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Wood Brightness Variation in Clones of Loblolly pine

By M. D. Wilcox

Forest Research Institute, New Zealand Forest Service, Rotorua

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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° 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.

Measurements

Optical properties: Brightness, specific light absorption coefficent (457 nm) and specific light scattering coefficient (457 nm) were measured on the shavings with an Elrepho photometer, using methods fully described elsewhere (Wilcox, 1975). Only the basic essentials of the theory and procedure will be repeated here.

Wood brightness is a function of the light scattering properties of the wood surfaces and the light absorbing properties of the cellulose, lignins, hemicelluloses and associated extractives in the wood itself. Scattering coefficient relates to the capacity of an opaque surface to scatter light. Rough surfaces with numerous reflecting edges scatter light more intensively and appear brighter than uniform surfaces. Absorption coefficient is a quantitative measure of the chromophores present. At a wavelength of 457 nm, it can be regarded as measuring the yellowness of wood. Pale, white woods have low absorption coefficients, while dark woods have high absorption coefficients.

Values of specific absorption and scattering coefficients at 457 nm of shavings were calculated by solving the following forms of the Kubelka-Munk equations:

$$s = \frac{1}{w} \cdot \frac{R_\infty}{1-R^2_\infty} \ln \frac{(RR_\infty - 1)(R^b - R_\infty)}{(R_b R_\infty - 1)(R - R_\infty)}$$

$$k = s \cdot \frac{(1-R_\infty)^2}{2R_\infty}$$

Where,

s = specific scattering coefficient (cm²/g) at 457 nm.
k = specific absorption coefficient (cm²/g) at 457 nm.
w = basis weight of oven-dry shavings (g/cm²).
R_∞ = reflectivity at 457 nm (Brightness = $R_\infty \times 100$).
R = reflectance over known backing.
R_b = reflectance of the backing.

The black metal top of the Elrepho specimen holder ($R_b = 0.044$) was used as the backing for the reflectance measurements of the individual shavings.

Latewood content: Latewood percent was measured on the same two shavings assessed for the optical properties. The total ring width and latewood width were measured for the first shaving on the ring closest to the centre of the shaving. An adjacent ring was measured on the second shaving. A transparent ruler graduated in 0.5 mm was used to make the measurements. Where compression wood occurred, it was often difficult to identify a boundary between earlywood and latewood. If possible, measurements of latewood width were therefore made where there was no compression wood.

Basic density: Basic density, the oven-dry weight per unit green volume, was measured by the water displacement method on the part of each block left after cutting the shavings. Extractives were not removed.

Compression wood content: The percent compression wood in disks was measured following the method of TAPPI T20 m-59. Only those parts of growth rings which were distinctly opaque were recorded as compression wood. Weighting factors of 0.4 for disk 1, 0.3 for disk 2, 0.2 for disk 3, and 0.1 for disk 4 were used to calculate tree means.

Statistical Analysis

The objectives were:

(1) To estimate clone means and general means, and to compare groups of clones.
(2) To determine any systematic differences in wood properties both along and across the stem.
(3) To partition the total variation in each wood property into among-clone and within-clone components.
(4) To estimate clonal correlations between different wood properties.
(5) To estimate clonal repeatability and gains from selection.

Apart from the special weighted estimator for compression wood, clone means were estimated from the arithmetic mean of all the individual measurements made on each clone. General means were estimated from the unweighted arithmetic mean of the 37 clone means. Certain groups of clone means were contrasted using Dunn's multiple comparison method (Dunn, 1961).

Variance and covariance components were estimated from analyses of variance and covariance in unbalanced nested classifications (*Table 1*). These models assume random sampling from infinitely large populations. Estimates of components were subsequently used to construct clonal repeatabilities and clonal correlations. Sampling variances and standard errors of estimates were computed for means, variance components, repeatabilities, correlations, and gains (Mahamunulu, 1963; Pederson, 1972; Tallis, 1959). No advantages were derived from using transformations to normalize data.

