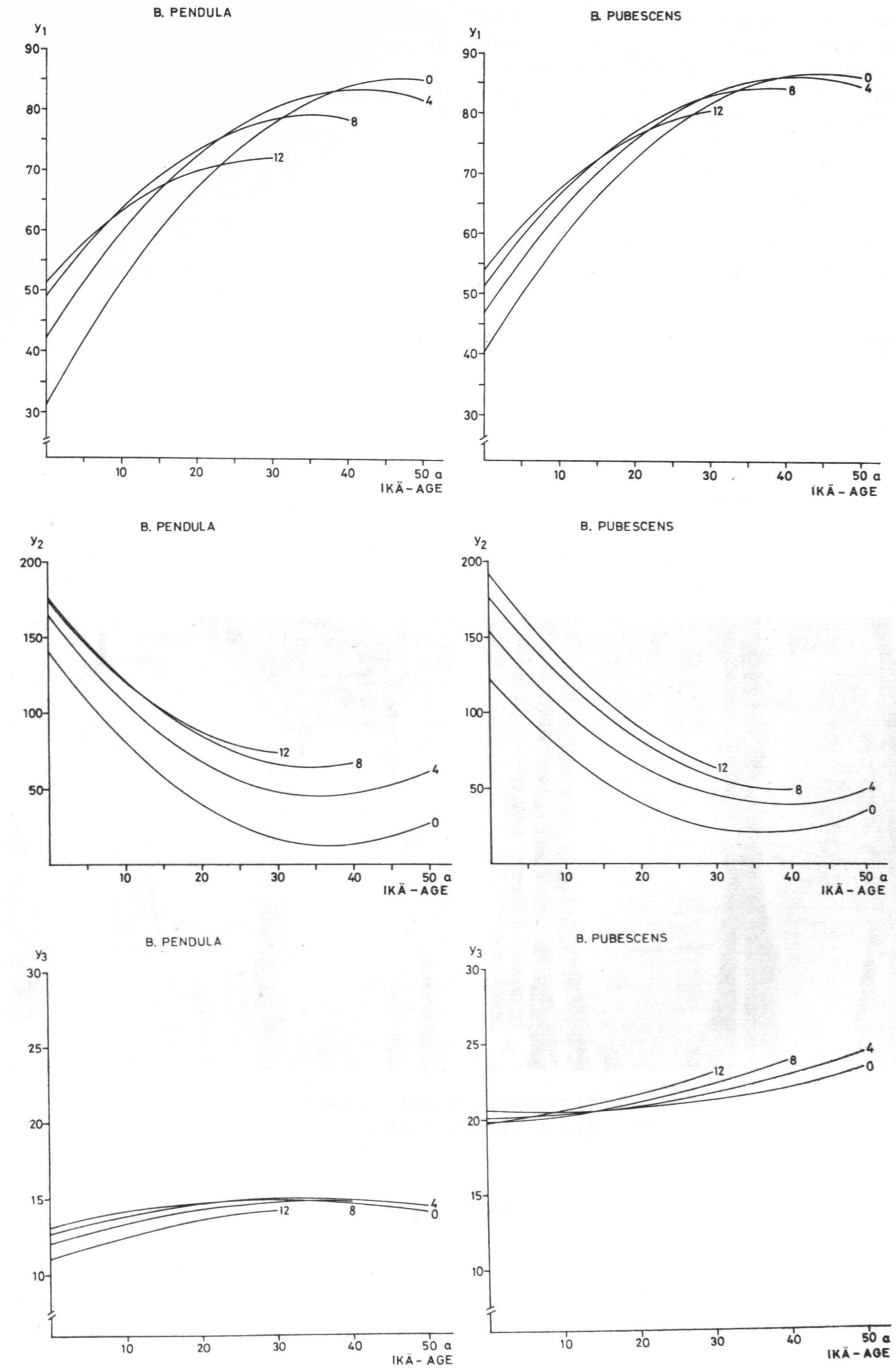
Fig. 1 . . . 8. Variation of some anatomical characteristics from pith to surface at various heights above the ground (0, 4, 8, and 12 m above the ground). In figs. 1 . . . 4 the distance is in mm, in figs. 5 . . . 8 in the number of growth rings.

