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VARIATION IN THE DENSITY OF WOOD OF DIFFERENT SCOTS PINE *(Pinus sylvestris* L.) AND NORWAY SPRUCE *(Picea abies* (L.) Karst.) ORIGINS IN PROVENANCE TESTS

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SELOSTE:

MÄNTY- JA KUUSIALKUPERIEN PUUAINEEN TIHEYDEN VAIHTELUSTA PROVENIENSSIKOKEISSA

In provenance tests, different geographical races of a particular tree species are compared with each other, and with the local provenance. Climatic and disease resistance, volume growth and also the external quality of the trunk are usually used as the comparison criteria. On the other hand, less attention has been paid to the *quality of the wood.* Growth and quality should be examined together since they both determine how much and what type of product will be obtained from the wood raw material.

The study presented here is concerned with variations in the *density* of the wood of different provenances in provenance test series for Scots pine *(Pinus sylvestris* L.) and Norway spruce *(Picea abies* (L.) Karst.). Basic density depicts the dry weight of a unit volume of fresh wood and is usually expressed as kg/m^3. It is perhaps the most important indicator of wood quality. Density is also a useful characteristic from the tree breeder's point of view in so far as its heritability has usually been found to be strong or at least moderate, values for narrow sense heritability being in most cases around 0.50 (e.g., ZOBEL 1961 and 1964, HATTEMER 1963, HARRIS 1965 and 1970, POLGE and ILLY 1968, ELLIOTT 1970, ARBEZ and MILLIER 1972, PERSSON 1972, VELLING 1974).

The experiments used in this study were established in different parts of Finland through the activities of Prof. Olli Heikinheimo in 1931. The same provenances were used in all the sub-experiments (Table 1). Only 11—12 provenances are still in existance in the sub-experiments of the Scots pine series, and 10—20 provenances of the spruce series. The variation in the number of the provenances remaining is partly due to the fact that a number of the provenances included in the experiments, especially the foreign ones, died at the seedling stage and others later on. The provenances still remaining have, in addition, suffered from wintering and fungal damage.

The study material was obtained by randomly selecting 10 sample trees from each sample block and then removing two 5 mm thick increment cores, using an increment borer, from the surface of the stems right to the pith. The increment cores were taken at breast height on the opposite sides of the stem. The mean density

Table 1 a. Origin of provenances and location of sub-experiments of the pine series.

No	Location		Origin		
			N°, Latitude	E, Greenwich	Elevation, m
		Provenances			
1	USSR	Pechanga (Petsamo)	69° 28′	31° 04′	200
2	Finland	Sodankylä	67° 26′	26° 35′	180
3	»	Rovaniemi	66° 29′	25° 40′	180–250
4	»	Simo	65° 39′	24° 55′	50–100
5	»	Haapavesi	64° 09′	25° 25′	100–150
6	»	Ähtäri	62° 34′	24° 08′	150–200
7	»	Pieksämäki	62° 18′	27° 10′	100–150
8	»	Kankaanpää	61° 47′	22° 25′	50–100
9	»	Punkaharju	61° 43′	29° 25′	85
10	»	Lammi	61° 05′	25° 08′	100–150
11	Norway	Gjøvik	60° 47′	10° 41′	400
12	Finland	Tuusula	60° 20′	25° 10′	60
13	USSR	Roshchino (Raivola)	60° 20′	29° 28′	0–110
14	»	Estonia Narva	59° 22′	28° 17′	0–100
No	Sub-experiments				
I	Punkaharju		61° 43′	29° 25′	85
II	Tuusula, Ruotsinkylä		60° 20′	25° 10′	60
III	Tenhola Solböle		60° 00′	23° 03′	25

at breast height was thus obtained as the average of these two cores and the density for each provenance as the mean value of the densities of the ten sample trees. The density at breast height in pine has been found to be slightly higher than the average value for the whole stem, the corresponding difference in the case of spruce is very small (e.g., HAKKILA 1966). However, the relative differences found in the density at breast height can be considered as being sufficient for the purposes of this study.

The density was determined from the increment cores using the V^D- method (*v*olume determination by water *d*isplacement) described by OLESEN (1971). In the case of the Punkaharju material, the mercury immersion method developed by ERICSON (1959) was used instead (VELLING 1976). Owing to the health hazard posed by the latter method, it is not nowadays used and has been replaced by the V^D- method. This method has proved to be fast, sufficiently accurate and suitable for wood samples of greatly varying size, shape and quality. The absolute values given by the mercury and V^D- methods are not directly comparable since the mercury method systematically gives values for the volume which are slightly too high and hence smaller density values. Any relative differences which may occur, however, will become evident despite the use of two different methods.

