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Growth and flowering of 'primary' and 'secondary' grafts of Scotch pine

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1. Introduction

In the establishment of seed orchards, the question arises which of two types of grafts gives better results: Primary grafts are made with scions taken from adult trees that are selected on the basis of field and/or progeny-test performance. Secondary grafts are made using scions collected from the primary grafts. In the latter case one does not need to again climb a tall tree if it were to be included in an orchard. Moreover, the ortets are sometimes very old and thus difficult to propagate. It is advisable in the beginning to produce only a few grafts so that sufficient quantities of reasonably vigorous scions can be collected later. The existence of such primary ramets also provides the possibility of making experiments where clonal effects are to be tested under scrutiny (QUIJADA et al. 1973).

The behavior of the resulting two types of grafts was originally to be compared in three field experiments. It was planned to simultaneously study the effect of increased distance between the origins of the ortets and the environment of the grafts. In all, three plantations in northern, central, and southern Sweden were to be studied. The plantation in northern Sweden had, however, to be culled since various adverse environmental conditions lead to the loss of most of the experimental material.

2. Material and Methods

The locations of the 10 indigenous ortet trees in northern Sweden are shown in *Figure* 1. This figure also shows the locations of the two remaining field trials that were established with graft material from these clones. The ortets represent plus trees (ANDERSSON 1963) that entered various seed orchards in Sweden. The geugraphic positions of the

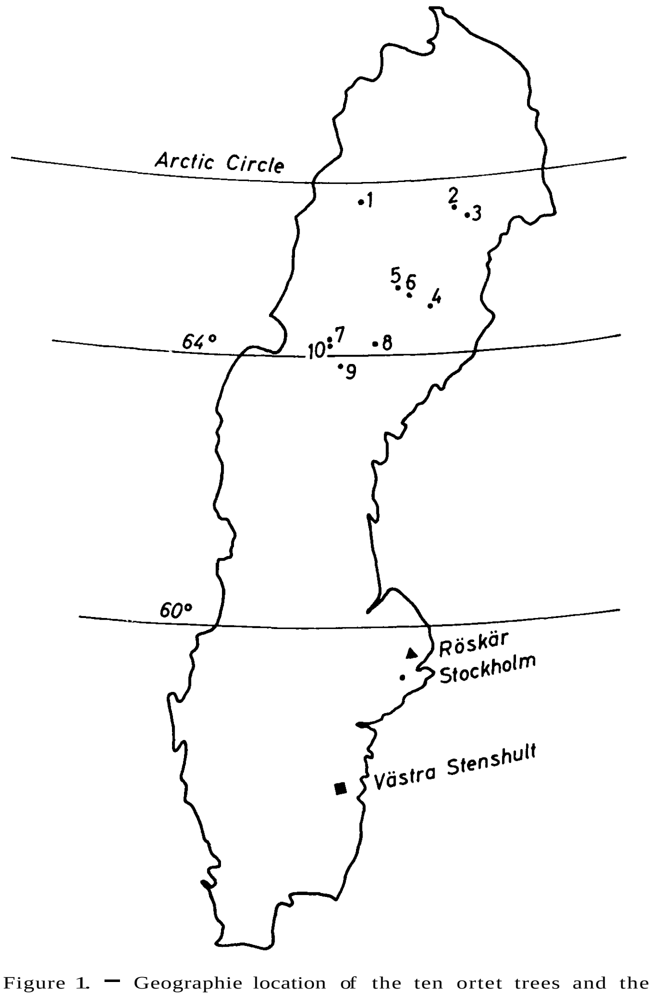

Figure 1. — Geographie location of the ten ortet trees and the two field experiments.

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Table 1. – The ortet trees

no.			location	elevation a.s.l. (m)
1	BD	1032	Heikka	450
2	BD	1178	Spikberg	275
3	BD	1180	Långberget	180
4	AC	1005	Kammarberget	250
5	AC	1014	Mötsokberget	330
6	AC	1016	Trollberget	365
7	AC	1019	Fågelberget	320
8	AC	4210	Lövberget	380
9	Y	3001	Moarna	230
10	Y	3020	Lunne	275

two remaining field experiments are far south of the stands where the ortets grow. Additional information about the ortets is given in *Table 1.*

Years before the experiment was started, the first grafts were made, and subsequently grown in the same nursery. The method applied in producing the grafts was top grafting. In 1960 scions were collected from both ortets and primary grafts. This material was field-planted in 1962.