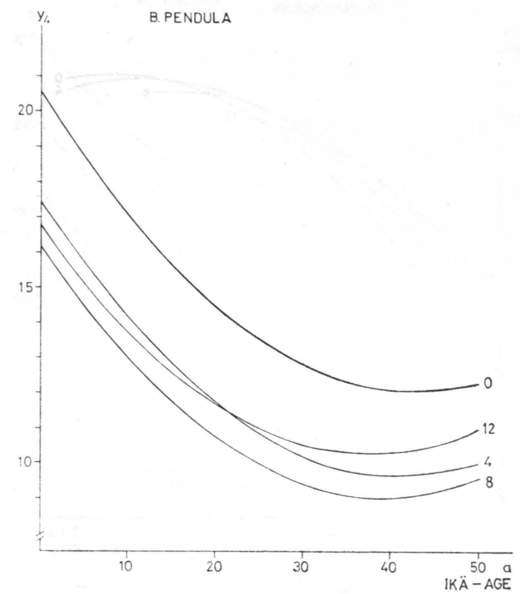
Kuvat 1 . . . 8. Eräiden anatomisten ominaisuuksien muutos ytimestä pintaan päin rungon eri korkeuksilla (0, 4, 8 ja 12 m maasta). Kuvissa 1 . . . 4 etäisyys on mm, kuvissa 5 . . . 8 vuosilustoja ytimestä.