Table 1. — Analysis of variance models for variance component estimation¹)

Source of variation	d.f.	Expected mean squares
(A) Three-way nested model — individual shavings		
Clones	36	$\sigma^2_e + 2\,\sigma^2_b + 23.28\,\sigma^2_r + 38.37\,\sigma^2_c$
Ramets : clones	25	$\sigma^2_e + 2\,\sigma^2_b + 22.71\,\sigma^2_r$
Blocks : ramets	653	$\sigma^2_e + 2\,\sigma^2_b$
Shavings : blocks	715	σ^2_e
(B) One-way model — weighted tree means		
Clones	36	$\sigma^2_r + 1.67\sigma^2_c$
Ramets : clones	25	σ^2_r

¹) Analogous models used for covariance component estimation.

Results and Discussion

Means and ranges

Mean wood properties, and ranges of clone and block means, are listed in *Table 2*. Individual clone means are listed elsewhere (Wilcox, 1973).

Clonal Group Comparisons

There were some differences in wood properties among clones from different physiographic sources (*Table 3*). In clones whose ortets were from North Carolina, those from the Piedmont region had a lower mean wood density and higher scattering coefficient than those from the Coastal Plain region, but there were no regional differences in brightness or absorption coefficient.

Within the Piedmont region, the wood of North Carolina clones was distinctly brighter, and had lower compression wood content, density and absorption coefficent than the wood of Georgia and Alabama clones. Scattering coefficient did not differ between these two clone groups. The density differences agree with other results reported (Zobel *et al.*, 1972), but the differences in compression wood were unexpected.

Systematic Variation within Trees

Variation along the stem: Brightness and scattering coefficient increased linearly up the tree but there were no significant differences among disk levels for absorption coef-

Table 2. — Mean wood properties and ranges of 37 Loblolly Pine clones based on 12-year old grafts

Property	Mean (±S.E.)	Range of clone means	Absolute range[1])
Brightness (%)	49.5 ± 0.2	44.7 — 52.2	34.4 — 56.5
Absorption coeff. (cm²/g)	53.0 ± 0.8	45.0 — 70.0	32.3 — 114.4
Scattering coeff. (cm²/g)	202 ± 2	182 — 222	148 — 261
Latewood content (%)	15.9 ± 0.5	11.1 — 22.9	4.4 — 64.3
Basic density (kg/m³)	358 ± 3	305 — 412	282 — 552
Compression wood content (%)	3.4 ± 0.4	0.2 — 11.8	0.0 — 26.4

[1]) Absolute range of 715 individual wood blocks (range of 248 disks for compression wood)

Table 3. — Comparisons among physiographic sources

Physiographic source	Number of clones	Brightness (%)	Absorption coefficient (cm²/g)	Scattering coefficient (cm²/g)	Latewood content (%)	Density (kg/m³)	Compression wood content (%)
North Carolina, Piedmont	7	50.2 a[1])	51.0 a	205 a	15.3 a	342 a	2.69 a
North Carolina, Coastal Plain	21	49.4 ab	52.0 a	198 b	16.4 a	365 b	2.96 a
Georgia and Alabama, Piedmont	7	48.4 b	57.1 b	203 a	15.8 a	356 b	6.10 b

[1]) Means not sharing a common letter differ at the 1% level (Dunn's test)

ficient and compression wood percent. Both density and latewood percent decreased linearly with height *(Table 4)*. Some of the trends appear to be correlated. For example, as density and latewood percent increased, scattering coefficient and brightness decreased. Brightness was more obviously associated with scattering coefficient in this comparison than with absorption coefficient.

Variation across the stem: All wood properties except brightness and latewood percent clearly differed between the two radial zones in the bottom two metres of the tree *(Table 5)*. Outer wood (rings 6—10) had a higher density, lower absorption coefficient and lower scattering coefficient than inner wood (rings 1—5). The lower scattering coefficient of the outer wood was probably related to its higher density. A possible explanation for the higher absorption coefficient of the wood in the inner zone is that it contained more compression wood and had greater concentrations of lignin and extractives. Differences between zones in scattering and absorption coefficients cancelled each other, resulting in similar brightness in both zones. These results indicate that variation in absorption and scattering coefficient is at least partially associated with radial zone.

Random Variation Among and Within Clones

Variation among clones was a significant, though in most cases, small part of the total phenotypic variability of each wood property *(Table 6)*.

