Wood and kraft fibre property variation within and among nine trees of Eucalyptus nitens

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Understanding the distributions of wood and fibre properties among logs within trees is of importance to the wood processor since it will allow selective log utilisation to maximise product quality and minimise processing costs. Such advantages can be at both the solidwood and reconstituted product levels. Furthermore, understanding of the levels of variation among both trees and logs will allow breeding programs/strategies and rotation ages etc. to be directed to product requirements at the log level.

For nine 15-year-old E. nitens trees, the wood and kraft fibre property variation is extremely high among trees and among the four or five 5.5 m logs of each tree. Some critical property distribution trends within trees are:

- Chip basic density, xylose and ash contents increase linearly with increasing height (log number) from the ground.
- Chip lignin increases, and glucose content decreases, non-linearly from log 2 to the toplog, but mainly show reversed trends from log 1 to log 2. Hence, kraft pulp yields can be expected to be particularly low for logs 4 and 5.
- Kraft fibre length, perimeter and coarseness initially increase from log 1 to log 2 but then decrease markedly thereafter. Hence, numbers of fibres/g are high, and handsheet bulk values particularly low for kraft pulps made from logs 4 and 5.

Keywords

Fibre dimensions, handsheets, wood density, wood chemistry, interrelationships

Eucalyptus nitens, E. fastigata and *E. regnans* are the three eucalypt species considered to be most suitable for growing in New Zealand in commercial plantations for pulp production *(1)*. A comprehensive program is underway to quantify the potential of each species for solidwood and/or pulp and paper product end uses. The wood, and kraft fibre and pulp property variation among 29 *E. nitens* and 29 *E. fastigata* trees of age 15 years have recently been reported *(2,3,4)*. The properties of cold soda mechanical pulps made from 9 of the 29 *E. nitens* trees have also been reported (5) with comparable information on *E. fastigata* and *E. regnans* forthcoming. Both the 29 and 9 tree sets were selected to cover the range of wood basic density available.

This report covers the second phase of the assessment of *E. nitens* where the variation within and among trees of wood density and chemistry, and kraft fibre dimensions and pulp quality are quantified. This is done by the separate assessment of all 5.5 m logs and toplogs in each of 9 of the 29 *E. nitens* trees *(2)*, the same 9 trees as used in the mechanical pulping study *(5)*. Subsequent reports will relate these among-log, within-tree and among-tree wood and kraft fibre property data to comparable values measured in situ in logs and trees using SilviScan technology *(6)*.

The characterisation of the radial and vertical distributions of wood and fibre properties within eucalypt trees has been a long and incremental process and remains far from complete. Nicholls and Griffin *(7)* demonstrated the pith to bark distributions of wood density and fibre length in *E. obliqua* and *E. regnans* and showed that both increased from the pith outwards, with the most rapid increases occurring within the first 5 to 10 growth layers from the pith. Wilkes showed similar pith-to-bark trends as well as vertical distributions, where wood density increased and fibre length decreased with increasing tree height *(8)*. In more recent years, improved measurement technologies, as well as a recognition of the importance of this information, has allowed more detailed and expansive research projects to be initiated. Recent reports confirm that the broad wood density and fibre length trends of Nicholls and Wilkes hold for eucalypt species as a group, and indicate detailed within-tree trends/maps for these and additional fibre dimension properties, as well as sampling strategies for selected wood properties *(9-12)*. The big need is for rapid and non-destructive measurement of fibre dimensions in standing eucalypt trees, a measurement requirement that is anticipated to be met by SilviScan technology *(6)*.

EXPERIMENTAL

Sample origin

The trees used in this individual-log study are nine of 29 trees previously assessed for individual-tree wood, and kraft fibre and handsheet properties *(2,3)*. The nine 15-year-old *E. nitens* trees of central Victorian provenances were taken from the Provenance-Progeny Trial R 1977, Cpt. 1217, Kaingaroa Forest, planted in 1979. The nine-tree sample was made up of three trees each of low, high and medium density. Logs were numbered from 1 to 5 starting from ground level, with each log being 5.5 m long (except the toplogs which were taken to 100 mm sed and ranged in length from 4 to 7 m). Only the upper 4.1 m of the butt log was chipped as the lower 1.4 m billet was used for solid wood property assessment *(2)*. Logs were chipped in a commercial chipper and accept chips were those that passed through a 40 mm diameter hole screen and were retained on a 10 mm diameter hole screen. Composite individual-log chip samples were collected at the chipper outfall, and before the chips of the logs of each tree were recombined to give individual-tree chip samples *(2,5)*.

Chip basic density

Chip basic density was determined in accordance with AS 1301.P1s-79, except that the fresh chips were not given the specified soaking period *(13)*.

Chemical analyses

300 g o.d. chip samples were collected for chemical analyses prior to pulping. Chips were air-dried for three days prior to

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grinding (20 mesh). Samples were extracted in a Soxtec extractor with dichloromethane – boiling time 30 minutes, rinsing time 60 minutes. Extractives were vacuum dried overnight. Moisture contents were determined on separate samples.

Dichloromethane extracted samples were further ground to 40 mesh for analysis of lignin and carbohydrates. After acid hydrolysis these were analysed following TAPPI T222 om-88 for lignin, TAPPI um 250 for acid soluble lignin, and the method of Pettersen and Schwandt *(14)* for carbohydrates. Reported klason lignin values could include some non-lignin polyphenolic substances not extracted by dichloromethane (AS 1301. P11s-78, J. A. Lloyd unpublished data).