In addition to density variations between provenances, the interdependance between the density variation and factors affecting volume growth were also studied using the provenances grown at Punkaharju. An attempt was then made to estimate the importance of density in the formation of dry matter yield of different provenances.

According to the results of the study, the density w i t h i n t h e s t e m in the radial direction clearly increased in pine on moving from the pith outwards. In spruce the case was quite the opposite, although the trend was not as clear as it was with pine. The coefficient of variation of the density b e t w e e n s a m p l e t r e e s of the same provenance varied, in the case of pine, from 3,2 to 8,6 %, and in spruce, from 3,2 to 9,8 %. These values are in very good agreement with the normal variation in density within a stand. Since one important factor which affects this variation, namely the age of the sample trees, was constant in all the experiments studied, the observed variation values can be considered to be close to the describer of individual variation.

Table 1b. Origin of provenances and location of sub-experiments of the spruce series.

No	Location		Origin		
			N°, Latitude	E, Greenwich	Elevation, m
		Provenances			
1	Finland	Muonio	67° 58′	23° 40′	200–300
2	»	Sodankylä	67° 26′	26° 35′	180
3	»	Rovaniemi	66° 29′	25° 40′	250
4	»	Rovaniemi	66° 29′	25° 40′	180
5	»	Simo	65° 39′	24° 55′	50–100
6	»	Kajaani (?)	64° 12′	27° 45′	130
7	»	Liperi	62° 33′	29° 29′	0–100
8	»	Pieksämäki	62° 18′	27° 10′	100–150
9	USSR	Sortavala	61° 40′	30° 40′	0–100
10	Finland	Urjala	61° 06′	23° 35′	100–150
11	Norway	Gjøvik	60° 47′	10° 41′	400
12	Finland	Elimäki	60° 43′	26° 30′	0– 50
13	»	Tuusula	60° 20′	25° 10′	60
14	USSR	Roshchino (Raivola)	60° 20′	29° 28′	0–100
15	»	Estonia Peravalla	58°	27° 30′	30– 55
16	»	Latvia Kuldiga (Goldingen)	57°	22°	0–100
17	Germany	Schmiedefeld	50° 40′	10° 45′	600
18	»	Carlsfeld	50° 26′	12° 36′	900
19	»	Schilbach	50° 25′	12° 30′	600
20	Poland	Wisla	49° 39′	18° 50′	430
21	»	Oszezepskie			160
22	Germany	Spiegelau	48° 50′	13° 25′	700
23	USSR	Volovets	48° 44′	23° 14′	700–900
24	Hungary	Köszeg	47° 23′	16° 32′	~500
25	Switzerland	Vintschgau	46° 40′	10° 45′	<800
26	»	»	»	»	>800
27	»	Münsterthal	46° 30′	8° 15′	>1300
No	Sub-experiments				
I	Rovaniemi, Kivalo		66° 29′	25° 40′	250
II	Muhos, Pyhäkoski		64° 49′	26° 00′	90
III	Vilppula		62° 02′	24° 30′	125
IV	Punkaharju		61° 43′	29° 25′	85
V	Tuusula, Ruotsinkylä		60° 20′	25° 10′	60
VI	Tenhola, Solböle		60° 00′	23° 03′	25

The following density values were obtained for the pine series:

Sub-experiment	$\bar{x}$	s		Range	
	kg/m³	kg/m³	%	kg/m³	%
Punkaharju (Hg)	378	21	5,6	367–402	97,1–106,3
Tuusula	444	24	5,4	426–457	95,9–102,9
Tenhola	451	26	5,8	436–464	96,7–102,9

The corresponding values for the spruce series were:

Sub-experiment	$\bar{x}$ kg/m³	s kg/m³	s %	Range kg/m³	Range %
Rovaniemi	401	25	6,2	385–429	96,0–107,0
Muhos	371	24	6,5	357–389	96,2–104,9
Vilppula	373	24	6,4	351–385	94,1–103,2
Punkaharju (Hg)	344	23	6,7	327–367	95,1–106,7
Tuusula	400	26	6,5	386–423	96,5–105,7
Tenhola	389	25	6,4	360–416	92,5–106,9

The density of the pine wood was noticeably higher than that of spruce. While the density of pine was, on average, as high as 450 kg/m³, it was usually below 400 kg/m³ for spruce. The coefficient of variation for spruce was slightly greater than that for pine, in both cases the ranges were of the same magnitude when calculated on a percentage basis. In comparison to the V^D- method, the mercury method clearly gave a lower density value. Some indication of the effect of site type on density is also visable in the results for the spruce series; the density values of the sub-experiments at Rovaniemi and Tuusula, which were clearly growing on less fertile sites than the other sub-experiments, were higher (Table 2 b).