An interpretation of the clonal component of variance in this experiment is:

$$\sigma^2_c = \sigma^2_G + \sigma^2_C + \sigma^2_S$$

where σ^2_G is the average genotypic variance within the several populations represented by the physiographic sources included in the study; σ^2_C is "c-effect" variance representing common effects or covariance among ramets and among other sub-samples of the same clone due to common

Table 4. — Systematic variation in wood properties with height in tree — disk means of 62 12-year-old Loblolly Pine grafts

	Brightness (%)	Absorption coefficient (cm²/g)	Scattering coefficient (cm²/g)	Latewood content (%)	Density (kg/m³)	Compression wood content (%)	
7m	50.15	53.62	213	13.8	342	4.45	7m
5m	50.14	52.12	208	14.9	352	3.44	5m
3m	49.51	53.06	202	15.3	355	3.03	3m
1m	48.83	53.19	195	17.5	367	3.46	1m
LSD[1]) (0.05)	0.67	2.29	4	1.3	6	1.27	
LSD (0.01)	0.88	3.01	5	1.8	7	1.69	

[1]) Least significant difference.

Table 5. — Systematic variation in wood properties across the stem in 12-year-old Loblolly Pine grafts[1])

Wood property	Inner zone (rings 1—5)	Outer zone (rings 6—10)	Difference	Significance level
Brightness (%)	48.09	48.60	0.51	0.179
Absorption coefficient (cm²/g)	57.52	52.17	5.35	0.0006
Scattering coefficient (cm²/g)	202.02	187.91	—14.11	0.0001
Latewood content (%)	17.51	19.61	2.10	0.072
Density (kg/m³)	356	374	18	0.0001

[1]) Zone means based on 90 radial wood segments from the bottom 2 metres (disk 1) of 37 clones

Table 6. — Variance component estimates for six wood properties in 12-year-old Loblolly Pine grafts obtained from nested sampling[1]

Property	Among clones ($\hat{\sigma}^2_c$)	Ramets within clones ($\hat{\sigma}^2_r$)	Within tree[3] ($\hat{\sigma}^2_b$)	Measurement error ($\hat{\sigma}^2_e$)
Brightness	1.17 ± 0.47[2] (11%)[4]	0.39 ± 0.32 (3%)	9.55 ± 0.51 (85%)	0.09 ± 0.04 (1%)
Absorption coeff.	10.46 ± 5.41 (8%)	0.81 ± 2.97 (1%)	118.09 ± 6.17 (89%)	2.34 ± 0.12 (2%)
Scattering coeff.	83.84 ± 37.40 (21%)	25.89 ± 13.29 (6%)	273.20 ± 15.49 (67%)	22.54 ± 1.14 (6%)
Latewood %	6.65 ± 4.35 (14%)	3.51 ± 1.65 (7%)	27.91 ± 2.03 (55%)	10.00 ± 0.51 (21%)
Density	353 ± 134 (35%)	153 ± 52 (15%)	507 ± 28 (50%)	—
Compression wood %	2.00 ± 1.27 (31%)	4.46 ± 1.14 (69%)	—	—

[1] Compression wood estimates from 1-way ANOVA; all others from 3-way nested ANOVA.

[2] Estimate ± standard error. (True confidence limits are asymmetric about the point estimates).

[3] A measure of the pooled variation among disks, among segments in disks and among blocks in segments.

[4] Percentage contribution of component to total phenotypic variance.

physiological age and other non-genetic similarities carried over from the ortet by cloning; and σ^2_S represents the variation among clones due to genetic differences among physiographic sources.

The unreserved use of σ^2_c as a direct measure of the genotypic variance in some definable population is obviously not justified. Variance due to c-effects (σ^2_C) could not be estimated in this experiment, and although σ^2_S obviously accounts for some of the clonal variance *(Table 3)*, no general estimate of its magnitude was obtained. Notwithstanding these reservations, results of past investigations of wood variation in loblolly pine (van Buijtenen, 1962; Zobel *et al.*, 1972) would suggest that much of the clonal variance observed for the six wood properties in this study represents genetic variation within populations.