Ash, hot water solubles and 1% sodium hydroxide extractives were also determined for the air dried chip samples as follows:

- Ash was determined according to ASTM D1102 at 580°C to constant weight.
- Hot water solubility was determined following TAPPI T207 om-88.
- One per cent sodium hydroxide solubility was determined following TAPPI T212 om-88.

Pulping

One kraft pulp of Kappa number 20±2 was prepared from each chip sample by varying the H-factor at constant alkali charge. The pulping conditions were:

12% effective alkali as Na_2O
33% sulfidity
4:1 liquor-to-wood ratio
90 minutes to maximum temperature
170°C maximum temperature

Pulps were prepared in 2.0 L pressurised reactors with 300 g o.d. chip charges. Pulps were disintegrated with a propeller stirrer and screened through a 0.25 mm slotted flat screen. After dewatering and fluffing, Kappa number, % rejects and total yield were determined

Handsheet preparation and evaluation

Handsheets were prepared and pulp physical evaluations made in accordance with AS 1301 procedures. The load applied during PFI mill beating was 1.77 N/mm. Pulps were treated at 10% stock concentration for 500, 1000, 2000 and 4000 rev.

Fibre dimension measurement

Kraft fibre dimensions of thickness, width, wall area and wall thickness were measured using image processing procedures described previously (Fig. 1) *(15)*. Measurements were made on dried and rewetted fibres reconstituted from kraft handsheets. The product, fibre-width x fibre thickness, is the area of the minimum fibre cross-section bounding rectangle. The ratio, width/thickness, is an indicator of the collapse potential of the dried and rewetted fibres. The greater the width and the lower the thickness of a fibre cross-section, the greater is the extent of fibre collapse. Relative number of fibres (per unit mass of pulp) were calculated using the reciprocal of the length x wall area product. Length weighted average fibre lengths were determined with a Kajaani FS 200 following TAPPI T271 pm-91.

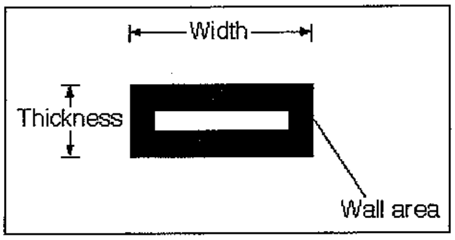

Fig. 1 **Cross section diagram of a fibre dried and rewetted from a handsheet.**

RESULTS AND DISCUSSION

Statistical analyses and comparison bases

Log number from ground: For the nine trees assessed, three contained five logs (3 trees x 5 logs) and six contained 4 logs (6 trees x 4 logs). Statistical analysis showed that the 'tree' and 'log' effects were both significant for many of the wood, pulp fibre, and handsheet properties. The two-way main effects analysis of variance (ANOVA) results, and least significant difference (LSD) values for comparison of tree means (averaged over logs) and LSD values for comparing log means (averaged over trees) are presented elsewhere *(16)*.

Mean-log number of growth layers: The SAS General Linear Models procedure was used to fit covariance (equal slopes) models for all responses. The tree identification was used as the classification variable in the models. The covariate used was the 'tree age less average number of log growth layers'. Models which included both linear and quadratic covariate terms were calculated for the responses of apparent density at 500 PFI rev, Kajaani length weighted fibre length, fibre mean width / thickness ratio, relative number of fibres, ash content, total lignin content, glucose content, and total carbohydrates content *(16)*. For the response variables, tensile index at 500 PFI rev, chip density, fibre mean width plus thickness, fibre mean wall area, fibre mean wall thickness, and xylose content, the quadratic term was not statistically significant (5% level), so models were recalculated including only the linear covariate term.

Basis of comparison: The mean-log values for the 3 tree x 5 log, and 6 tree x 4 log data sets may be compared with the equal-slopes model average curve for the important wood and fibre variables of chip density and fibre length, using log number from the ground as one comparison base and tree age less mean number of log growth layers as the other (Fig. 2,3). Individual-tree relationships for the two comparison bases are shown in Figures 4 and 5. Similar relationships are shown for both comparison bases. In

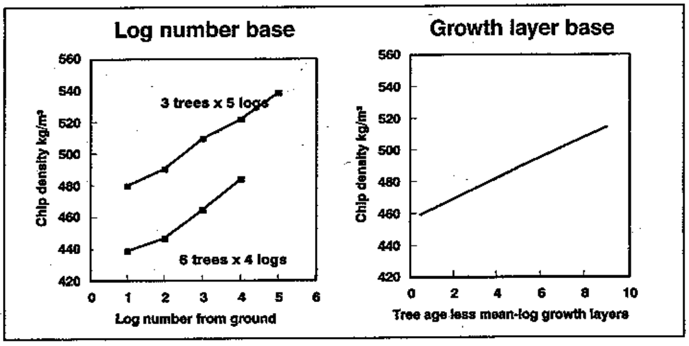

Fig. 2 **Mean-log chip density lines for 3- and 6-tree data sets, and the modelled average 9-tree trace based on mean numbers of growth layers in each log.**