Clones and treatments (primary vs. secondary grafts) were regarded as factors in a split-plot experiment. The ten clones (factor A) were grown in five replicates per location. Each large plot was divided into two subunits *(Figure 2)* or small plots that received one of the two treatments (factor B). The small plot consisted of a row of five grafts reducing the risk of missing plot means. In the underlying statistical model factor B was assumed to be fixed and factor A to be random.

In all, 15 traits were assessed in the Röskär test and 6 in the Västra Stenshult test. These traits are listed in *Table 2* together with various means etc. All plot means of the observations were subjected to analysis of variance. The observations of various characters are counts that

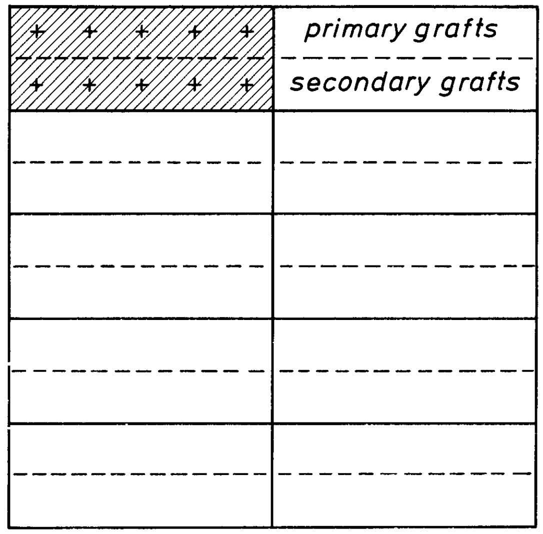

Figure 2. — Layout of one complete randomized block in the field. The ten whole-units (one denoted by hatching) consist of ten trees of same clone each. Every such whole-unit is formed by two subplots containing either five primary grafts or five secondary grafts.

were used as such. The decision to report original data was reinforced later when a re-run of the analyses on the transformed data yielded virtually the same test results.

Mortality amounted to about 10 per cent at the age of 6 years in both tests with little or no increase after that time. In all years, identical samples of grafts were used for the statistical analyses (i.e. a tree that did not survive at the age of 10 years was excluded from all other evaluations.

In the Västra Stenshult experiment, one missing subunit was inserted following the method devised by ANDERSON (1946).

Table 2. — Traits observed in the tests

No.	Description	Age in years after grafting	Experimental means		Range of clonal means			
					Röskär		V. Stensh.	
			Röskär	V. Stenshult	min.	max.	min.	max.
1	Tree height	5	100 cm	93 cm	75	133	64	112
2	Tree height	6	123 cm	119 cm	91	164	81	144
3	Tree height	8	191 cm		143	259		
4	Tree height	10	222 cm		169	279		
5	2-yr-cones[1])	6	4	5	2	8	2	7
6	♀ strobili	7	9	3[5])	4	20	<1	6
7	♂ strobili	7	.2		0	.5		
8	♀ strobili[3])	8	23	11	11	44	2	27
9	♂ strobili	8	1	.1[2])	0	3		
10	2-yr-cones	8		3			<1	7
11	♀ strobili[4])	9	15		8	23		
12	♂ strobili	9	3		<1	9		
13	♀ strobili	10	10		3	24		
14	♂ strobili	10	.3		0	1.5		
15	2-yr. cones[3])	10	13		5	33		
16	1-yr. cones[4])	10	9		4	23		

[1]) These averages are based on ratings rather than counts. Trees were given notes: 0 = no cones, 1 = between 1 and 10, 2 = between 11 and 20 etc. For computing plot means these ratings were converted to average frequencies like 0, 5.5, 15.5 etc.

[2]) Only a few trees produced flowers; observations not analyzed though there was no clone without any flowers.

[3]) Note the correspondence between counts of female strobili and later cone counts.

[4]) dto.

[5]) Only mean values available.

3. Results and Discussion

3.1 *Sources of variation in the individual experiments*

No significant difference was found between the two treatments for any of the traits studied. An inspection of the data revealed that primary and secondary grafts had as good as equal means.