The results of analysis of variance showed that there were statistically significant differences between the mean densities of different provenances in all the sub-experiments for spruce, but only in one pine sub-experiment. However, it was evident that these differences were not due to the latitude or altitude of the place from which the provenance had originated altough there were some indications of a density decrease as the latitude increased, both in pine and spruce (Table 2).

The density values of the same provenances in different sub-experiments mostly occurred in the same order, but entirely deviant orders were also found. The fact that the effect of the variation of density is strong at the individual level is also evident in this connection, especially when only 10 sample trees per provenance and sub-experiment were used. However, the density values of some provenances were

Table 2 a. Mean basic density of different provenances in the sub-experiments of the pine series.

Provenance	Basic density, kg/m³		
	I Punkaharju (Hg)	II Tuusula	III Tenhola
Pechanga (Petsamo)	378	—	—
Sodankylä	369	451	450
Rovaniemi	377	448	458
Simo	375	447	442
Haapavesi	381	437	432
Ähtäri	377	438	453
Pieksämäki	375	449	456
Kankaanpää	367	443	448
Punkaharju	373	443	457
Lammi	390	457	441
Gjøvik	384	444	462
Roshchino (Raivola)	402	441	464
Narva	—	441	—

Table 2 b. Mean basic density of different provenances in the sub-experiments of the spruce series.

Provenance	Basic density, kg/m³					
	I Rovaniemi	II Muhos	III Vilppula	(Hg) IV Punkaharju	V Tuusula	VI Tenhola
Muonio	392	359	376	343	390	387
Sodankylä	384	357	380	363	386	377
Rovaniemi 180 m	415		375	347		392
Rovaniemi 250 m	401	372	385	343	387	394
Simo	—	372	366	336	398	389
Kajaani (?)	386	379	381	327	394	372
Liperi	—	—	—	337	—	—
Pieksämäki	400	—	372	339	386	377
Sortavala	—	—	—	328	—	—
Urjala	394	—	—	—	—	—
Gjøvik	401	—	—	348	393	388
Elimäki	413	—	374	351	392	397
Tuusula	—	—	—	330	386	—
Roshchino (Raivola)	—	—	—	333	—	—
Peravalla	—	366	373	360	—	398
Kuldiga (Goldingen)	—	389	—	367	391	—
Schmiedefeld 600 m	395	360	378	346	413	393
Carlsfeld 900 m	403	372	351	332	389	400
Schilbach 600 m	404	—	366	349	415	403
Wisla	—	—	—	—	403	—
Oszezepskie	—	—	—	—	423	—
Spiegelau 700 m	391	383	363	344	396	372
Volovets 700–900 m	396	—	383	—	409	360
Köszeg	—	—	—	—	—	373
Vintschgau < 800 m	429	—	—	—	418	—
Vintschgau > 800 m	418	—	369	—	413	417
Münsterthal > 1 300 m	400	—	—	353	419	406

in all, or several sub-experiments, placed either at the beginning or at the end of the experiment. This conforms the opinion that the inheritance degree of basic density is high.

The correlations between basic density and some stand and stem properties illustrating growth were estimated in the Punkaharju sub-experiments. They were quite variable and weak both for pine and spruce (Table 3). The correlations between density and some factors affecting the climate of native locations of provenances were also variable and weak (Table 4).

The estimate of dry matter yield in the Punkaharju sub-experiments was obtained by weighing the volume yield/ha with the

Table 3. The correlation coefficients between density and some stand and stem properties in the Punkaharju sub-experiment (Velling 1976).