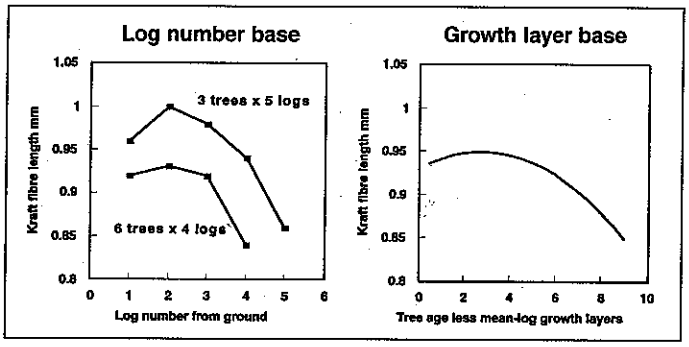

Fig. 3 Mean-log fibre length traces for 3- and 6-tree data sets, and the modelled average 9-tree trace based on mean numbers of growth layers in each log.

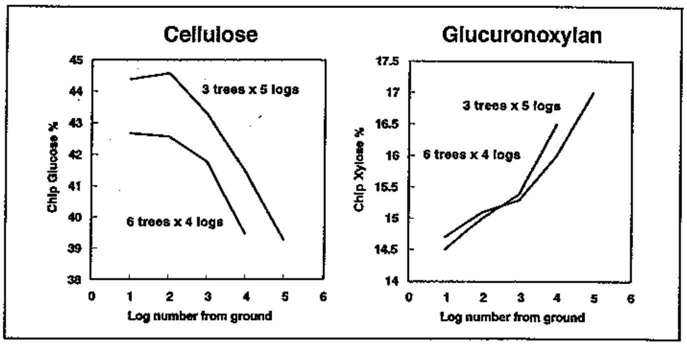

Fig. 7 Mean-log cellulose and glucuronoxylan content relationships.

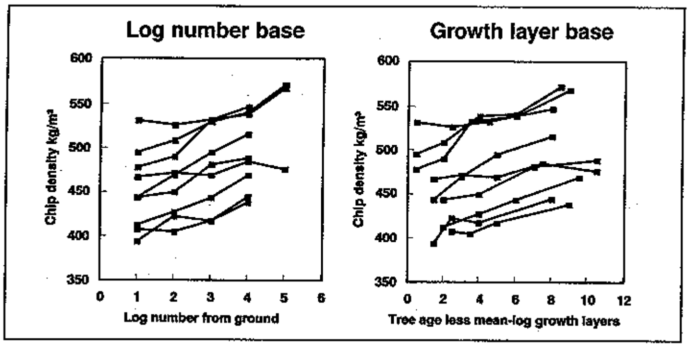

Fig. 4 Chip density variation among logs and among trees based on numbers of logs from ground and mean number of growth layers per log.

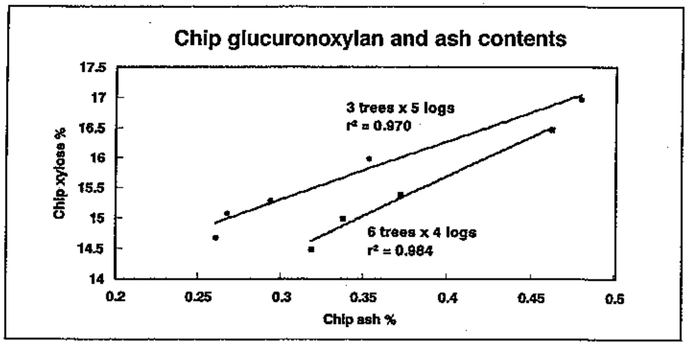

Fig. 8 Mean-log glucuronoxylan and ash relationships.

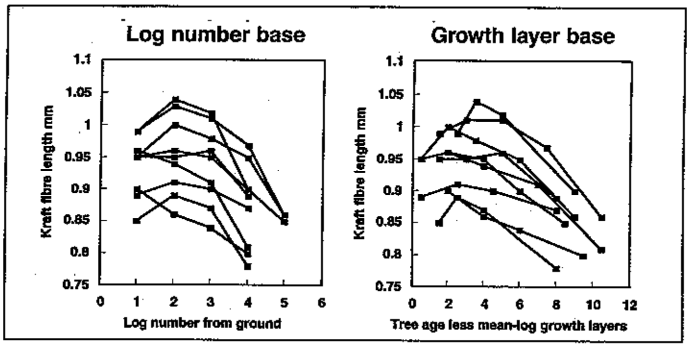

Fig. 5 Fibre length variation among logs and among trees based on numbers of logs from ground and mean number of growth layers per log.

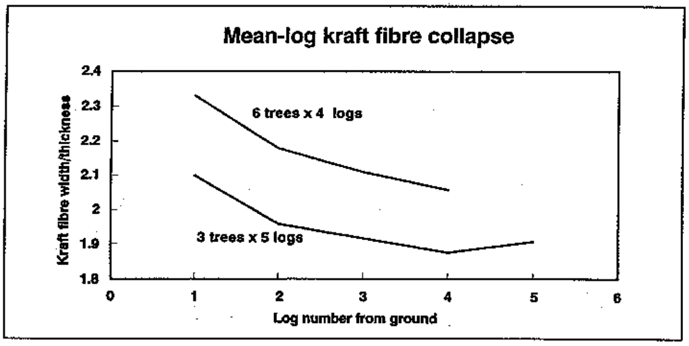

Fig. 9 Mean-log fibre width/thickness or collapse resistance.