There was however, interaction between clones and treatments with respect to tree height and the traits related to female flowering. This occurred without exceptions in the Röskär test, while the Västra Stenshult test showed interaction only in tree height. Clonal means of the number of male strobili were consistent in both primary and secondary grafts. An interpretation of this result may be the relation between flowering and growth. The female flowers are concentrated in the leader, branch tips, and youngest lateral shoots on both the stem and the branches. This concentration clarifies the relationship between the number of female strobili produced and the dimension reached by a graft. The male strobili are predominantly carried by side branches which do not show much elongation growth and therefore do not reflect the general growth pattern of a graft.

The conclusions to be drawn from the analyses of tree heights are not valid for height increments, indicating that clonal variability in the early development of the grafts, prior to the age of measurement, had a long-lasting effect up to the age of 10 years. However, the increments observed in some intervals were homogenous among the primary and secondary grafts of individual clones.

The above interpretation is supplemented by the generally continuous decrease of the interaction variance, relative to the variance between clones.

The interactions present in the two groups of traits thus may be due to the varying quality of the scions used. In the Röskär test, for instance, some clones had 40 cm more 5-year height in the secondary than in the primary grafts; in other clones, the opposite was the case. In the same test, one clone, at the age of 8 years, averaged 22 more female strobili in the secondary grafts, while another produced 14 more strobili in the primary grafts. The treatment means however, differed by only 2 strobili.

The 10 clones clearly differed in all of the traits observed. This has been reported in Scotch pine (cf. Bánó 1965 and Retkes 1965) and Norway spruce (Eriksson *et al.* 1973), both important conifer species in Scandinavia.

3.2 *Correlations among the traits*

Assessments of growth, flowering and the onset of cones were the primary problems investigated in this study. In addition, the correlations among these traits were also calculated.

The clonal differences in the abundance of both male and female flowering has an important impact on whether the present sample of clones can be regarded as potential components in the same seed orchard. In this context it might also be of interest whether male and female flowering are correlated. Due to the small number of clones it cannot be inferred whether generally the same clones show abundant or poor flower production in both sexes. However, the coincidence of a certain male and female flower

Table 3. — Summary of analyses of variance. Estimates of variance components with information on the significance of the respective mean squares[1])

Trait no. of table 2	Description		Clones 9 d. f.	Error (a) 36 d. f.	Clones x treatments 9 d. f.	Error (b) 40 d. f. [2])
a) Röskär						
1	Tree height age	5	328***	46	458***	185
2	Tree height age	6	469***	45	482***	231
3	Tree height age	9	1124***	153	480***	512
4	Tree height age	10	1382***	239*	547***	643
	leader growth	6	14.7***	4.1	0	11.3
	leader growth	7—9	153.7***	54.8	0	176.2
	leader growth	10	15.9***	15.4	1.8	16.6
7	♂ strobili	7	.02**	<.01	<.01	.08
9	♂ strobili	8	.70**	0	.35	2.52
12	♂ strobili	9	6.26***	.30	1.50*	6.16
14	♂ strobili	10	.16***	.07*	0	.17
5	2-yr. cones	6	3.45***	.68	2.10***	2.31
6	♀ strobili	7	21.33***	3.40	27.33***	13.84
8	♀ strobili	8	79.54***	18.21	50.94***	65.51
11	♀ strobili	9	33.29***	16.89	14.40*	23.36
13	♀ strobili	10	38.99***	11.19**	20.06***	15.62
16	1-yr. cones	10	33.11***	11.37*	15.28**	28.67
15	2-yr. cones	10	61.04***	9.28	29.64***	42.22
b) Västra Stenshult						
1	Tree height age	5	178***	182***	54***	61
2	Tree height age	6	313***	330***	73***	92
	leader growth	6	19.6***	23.6***	1.2	13.0
5	2-yr. cones	6	1.57*	2.84***	.17	2.97
10	2-yr. cones	8	3.15***	0	.03	3.21
8	♀ strobili	8	65.69***	40.79***	0	25.56

[1]) One, two or three asterisks refer to the 5%, 1% and .1% level of significance.
[2]) This variance has only 39 d.f. in the Västra Stenshult test.

intensity in the individual tree or plot of the field experiment can be studied. The Röskär test was used for computing the correlation matrix among trees within plots.

Stronger correlations could be expected from the weighted correlations among the error deviations of the subplot means corrected for all other effects present in the experiment. Using the numbers of surviving trees as weights, these correlations had 339 and 39 degrees of freedom, respectively.