The variation among ramets within clones is a measure of the environmental variance at the study site. This, too, is a guarded interpretation since some of the variation could have arisen from rootstock effects. Except for compression wood, ramet-to-ramet variance appeared small compared with the clonal variance, indicating that effects of common microsite, rootstock influences, and competition effects were generally unimportant *(Table 6)*.

Variation within tree was clearly identified as the dominant source of variation for all wood properties, especially the optical properties. It accounted for 50—60% of the variance in density and latewood percent, 70% of the variance in scattering coefficient and 80—90% of the variance in brightness and absorption coefficient. Only a small proportion of the within-tree variability was attributable to the systematic trends associated with wood age. For example, there were negligible differences in brightness between inner and outer wood *(Table 5)*, yet variation among blocks within segments accounted for 70% of the total variance in brightness. The large block-to-block variance may reflect asymmetric formation of compression wood or year to year variation, and will also contain very small effects of storage conditions and Elrepho settings peculiar to individual blocks.

The within-wood-block (i.e., shaving-to-shaving) variance was small for the optical properties, showing that measurement error was unimportant.

Inter-relationships Among Wood Properties

The estimated clonal correlation between two traits is:

$$\hat{r}_c = \frac{\hat{\sigma}_{xx'}}{\sqrt{\hat{\sigma}^2_x \, \hat{\sigma}^2_{x'}}}$$

where $\hat{\sigma}^2_x$ is the clonal variance estimate for trait x, $\hat{\sigma}^2_{x'}$ is the clonal variance estimate for trait x', and $\hat{\sigma}_{xx'}$ is the clonal covariance between the two traits. The correlation measures the degree of linear association between two traits following clonal propagation, and is directly proportional to the response (be it positive or negative) of one trait when clonal selection is applied to the other. Estimates are shown in *Table 7*.

Table 7. — Clonal correlations among wood properties estimated from 12-year-old Loblolly Pine grafts

Trait x	Trait x'	$\hat{r}_c$[1]
Absorption	x compression wood	0.96 ± 0.14
Brightness	x compression wood	—0.73 ± 0.18
Brightness	x absorption	—0.73 ± 0.13
Scattering	x density	—0.71 ± 0.09
Scattering	x latewood	—0.64 ± 0.09
Latewood	x density	0.56 ± 0.12
Brightness	x scattering	0.54 ± 0.21
Brightness	x density	—0.53 ± 0.21
Brightness	x latewood	—0.44 ± 0.23
Density	x compression wood	0.22 ± 0.39
Latewood	x compression wood	0.20 ± 0.30
Absorption	x scattering	0.17 ± 0.19
Absorption	x density	—0.05 ± 0.21
Absorption	x latewood	—0.04 ± 0.20
Scattering	x compression wood	0.04 ± 0.26

[1] Estimates involving compression wood were obtained from the one-way analyses of weighted tree means. All others are based on the three-way nested analyses.

Some general relationships among the wood properties are evident from the correlations. Since compression wood has a higher lignin content than normal wood, the very strong relationship between percent compression wood and absorption coefficient supports the findings that variation in sapwood absorption coefficient reflects variation in lignin content (Wilcox, 1975). In contrast to what was found in the analysis of systematic variation and covariation among the disk levels along the stem, clonal variation in brightness was more strongly associated with absorption coefficient and compression wood content ("wood chemistry") than with density, latewood content and scattering coefficient ("wood morphology").

The strong association between high latewood content and low light scattering coefficient is attributable to the thick-walled latewood cells having much less light scattering power than the thin-walled earlywood cells. Although a direct comparison was not made, the correlations indicate that earlywood is brighter than latewood, and that low density wood is thus generally brighter than high density wood.

A striking result from the correlation analysis is the almost complete independence of absorption coefficient and density (and latewood content), and the stronger association of brightness with absorption coefficient and compression wood than with density, latewood percent or scattering coefficient.

Results With Samples Lacking Compression Wood

Of the 248 disks sampled in the main part of the study, only 40 were completely free of compression wood. Separate analyses on these 100% normal wood samples showed significant clonal variation remaining in brightness and absorption coefficient, independent of that due to variation in compression wood content. Phenotypic correlations corroborated the previous finding that brightness is more strongly influenced by absorption coefficient than by scattering coefficient. Density and latewood content affected brightness only through association with scattering coefficient and not through association with absorption coefficient.