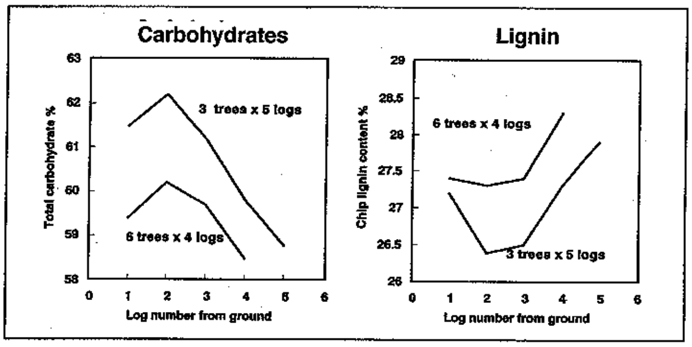

Fig. 6 Mean-log total carbohydrate and lignin content relationships.

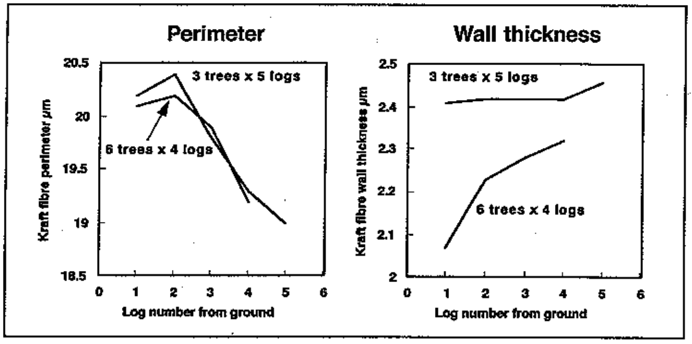

Fig. 10 Fibre perimeter and wall thickness relationships.

this report, 'Log number from the ground' is used as the comparison base since mean-log and mean-tree trends are able to be graphed directly, rather than predicted from fitted covariance models. Furthermore, the wood and fibre property curves and relationships obtained for the two mean-log data sets (3 tree x 5 log and 6 tree x 4 log) are remarkably similar when the 'log number from ground' comparison base is used. Finally, the statistical analyses show that the amount of variation explained by the fixed effect model (9 trees x 4 logs) and the growth layers based covariance models are similar for all properties *(16)*.

Variation among logs: Logs are numbered 1 to 4 or 5 from the ground depending on individual-tree size. Mean-log wood and kraft fibre properties are assessed as independent 6 tree x 4 log and 3 tree x 5 log data sets. Mean-log chip chemical composition, chip density, and kraft fibre and handsheet property data are listed elsewhere for the two data sets *(16)*. Important trends are highlighted as follows:

Mean-log chip chemical composition: Total carbohydrate content increases from the butt to second log and then decreases through log 3 to log 4 or 5 (Fig. 6). Lignin contents show the reverse trend. Both data sets show the same trends with mean-log values for the 3-tree set being of high carbohydrate and low lignin content compared to those of the 6-tree set.

Mean-log total carbohydrate and to a lesser extent lignin content differences between the two sets of data are relatively large for logs of the same number but minimal for the toplog samples (Fig. 6). Hence, toplog mean carbohydrate contents are roughly the same.

Cellulose (glucose) and glucuronoxylan (xylose) contents respectively decrease and increase with increasing log number from the ground (Fig. 7). Mean-log cellulose contents are markedly higher for the logs from the 3-tree set than those from the 6-tree set, although toplog cellulose contents are the same. Xylan contents, on the other hand, are roughly the same for the 3- and 6-tree data sets. Furthermore, ash contents also increase with increasing log number and are correlated with glucuronoxylan (uronic acid) contents (Fig. 8), as expected *(17)*.

Mean-log chip density and fibre length: Mean-log chip basic density increases linearly with increasing log number from the ground whereas fibre length first increases and then decreases to minimum values in the toplogs (Fig. 2,3). For the chip density/log number regressions, coefficients of determination (r^2) are respectively 0.992 and 0.972 for the 3- and 6-tree data sets. Mean chip density and fibre length values for the 3-tree data set are markedly greater than those of the 6-tree set. Furthermore, toplog fibre lengths, but not basic densities, are similar for the 4- and 5-log data sets. Chip density values for log 1 could be slightly lower than expected since the highest density portion of log 1 (the first 1.4 m) was excluded from the analyses *(12)*.

Mean-log kraft fibre dimensions: The papermaking qualities of kraft pulps are strongly influenced by the interactive effects of fibre length, slenderness (perimeter – width + thickness), coarseness (wall area), resistance to collapse (width/thickness), and numbers of fibres (Fig. 1) *(2,3)*.

Mean-log fibre width/thickness decreases with increasing log number from the ground with the fibres in top or high numbered logs being most resistant to collapse (Fig. 9). General trends are similar for the 3- and 6-tree data sets. Fibre width/thickness trends are the reverse of those shown for chip density (except for the log 5 data), although both fibre collapse resistance and chip density increase with increasing log number from the ground (Fig. 2,9).