The two types of environmental correlations revealed the same pattern. This is not necessarily to be expected in any trait and at any location. For example, the pattern of the soil variation in the Västra Stenshult experiment differs markedly from that of the Röskär test, as shown by the magnitude of the variance component of error (a) relative to that of error (b). The correlations themselves were, however, closer among subplot error deviations.

Table 4. — Correlations among female and male flowering during four years

female strobili at age	male strobili at age 7	8	9	10
7	.172	-.171	-.260	.216
8	.050	-.304	-.127	.029
9	.206	-.275	.013	.027
10	.114	.021	.078	.188

There is no obvious interpretation of the absence of correlations between the numbers of strobili in the two sexes (cf. *Table 4)*; this means that the number of female strobili produced was essentially independent of male strobili. The latter, however, do vary in size and their count cannot be used as a reliable indicator of the number of flowers, nor of the quantity of pollen shed. The correlations among numbers of strobili produced in a given year are not stronger than those of different years. In this study only 8 of the 10 clones produced male flowers at the age of 7 years. Up to the age of 10 years, there was a considerable percentage of subplots without male flowers. In any year, female flowers were present in all subplots, with two exceptions at the age of 10 years. About ¾ of the individual ramets bore female flowers in any of the years.

Another question of interest is the correlation of flowering behavior in successive years. These correlations cannot possibly measure the consistency of clonal behaviour in time but merely provide some information as to whether plots that flowered in a given year maintained this trend. There exists in the female sex a weak tendency for the same plots to produce either many or few strobili. This tendency is not due to different trees coming into flower since the respective correlations among trees within plots are positive.

Table 5. - Year-to-year correlations of strobili production

	(a) female strobili age 8	age 9	age 10		(b) male strobili age 8	age 9	age 10
age 7	.405	.510	.377	age 7	.061	.104	.122
age 8		.513	.233	age 8		.298	-.167
age 9			.191	age 9			-.148

During the two years following female flowering in pines, the number of strobili is reduced to the number of one-year-old and two-year-old cones. The latter are of more interest to the forester since more cones mean more seeds. This reduction is due to a drying-out of the strobili during the flowering period (in 1968, in the Västra Stenshult test 80 per cent of the female strobili were killed by drought at an age of 8 years), to premature cone abscission following insufficient pollination, and to other causes. Only 13 mature cones per ramet were left of the 23 female strobili produced at the age of 8 years, and only 9 one-year-old cones were left of the 15 female strobili produced at the age of 9 years. Both the die-off of flower organs mentioned above and the reduction between flowering and the counting of the cones varied with clones. The environmental correlations among the plots in these two instances were .751 and .488, respectively, while those at the single-tree level were .672 and .459. These correlations are somewhat closer than the year-to-year correlations in flower onset, and have some parallel in the year-to-year correlations of the number of cones. The counts at the ages of 6 and 10 years were correlated at .602 (one-year-olds) and .693 (two-year-olds), while at the age of 10 years the number of cones of different ages were correlated at .650.

The correlation among the number of female strobili and the number of cones is only a moderately good method of forecasting the cone crop. The latter may not accurately reflect the number of seeds per ramet since the number of viable seeds, provided sufficient pollination, varies greatly among clones. This has been confirmed recently by Alfjorden (1973) and Hadders (1973). The mature stands around the Röskär field experiment might have formed an abundant pollen source. The timing of the receptivity of female flowers in the field test, and the pollen shed in the stand of local origin was, however, not observed.

The timing of these two traits has both a provenance and a clone component of variation (Schmidt 1970).

Data reported by Bánó (1965) revealed rather close correlations (estimated from a balanced sample of 30 clones) among the numbers of cones produced in successive years, ranging between .6 and .9 in two places in Hungary. They may not be directly compared with the estimates in the present paper; however, their patterns may be studied. No increase in correlation between the two places (4 assessments each) was found when counts (at the time of collection) made in the same year were related if compared to counts made in different years. This indicates similar interaction between clones and years and between clones and places. Bánó (1965) also reported data on the relation between tree height and the number of cones produced in the two orchards that were at least 7 years old. In one orchard, the correlation coefficients estimated from the sample of 30 clones were approximately. 3 while the other orchard had correlation coefficients near zero.