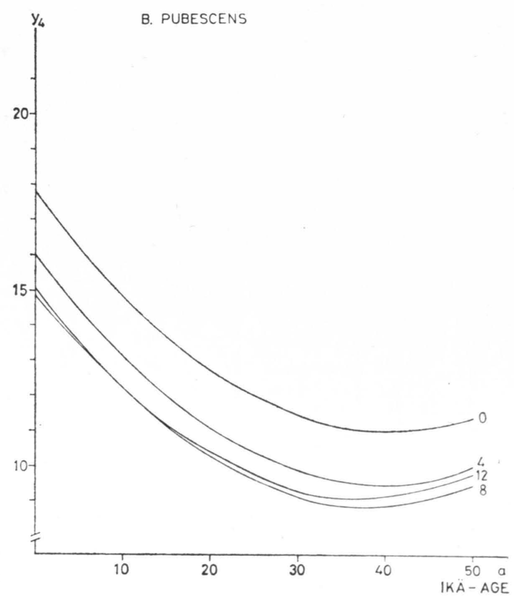
Properties — *Ominaisuudet:*

See table 2 — *Ks. taulukko 2.*


B. PENDULA
B. PUBESCENS
y_2
y_3
y_4
ETÄISYYS - DISTANCE
mm
0
4
8
12


B. PENDULA
B. PUBESCENS
y_1
y_2
y_3
IKÄ - AGE
50 a
0
4
8
12





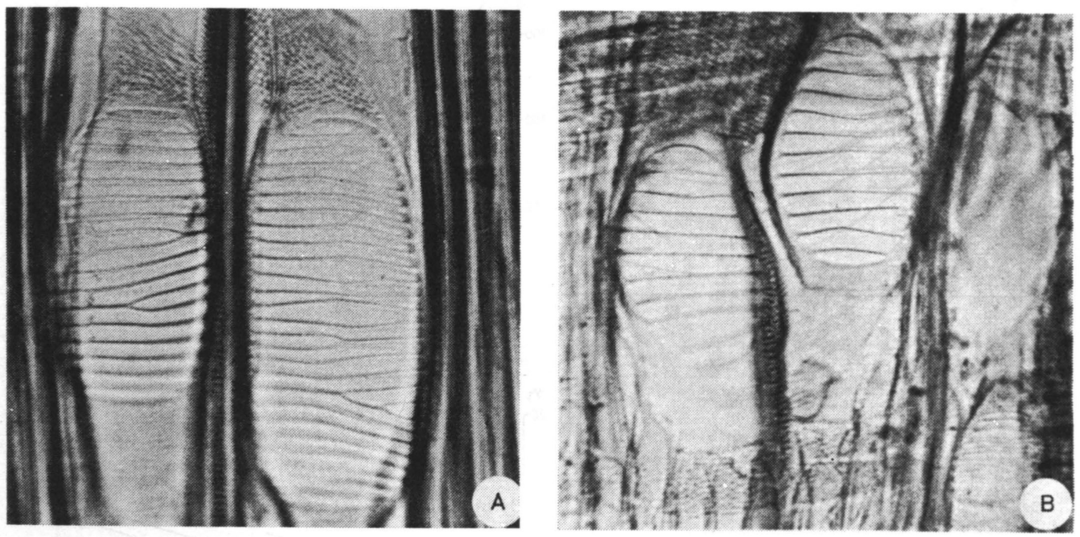


Fig. 9. Vessel perforation plate of Betula pubescens (A) and B. pendula (B).
Kuva 9. Hieskoivun (A) ja rauduskoivun (B) perforaatiolevy.

4. CONCLUSION

According to the results, it appears to be possible to distinguish *B. pendula* from *B. pubescens* on the basis of the number of bars per perforation plate, although the accuracy can be improved to some extent using the vessel frequency as another factor. This finding is supported by the paper of Stark (1953). In his study the number of

bars was an identication criteria in distinguishing some American birch species from each other.

However, this simple method cannot be exact due to natural variation. Furthermore, the fact that the results were obtained from four trees only must be taken into account. More research is needed in order to be able to make more reliable conclusions about the suitability of the number of bars per perforation plate as an identification factor. However, great changes are unlike to occur.

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SELOSTE:

RAUDUS- JA HIESKOIVUN EROTTAMINEN PUUAINEEN ANATOMIAN PERUSTEELLA

Monissa teollisuuden puuraaka-aineen laatua ja käyttöä koskevissa tutkimuksissa olisi suotavaa, että kaksi tärkeintä kotimaista koivulajia, raudus- ja hieskoivu, pystyttäisiin erottamaan toisistaan jollakin luotettavalla menetelmällä, joka ei perustu kuoren, lehtien tai oksien ominaisuuksiin. Tiedetään nimittäin, että koivulajit eroavat monessa jalostusteknisessä suhteessa toisistaan, ja ellei tunnistaminen onnistu puuaineen perusteella, se joudutaan tekemään jo metsässä sekä pitämään koe-erät erillään teollisuudessa. Monessa tapauksessa tämä lisää tutkimuskustannuksia ja rajoittaa kokeiden suunnittelua.

Käsillä olevassa työssä etsittiin puuanatomisia tunnuksia, jotka erottelisivat toisistaan raudus- ja hieskoivun. Tavoitteena oli löytää tunnus, joka muuttuisi mahdollisimman vähän ytimestä pintaan päin ja tyvestä latvaan päin, koska tällainen vaihtelu vaikeuttaa tunnistamista.

Kahden raudus- ja kahden hieskoivun aineistosta tehtiin kaikkiaan 87 palaa eri etäisyyksiltä ytimestä ja eri rungon korkeuksilta. Näistä paloista mitattiin putkiloiden läpimitta tangentin suunnassa, putkiloiden määrä mm^2 kohti, putkiloiden perforaatiolevyn aukonvälien lukumäärä sekä ydinsäteiden määrä tangentiaalista mm kohti. Lisäksi mitattiin osasta näytteitä myös ydinsäteiden korkous ja leveys sekä absoluuttisina mittoina että solujen lukumäärinä. — Kaikkiaan mittauksia tehtiin muuttujaa kohti jopa 4 500 kpl.

Paras puulajeja erottava tekijä oli aukonvälien lukumäärä perforaatiolevyssä. Se muuttui vähän rungon sisällä, mutta puulajien ero oli suuri. Erotteluanalyysin mukaan tunnistamisraja on 17,6 aukonväliä: jos luku on suurempi, kyseessä on ilmeisesti hieskoivu, ja jos pienempi, rauduskoivu. — Lisätekijänä voidaan käyttää putkiloiden pinta-alatiheyttä, joskin se lisää tunnistamisvarmuutta suhteellisen vähän.