The fibre width/thickness trends of Figure 9 are best explained with reference to the fibre dimensions of perimeter and wall thickness, since collapse in dried and rewetted fibres must decrease as the perimeter/wall thickness ratio decreases. For the 3- and 6-tree data sets, fibre perimeters are roughly the same, increase slightly from log 1 to log 2, then decrease with increasing log number (Fig. 10). Wall thickness values on the other hand increase rapidly for the 6-tree series and very slowly for the 3-tree series. The high wall thickness and similar perimeter of the 3-tree data, compared to the 6-tree data, account for the low width/thickness or high resistance to fibre collapse of this mean-log sample. The mean-log width/thickness value for log 5 (3-tree set) is higher than expected because of a high value in one (tree 43) of the three individual-log samples *(16)*.

Wood, kraft fibre and handsheet property relationships: Both individual-tree chip density and kraft fibre width/thickness ratio have been shown to be correlated with kraft handsheet apparent density or bulk (at 500 PFI mill rev), which is considered to be a critical eucalypt kraft pulp quality determinant *(3)*. These relationships are substantially improved when individual-tree kraft fibre length is included in the regression relationships *(2.3)*. For the two sets of mean-log data similar trends are obtained, with handsheet density decreasing with increasing chip density and decreasing fibre width/thickness, but only for logs 1-3 from the ground (Fig. 11). The short fibres in logs 4 and 5 (Fig. 3) apparently cause sheet density trends to change and increase abruptly despite increasing chip density or decreasing fibre collapse. Overall, the wood from the 3 tree set is consistently shown to be of markedly higher density with long fibres which are resistant to collapse compared to that from the 6-tree set.

Multiple regression analyses of the 39 sets of individual-log wood and pulp data are used to determine levels of correlation with handsheet properties *(16)*. Handsheet bulk or apparent density prediction from either the chip density and fibre length combination (wood property), or the fibre width/thickness ratio and length

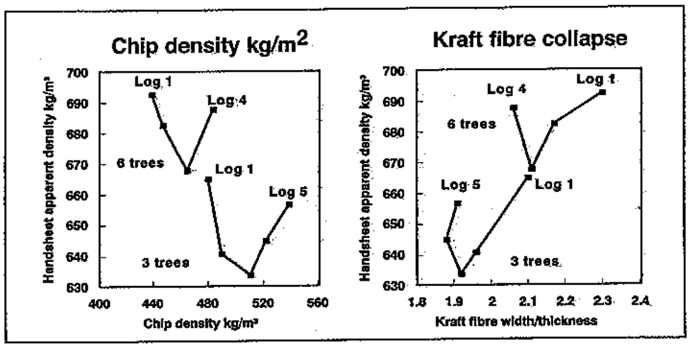

Fig. 11 Mean-log handsheet density and chip density and kraft fibre collapse (width/thickness) relationships.

combination (kraft pulp property), are relatively high for the 39 individual-log compared to 29 related individual-tree pulps *(2,3)* (Table 1). The influence of fibre length appears to be roughly the same for 29 individual-tree pulps from *E. nitens* trees, and 39 individual-log pulps from 9 of the 29 trees.

Variation among logs and trees

Chip density and kraft fibre dimensions: Variation in chip density and kraft fibre collapse is extremely high among logs and among the 9 trees (Fig. 12) *(16)*. Individual-log chip density normally increases with increasing log number above the ground with high variation among trees in agreement with the 9-tree selection criteria. The exception is tree 43, which is of medium density, where the chip density versus log number relationship is relatively flat. The kraft fibre width/thickness ratio normally decreases with increasing log number above the ground and exhibits a reverse trend to chip density as expected *(3)*. The level of variation among trees and logs is also similar although there is a greater incidence of direction change in log 4 and log 5 properties for the width/thickness ratio. This, however, appears to be related to a corresponding reverse or gradient change for chip density, as indicated by trees 43 and 84 in Figure 12.

The 3 x 5-log trees are normally of high density and fibre collapse resistance compared to the majority of the 6 x 4-log trees. An exception is tree 98, which has a high fibre collapse resistance and the highest chip density among the 39 logs and 9 trees.

Fibre length variation is high both among logs and among trees (Fig. 13). Fibre length within trees most often increases, but can decrease, from log 1 to log 2, and progressively decreases through log 3 to log 4 or 5. Although the influence of fibre length on the quality of eucalypt kraft pulps is generally small compared to width/thickness or chip density, increased length can improve the bulk of pulps deficient in fibre collapse resistance, or adversely effect web formation *(3)*. Fibre lengths are consistently high for the 3 x 5-log trees but are overshadowed by the length of the fibres from one of the 4-log trees, tree 55. This tree is of relatively low wood density, and long fibred, confirming the poor correlation between tree density, fibre length and growth recently reported by Raymond *(9)*.

The fibre properties of perimeter and wall area or coarseness show high levels of variation among logs and trees, which can increase from log 1 to log 2 and decrease thereafter or decrease continuously from log 1 to log 4/5 (Fig. 14). Overall, however, fibre perimeter and wall area are generally independent of the number of 5.5 m logs per tree since the traces for the 5-log trees are scattered among those of the 4-log trees. Relative numbers of fibres per unit mass of pulp show a trend towards a low number for the 5-log trees in response to their high long fibre content (Fig. 13,15). In contrast, individual-log pulps from tree

Table 1
Coefficients of determination for handsheet apparent density prediction from wood and kraft fibre properties.