Eriksson *et al.* (1973) found much closer correlations in 22 Norway spruce clones after summing, over a 6-year-period, tree height and the number of strobili. Coefficients were .61 for the female and .53 for the male sex. These authors, also, studied the variation in cone production among clones after correcting for the effect of tree height. This technique was not applied in the present study since the variation on flowering behavior of the plots was to be analysed under the given variation in growth. Since the number of cones as such possesses the main interest, it appeared to be unimportant whether trees with a given cone-onset were tall or short. Correcting for height allows to study the variation of density of cones, which shows rather pronounced differences between pine clones (Retkes 1965).

The causations behind relationships summarized in *Table 6* are not clear. However, they are reported to show their

Table 6. – Correlations between various height measurements and the number of cones produced

tree height at age	no. of cones age 6 (mature)	age 10 (mature)	age 10 (1 year old)
5	.579	.678	.486
6	.590	.688	.525
9	.505	.622	.531
10	.478	.599	.518

homogeneity. The correlations between the various height measurements and female strobili counts ranged from .3 to .7 while correlations between height and male strobili counts were near zero (all within ±.1). The correlation coefficients between height increments and female strobili numbers were smaller than for the tree heights, but all were positive and indicated no retardation of growth due to cone crop. The intensity of flowering was generally moderate at this early age of the grafts.

3.3 *Combined analyses of the two experiments*

Since there was no effect of the type of scion used, the combined analyses were run on the whole-plot means. The pooled analysis of this experimental series should yield information on the performance of clones in two relatively distant locations. Not only did the clones differ significantly in both growth and height increment at an early age, but differentiation among the clones in both locations was also significantly different. In the two traits related to female flowering interaction was even more pronounced, so that the overall differences among the clones were not significant *(Table 7 (a))*.

Eiche and Andersson (1974) described the performance of provenances in terms of how far they were transferred from the place of origin to the experimental site. Also, the change in length of the growing season was investigated as a means to explain the variation in tree height. The same technique was applied in this study to show whether the interaction between clones and planting sites was ascribable to the differential distance in latitude, longitude and elevation between the 10 origins and the two test site locations *(Figure 1)*. This resulted in 20 items per trait being subjected to regression analysis. The means of each of the 10 clones in both locations were based on approximately 45 ramets each. The multiple regressions *(Table 7 (b))* on the geographic data alone had R^2 values approximating .4 and most were significant. In the flowering-data additional fitting of the contrast between the two locations resulted in a considerable increase in correlation. But this type of relationship needs more extensive experiments to be fully understood. There is clearly a way to quantitatively estimate the increase in flower production due to a southward transfer of the ramets, which in this investigation resulted in a more favorable light and temperature regime. That regressions of this type exist is remarkable since the population in the region of origin was sampled by scions from single trees rather than pooled seed progeny of stands.

Acknowledgement

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4. Summary

a) There was no detectable difference between the two types of grafts studied. However, in individual clones the conditions of grafting affect growth and female flowering up to a minimum age of 10 years.

b) Environmental correlations among male and female strobili production were approximately zero. Correlations among female strobili production in successive years were moderate. The number of female strobili or mature cones was positively related to tree size while male flowering apparently was independent of the tree dimension.

c) The performance of the clones in two locations could, to some degree, be described by the regression on the latitudinal, longitudinal and elevational difference between their place of origin and the experimental sites.

Key words: *Pinus sylvestris* L., Seed Orchards, Grafts, Growth, Flowering.

Zusammenfassung

a) Es konnte zwischen den beiden Typen der geprüften Pfropflinge kein Unterschied gefunden werden. Jedoch werden bei einzelnen Klonen Wachstum und weibliches Blühen bis zu einem Mindestalter von 10 Jahren von den Bedingungen der Pfropfung beeinflußt.

b) Umwelt-Korrelationen zwischen der Menge männlicher und weiblicher strobili waren etwa Null. Korrelationen zwischen den Anzahlen weiblicher strobili in aufeinanderfolgenden Jahren waren mäßig. Die Zahl der weiblichen strobili oder reifen Zapfen war positiv mit der Größe des Baumes korreliert, während männliche davon offenbar unabhängig waren.

c) Die Leistung der Klone an zwei Standorten konnte bis zu einem gewissen Grad durch die Regression auf Längen- und Breitengrad und Höhendifferenzen zwischen Herkunfts- und Versuchsort beschrieben werden.