Stand/stem property	Density	
	Pine	Spruce
Cubic volume	0,024	–,511*
Cubic volume/tree[1]	,217	,390
Number of stems	–,340	,018
Mean diameter	,234	–,406
Dominant height	,462	–,162

[1]) The average value/tree estimated by means of cubic volume/ha and number of stems.

density. The best pine provenance, Roshchino, produced about 30 % more dry matter than the local provenance and the very northern Pechanga provenance only about 50 % of the yield of the local index provenance. In the case of spruce, the best provenance, Kajaani, the origin of which is a little uncertain, was 50 % more productive than the estimated local index provenance. The Swiss mountain provenance, Vintschgau, on the other hand produced 20 % less than the local provenance. The effect of density variation on dry matter yield remained small, at most only 9 % for pine and 7 % for spruce. Thus the volume growth seems to be the dominant component in the formation of dry matter yield. The effect of density has some significance, however, and therefore it should be taken into consideration.

The results concerning *spruce* indicated that *provenance transfers are profitable* at least in South and Central Finland. The possible provenances come from southern parts of Finland and from south and southeast of Finland. These provenances grow faster and the wood basic density does not seem to be systematically so much lower that it would significantly reduce dry matter yield and reduce the quality of raw material.

The results of the *pine* series, on the other hand, suggest that it *does not seem profitable to transfer provenances*, even though the number of origins examined was much

Table 4. The correlation coefficients between density and some climate factors of native locations of provenances in the Punkaharju sub-experiment (Velling 1976).

Climate factor	Density	
	Pine	Spruce
Mean temperature of months with a mean temperature of at least + 10° C	0,53 (*10 %)	0,05
Mean temperature of the warmest summer month	0,38	0,26
Mean temperature of months with a mean temperature of 0° C or below	0,52 (*10 %)	0,20
Difference in mean temperature between the warmest and the coldest month of the year	–0,32	–0,07
Annual precipitation	0,41	–0,19
Latitude	–0,30	–0,14
Sum of effective temperature	0,45	0 16

smaller than for spruce. The pine populations, at least in southern Finland, are probably so well adapted to their growing sites with regard to growth, wood quality and resistance that the individual selection from local populations and crossings are the most effective ways to increase dry matter yield and improve wood quality. The bases for this conclusion are the high inheritance degree of density, and the definitely smaller, but in every case significant inheritance of volume growth and the great variation of these properties within the stand on the individual level.

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SELOSTE:

MÄNTY- JA KUUSIALKUPERIEN PUUAINEEN TIHEYDEN VAIHTELUSTA PROVENIENSSIKOKEISSA

Tutkimuksessa on tarkasteltu mänty- ja kuusialkuperien puuaineen tiheyden vaihtelua provenienssikokeissa, jotka 1930-luvun alussa perustettiin eri puolille Suomea prof. Olli Heikinheimon toimesta. Tutkimuksen aineisto koottiin kairanlastuina, joista tiheys määritettiin OLESENin (1971) kuvaamalla menetelmällä, paitsi Punkaharjun osakokeissa, joissa vielä käytettiin nyttemmin hylättyä ERICSONin (1959) menetelmää.

Runkojen välinen tiheys vaihteli mäntyalkuperien sisällä 3—9 % keskiarvon ollessa noin 450 kg/m³, kuusella vastaavasti 3—10 % keskiarvon jäädessä yleensä alle 400 kg/m³. ERICSONin menetelmä antoi kuitenkin OLESENin menetelmää selvästi pienemmät tiheysarvot. Eri kuusialkuperien välillä oli tiheydessä tilastollisesti merkitseviä eroja kaikissa osakokeissa, männyllä vain yhdessä osakokeessa. Erot eivät kuitenkaan sel-

västi ryhmittyneet alkuperän leveysasteen tai korkeuden mukaan. Myös kasvua kuvaavat metsikkö- ja runkotunnukset sekä alkuperäalueiden ilmastoa luonnehtivat tunnukset korreloituivat tiheyden kanssa yleensä heikosti. Niiden vaikutusta tiheyteen samoin kuin tiheyden vaikutusta rungon kuivan massan tuotokseen tutkittiin Punkaharjun osakokeissa. Tilavuuskasvu osoittautui selvästi määrääväksi tekijäksi kuivan massan muodostumisessa, sillä tiheyden osuus siitä oli männyllä suurimmillaan vain 9 %, kuusella 7 %.

Tutkimuksessa saatujen tulosten mukaan puuaineen tiheyden alkuperävaihtelu ei ole sitä luokkaa, että se asettaisi kasvunopeuden lisäämiseen tähtäävät ja lupaaviksi todetut kuusen provenienssisiirrot kyseenalaisiksi. Kun tiheys puuta jalostettaessa kuitenkin vaikuttaa sekä saantoon että laatuun, on se provenienssivaihtelun hyväksikäytössä syytä ottaa huomioon.