		39 individual log pulps from 9 trees		29 individual-tree pulps (2)	
		r^2	Std error	r^2	Std error
Apparent density	W/T	0.60	22.12	0.57	19.0
	W/T + L	0.70	19.53	0.68	16.9
	D_C	0.67	20.30	0.36	23.3
	D_C + L	0.86	13.40	0.64	17.8

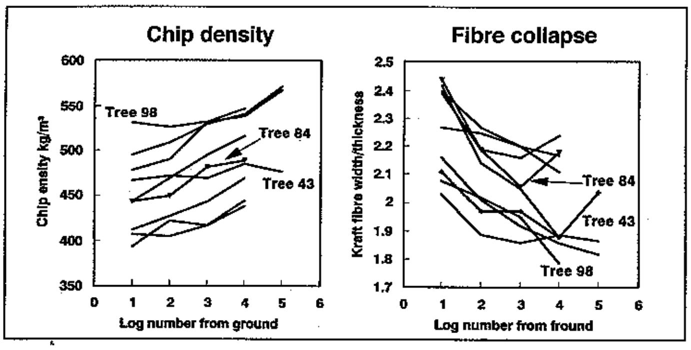

Fig. 12 Chip density and kraft fibre collapse variation within and among trees.

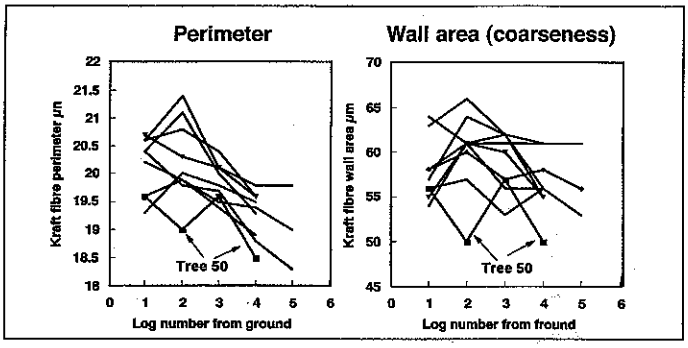

Fig. 14 Variation in fibre perimeter and wall area (coarseness), within and among trees.

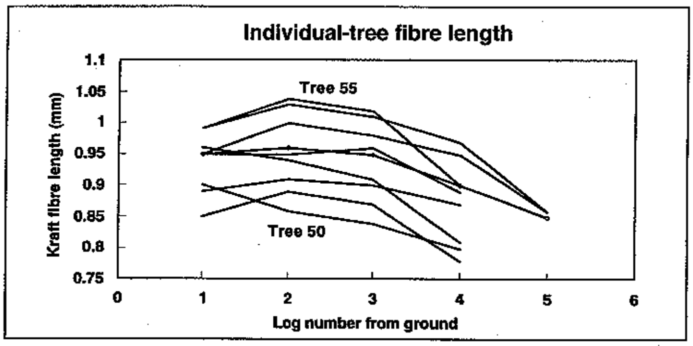

Fig. 13 Fibre length variation within and among trees.

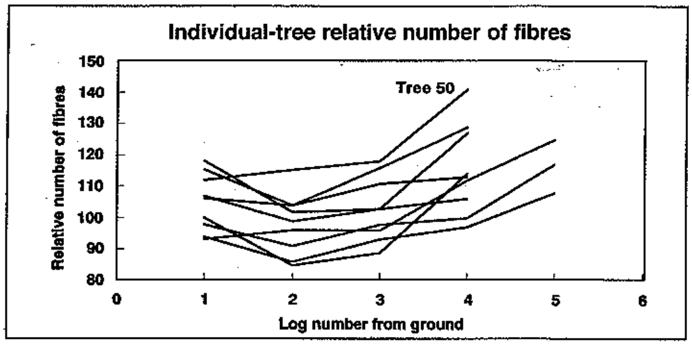

Fig. 15 Variation in relative number of fibres, within and among trees.

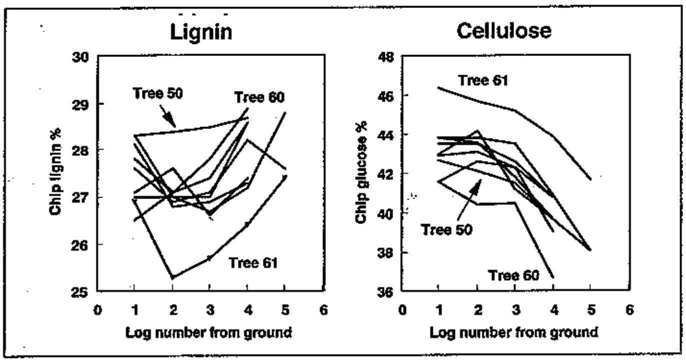

Fig. 16 Chip lignin and glucose content variation within and among trees.