Table 7. – Analyses of variance of traits assessed in both locations.
(a) The table entries are variance components, expressed as percentages of their respective sums. Asterisks refer to the 5 per cent level of significance

Source	d.f.	1 tree height age 5	2 leader growth age 6	2 tree height age 6	5 2-yr.-old cones age 6	8 female strobili age 8
Clones	9	.41*	.35*	.48*	.56	.27
interaction	9	.12*	.12*	.12*	.17*	.31*
pooled whole-plot error	72	.47	.53	.40	.27	.42

(b) Degree of multiple determination (R^2) of a linear model containing the origin data and the contrast between the two locations

origin data alone	3/16	.379*	.428*	.363	.531*	.418*
origin data and location	4/15	.394	.429	.372	.592*	.573*

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Wood Brightness Variation in Clones of Loblolly pine

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Introduction

Mechanical pulping gives high yields and avoids the pollution caused by chemical pulping. Despite these advantages, mechanical pulps are presently limited in use because of low strength, poor brightness and bleachability, and tendency to yellow on exposure to daylight.

The brightness of mechanical pulp is related to the colour of the wood it was made from. Since the colour of pine sapwood can be characterised from measurements of brightness, absorption coefficient and scattering coefficient, reduction in pulpwood colour is a possible way of improving the brightness and bleachability of high-yield pulps, thereby extending their use (Wilcox, 1975).

The objective of this study was to determine if wood brightness, and subsequent mechanical pulp brightness, can be improved by clonal selection, and if so, whether it would be to the detriment of other wood properties. Measurements were made of the wood brightness, absorption coefficient and scattering coefficient in certain clones of loblolly pine (*Pinus taeda* L.) currently used in seed orchards. Interrelationships of optical properties with wood density, latewood percent, compression wood percent and position in the tree were also investigated.

Materials and Methods

Source of Wood

The trees studied were grafts of 37 selected clones of loblolly pine growing in the Schenck Forest clone bank of North Carolina State University at Raleigh, North Carolina. The grafts were 12 years old, and contained no heartwood. Sixty two trees, representing 1—4 ramets per clone, were felled and scion samples taken in May 1972.

Sampling Procedure

Disks: Four pairs of 5-cm thick disks were cut from each tree at approximately 1, 3, 5 and 7 metres above the graft union, and labelled disk pair, 1, 2, 3 and 4 respectively. The disks were free of knots, and were at least 15 cm from a major branch or from a graft union. Diameters of disks ranged from 5 to 23 cm. The upper disk in each pair was used for determining percent compression wood. All other wood measurements were made on the lower disk of each pair.

Segments within disks: Depending on disk diameter, 1—3 segments were sampled per disk. The segments were approximately 5 cm wide and 5 cm thick, and were cut radially across the disk without regard to the occurrence of compression wood.

Blocks within segments: Either one or two blocks were cut from each segment. Where two were cut, the block from the outer part of the segment (rings 6—10) was labelled block 1, and that from the inner part (rings 1—5), block 2. This enabled detection of possible differences in wood properties between the two age categories. The number of blocks sampled from each disk was roughly proportional to the amount of wood in the disk.

Blocks were cut to the following specifications: (a) one face a near-perfect radial surface with latewood bands parallel to the edges and perpendicular to the surface; (b) no exposed pith; (c) the outermost growth layer of the disk excluded because of possible incomplete lignification and latewood formation; (d) the radial surface with approximate dimensions of 4.2 cm parallel to the latewood bands and 3.2 cm across. Block thickness was not critical, but had to be approximately 3 cm in the tangential direction. Specimens with these dimensions were just small enough to fit in the holder of the microtome, and provided shavings big enough to cover the aperture of the Elrepho photometer used for reflectance measurement (Wilcox, 1975).

Prepared blocks were washed in distilled water to remove sawdust and stored in darkness at 4^0 C in polythene bags charged with nitrogen gas. All blocks were assigned at random to individual bags so as to avoid possible covariances within clones due to common storage conditions of the blocks or to common settings of the Elrepho photometer.

Shavings within blocks: Twelve shavings, 80—90 μm thick, were cut from the radial face of each block with a microtome and two used for determination of optical properties and latewood percent. The remaining ten acted as the opaque pad for brightness measurements.