Prospects for Genetic Improvement

Repeatability of Clone Means

The reliability with which true clonal differences can be assessed from a given sampling method can be measured from the repeatability of clone means given by

$$R = \frac{\text{clonal variance}}{\text{phenotypic variance of clone means}}$$

$$= \frac{\sigma^2_c}{\sigma^2_c + \text{var}(\mu_c)}$$

where $\text{var}(\mu_c)$ is the variance of a clone mean. In the 3-way nested sampling scheme used in this study, the generalised repeatability of individual clone means is

$$R_1 = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_r/r + \sigma^2_b/rb + \sigma^2_s/rbs}$$

where r is the average number of ramets per clone, b is the average number of blocks per ramet, and s is the number of shavings per block.

In the 1-way analysis of weighted ramet means used for compression wood, this repeatability reduces to the form

$$R_2 = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_r/r}$$

Despite the massive variability within trees, estimates of these repeatabilities were reasonably high *(Table 8)*, showing that the sampling scheme was effective in allowing detection of clonal differences. Improvement by selection is therefore possible.

Gains from Selection

The gain from selecting the best clone is the product of the selection differential and repeatability. Estimated gains from selecting the best single clone independently for each wood property are shown in *Table 8*.

Table 8. — Repeatabilities of clone means and gain from clonal selection[1])

Wood property	Selection differential	Repeatability	Gain[2])
Brightness (%)	2.7 ± 0.8	0.61 ± 0.14	1.6 ± 0.4[3])
Absorption coefficient (cm^2/g)	—7.9 ± 2.6	0.61 ± 0.11	—4.8 ± 0.9
Scattering coefficient (cm^2/g)	19.5 ± 5.5	0.73 ± 0.07	14.2 ± 1.4
Latewood content (%)	7.0 ± 1.9	0.64 ± 0.07	4.5 ± 0.5
Density (kg/m^3)	54 ± 10	0.75 ± 0.08	41 ± 4
Compression wood content (%)	—3.3 ± 1.6	0.43 ± 0.19	—1.4 ± 0.6

[1]) Selection differentials and gains are from selecting the best clone out of the 37 independently for each trait.

[2]) Gain = Selection differential x repeatability.

[3]) Standard error of estimated gain = selection differential x S.E. of repeatability.

A disappointingly low selection differential limited the gain in wood brightness in this study to only 1—2 points. Though small, a gain of this magnitude may still be economically significant in pulping since it was shown that wood brightness differences among clones were maintained in laboratory-scale refiner mechanical pulps (Wilcox, 1973, 1975). Furthermore, it should be remembered that the clones used in this study had previously been intensively selected for their phenotypic superiority in stem straightness. Straight trees will tend to have less compression wood than crooked trees and therefore the gain in wood brightness over the completely unselected base population could be higher than that over the mean of the selected clones. It is felt that gains of up to 3 points in pulp brightness could be achieved through very intensive selection for high wood brightness.

Improvement in absorption coefficient is technically possible. In this study, the estimated gain from selecting the best clones amounted to a reduction of about 5 cm^2/g, which is equivalent to reducing lignin content by about 0.5% (Wilcox, 1975). This reduction in wood lignin content was accompanied by greater uniformity throughout the tree (Wilcox, 1973; Wilcox and Smith, 1973). Clones with low absorption coefficients should therefore have good chemical pulping properties.

Actual gains in an operational programme would be less than those estimated here from selecting clones independently for each character. If improvement is to be achieved through sexual reproduction in general combining ability seed orchards, the gain will be reduced if much non-additive genetic variance is contributing to clonal differences, and if unfavourable genetic correlations occur between traits. There will be additional erosion of the gain if there are genotype × environment interaction effects; neither these nor the relative importance of additive and non-additive effects could be estimated in this study.

The problem of selecting the best of these 37 clones based on multiple trait superiority was investigated by Wilcox and Smith (1973) who developed several wood quality selection indices. Some improvement in wood brightness was obtained by selecting only for low wood density. Using indices, however, improvement in brightness was obtained simultaneously with an increase as well as with a decrease in mean wood density. Clone 8-67 was selected as the best allround clone for pulp and paper making. It has bright wood with low and uniform lignin content, a high density yet a very low latewood percent, and a low percentage of compression wood.