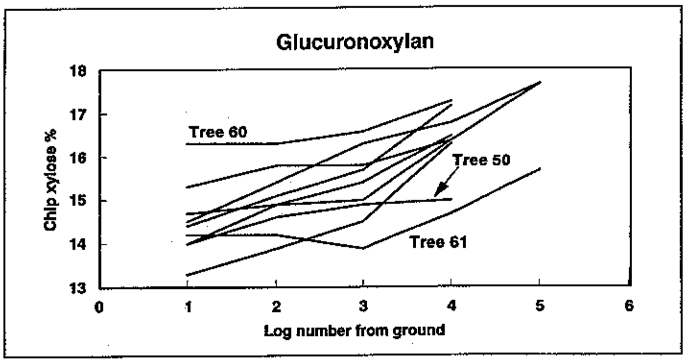

Fig. 17 Chip xylose content variation within and among trees.

50 contain high numbers of fibres because fibres are relatively short with low wall areas (Fig. 13,14). The fibres of tree 50 are also consistently of low perimeter, although fibre perimeter and other cross section dimension values for log 2 are anomalous (Fig. 14) *(16)*. The relative number of fibres in a pulp is proportional to the reciprocal of the product fibre length x wall area.

Wood chemistry: Chip total lignin and glucose contents vary widely both among logs and among trees (Fig. 16). Although lignin and glucose overall respectively increase and decrease with increasing log number from the ground, some consistent patterns can be seen. For example trees 60 and 61 show extreme glucose and lignin contents on either side of relatively compact bands for the remaining trees. Furthermore, tree 61 chips are of exceptionally low lignin and high glucose (cellulose) content. Conversely, tree 60 is of high lignin and exceptionally low cellulose content. Chips from both tree 60 and 61 show the 'typical' decrease in lignin content from log 1 to log 2 with a continual increase thereafter to values similar to or greater than those of log 1 (Fig. 6,7,16). In contrast, tree 50 is of exceptionally high lignin content with little variation among logs. Cellulose contents for the logs of tree 50 are correspondingly low, as expected, although the pattern of log-to-log variation is not abnormal compared to the other 8 trees.

Xylose (glucuronoxylan) contents within trees increase consistently with increasing log number from the ground (Fig. 17). Patterns are generally more consistent and linear than those for the glucose contents as indicated by the mean-tree trends of Figure 8. Between-tree differences show that a low chip glucose content can equate to a low xylose content and vice versa as indicated by trees 60 and 61 in Figures 16 and 17. Such direct relationships between chip glucose and xylose contents are absent for the remaining 7 trees which show closely banded properties. The glucose and xylose content trends of tree 50 are clearly the reverse of those of the widely separated trees 60 and 61 (Fig. 16).

Wallis and co-workers have shown chip glucose or cellulose content to be a good predictor of kraft pulp yield *(18)*. This is supported by chemical compositions of trees 61, 60 and 50 (Fig. 16, 17), which have respective individual-tree pulp yields of 59, 55 and 55% *(2)*. Wallis et al. also showed that chip lignin and total carbohydrate content could also be used as indicators of pulp yield, although to a lesser extent than chip cellulose or glucose content. The tree-to-tree variation can be high for chip lignin and glucose contents, as can patterns of variation within a single tree (Fig. 16). At the individual-tree level (2), total lignin ($r^2 = 0.48$), glucose ($r^2 = 0.27$), and total carbohydrate ($r^2 = 0.37$) contents are correlated with pulp yield to moderate levels, with trees 50, 60 and 61 having some extreme lignin, glucose and/or carbohydrate contents *(16)*. The corresponding correlation between xylose and pulp yield is not significant. Unfortunately comparable pulp yield values for the individual-log pulps are unavailable.

Handsheet bulk or apparent density: In the assessment of fibre types for different paper and pulp grades, the bulk or apparent density of 'unrefined' pulps (500 PFI mill rev) is considered the critical handsheet property and the base against which other 'unrefined' handsheet properties are compared *(3)*. Bulk or apparent density is a direct measure of fibre packing density and arrangements in handsheets, and is determined by fibre

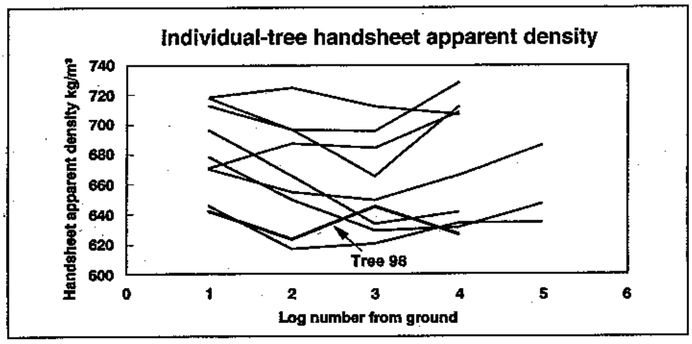

Fig. 18 Handsheet apparent density variation among logs and individual trees.

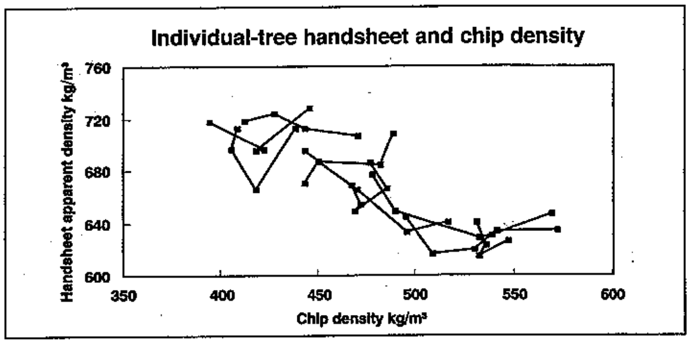

Fig. 19 Handsheet apparent density and chip density relationships among trees and among logs within trees.

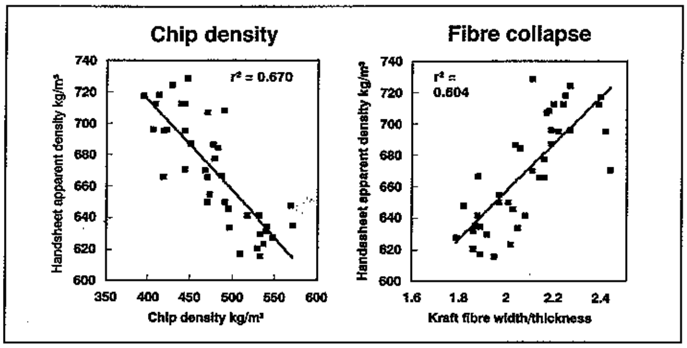

Fig. 20 Individual-log variation in handsheet density versus chip density and fibre collapse relationships.

length and cross-section dimensions, and the related morphological configurations of collapse and straightness. Full handsheet physical evaluations were carried out for all 39 individual-log pulps *(16)*. For the reasons given above and elsewhere *(3)*, apparent density is taken to be the critical link between wood, fibre and handsheet properties.

The among-tree variation in handsheet apparent density is high for the 9 individual-tree pulp-sets made up, in total, of 39 individual-log pulps (Fig. 18). Apparent density values used are for minimally refined pulps processed for 500 PFI mill rev only. Noteworthy features are the low sheet density values of the 3-tree data set compared to all but tree 98 of the 6-tree set, and the increase rather than continued decrease in apparent density from log 3 through logs 4 and 5. Tree 98 has the highest chip density of the 9-tree sample and hence, a low apparent density or high bulk is to be expected *(2,3)*.

The abrupt increase in apparent density which occurs with the log 4 and log 5 pulps (Fig. 11,18) is unexpected but explainable by the shortness and large number of slender and low coarseness fibres in the upper logs (Fig. 13,14,15). Handsheet apparent density and chip density relationships show extremely wide variation among the 9 trees, as well as indicative trends among logs within trees, consistent with those of the simplified Figure 11 (Fig. 19). Explanations for the wide variability between samples are obscured when comparisons are made at the 39 individual-log level only (Fig. 20).

CONCLUSIONS

Wood and fibre property variation among logs within trees

Average log-within-tree trends shown for both the 3-tree x 5-log and the 6-tree x 4-log data sets are as follows:

- Chip basic density generally increases linearly with increasing log number (height above the ground) as do chip xylose (glucuronaxylan) and ash contents.
- Chip lignin content decreases from log 1 to log 2 and then increases progressively from log 3 through log 4 or 5 depending on log numbers per tree.
- Chip cellulose content is roughly constant for logs 1 and 2 and decreases rapidly through log 4 or 5.
- Fibre length, perimeter and wall area (coarseness) can increase or remain roughly the same through log 1 to log 2 and progressively decrease through log 3 to log 4 or 5.
- The critical kraft pulp quality determinant, fibre width/thickness or fibre collapse, decreases with increasing log number from the ground.
- Fibre numbers per unit mass of pulp generally decrease from log 1 to log 2 and progressively increase thereafter as fibre lengths and wall areas (coarseness), as well as perimeters, decrease continuously.

Wood and fibre property variation among trees

Wood and fibre property variation among trees is high and generally independent of tree size or log number per tree. The three large 5-log trees are of high basic density, and low lignin content, with long fibres compared to most but not all of the six smaller 4-log trees. At least one of the smaller trees is of the highest chip density, contains the longest fibres or is of low chip lignin content.

Wood and fibre property and handsheet bulk relationships

Bulk or apparent density is considered the critical handsheet property in the assessment of fibre types for different paper and pulp grades. Some wood and kraft fibre property influences on handsheet density are as follows:

- Handsheet apparent density decreases from log 1 through log 3 and then increases through log 4 or log 5 depending on the number of logs per tree.
- Handsheet density decreases with increasing chip density and decreasing kraft fibre width/thickness ratio, but only for logs 1 to 3 from the ground. This is followed by an abrupt increase in apparent density through logs 4/5 due to the influence of short fibres on packing arrangements within handsheets.
- For the 39 individual-log samples, excluding among-tree effects, the chip density and fibre length combination, and the kraft fibre width/thickness ratio and length combination, are strongly correlated with handsheet density with respectively r^2=0.86 and r^2=0.75.

Implications

The high among-log variation with tree height is non-linear for most wood and kraft fibre properties and has implications for:

- The non-destructive sampling/screening of standing trees.
- The destructive sampling for kraft pulp quality assessment of eucalypt forest stands of different species, age and site etc.

For *E. nitens* trees grown on sawlog regimes, toplog residues directed to kraft mills will give pulps of low yield and bulk as a result of their low cellulose and high lignin contents, and short, slender and low coarseness fibres. Part of these deficiencies could be countered by processing together toplog and sawmill slabwood residues.

The high hemicellulose (xylan) content of toplogs may influence their utilisation potential for solidwood products since their sensitivity to changes in ambient humidity can be expected to be abnormally high.

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