Conclusions

(1) The colour of wood, measured by brightness, absorption coefficient and scattering coefficient, can be determined and analysed as a metric trait by conventional methods of quantitative genetic analysis.

(2) Differences among clones in brightness are small and can only be detected by intensive within-clone sampling. Variation within clones is very large relative to variation among clones, primarily due to massive within-tree random variation.

(3) A minor part of the within-tree variability occurs as systematic trends along or across the tree. Brightness itself was higher in the upper part of the tree, but did not vary systematically across the tree.

(4) Earlywood is brighter than latewood because of its higher light scattering coefficient, and not because of any

important difference in intrinsic wood colour as measured by absorption coefficient.

(5) Clonal variation in wood brightness and absorption coefficient are strongly associated with variation in compression wood content. This and other evidence suggest that absorption coefficient of sapwood is largely a reflection of lignin content.

(6) Clonal selection can give substantial gains in wood brightness only with intensive selection to obtain a large selection differential and intensive sampling within clones to obtain precise estimates of clone means.

(7) There is a negative but apparently incomplete correlation between brightness and density. Aggregate gains from multiple-trait selection are therefore greatest when the desired combination of characteristics is high wood brightness and low density, though moderate gains in brightness should also be obtained in conjunction with increases in density.

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Summary

Brightness, specific light absorption coefficient, specific light scattering coefficient, basic wood density, latewood percent and compression wood percent were measured on fresh sapwood of 37 select loblolly pine clones. Though most of the variation in these wood properties occurred within trees, there were clear-cut differences among clones.

Clone ranges for the optical properties were 44.7%—52.2% for Elrepho brightness, 45.0—70.0 cm^2/g for absorption coefficient at 457 nm, and 182—222 cm^2/g for scattering coefficient at 457 nm. Extreme brightness values recorded for radial wood shavings were 34.4% and 56.5%.

High brightness was strongly associated with low compression wood content and low absorption coefficient, this latter characteristic itself being a reflection of low lignin content. High brightness also tended to be associated with low wood density and latewood content but only through common association with high scattering coefficient. Absorption coefficient was independent of wood density.

An estimated genetic improvement of 1.6 points in wood brightness, and subsequent mechanical pulp brightness, was obtained by selecting the brightest clone.

Key words: Brightness, light absorption coefficient, wood colour, clonal variation, mechanical pulping, clonal correlation, *Pinus taeda* L.

Zusammenfassung

An frischem Splintholz von 37 selektierten Klonen der Art *Pinus taeda* L. wurden untersucht: Weißgehalt des Holzes, spezifische Koeffizienten für Lichtabsorption und Lichtzerstreuung, Raumdichte des Holzes, Spätholzanteil und Anteil an Reaktionsholz. Obwohl der größte Teil der Variation dieser Holzeigenschaften durch Schwankungen innerhalb der Bäume zu erklären war, konnten deutliche Unterschiede zwischen den Klonen aufgezeigt werden. Bei den optischen Eigenschaften betrug die Variationsbreite der Klone 44,7%—52,2% für Weißgehalt (Elrepho brightness), 45,0—70,0 cm^2/g für den Absorptionskoeffizienten und 182—222 cm^2/g für den Zerstreuungskoeffizienten bei 457 nm. Extreme Werte für Weißgehalt mit 34,4% und 56,5% wurden von radialen Holzspänen erhalten.

Hoher Weißgehalt war streng korreliert mit geringem Reaktionsholzgehalt und mit geringem Absorptionskoeffizienten, der wiederum auf geringen Ligningehalt zurückzuführen war. Ein hoher Weißgehalt des Holzes scheint weiterhin verknüpft zu sein mit niedriger Holzdichte, geringem Spätholzanteil sowie über gemeinsame Verbundenheit mit hohem Zerstreuungskoeffizienten. Der Absorptionskoeffizient war unabhängig von der Holzdichte. Eine geschätzte genetische Verbesserung des Weißgehalts des Holzes und des mechanischen Zellstoffs um 1,6 Punkte wurde erhalten durch Selektion des hellsten (brightest) Klones.

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