# Geographic and Individual Tree Variation in Some Wood Characters of Teak (Tectona grandis L. f.)

## I. Fibre Length

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### 1. Introduction

A programme for improving teak by selection and breeding has been taken up by the Forest Genetics Section of the Forest Research Institute, Dehra Dun and the selection of plus trees that are to serve as parents in seed orchards and cross breeding has begun. The selection of the plus trees must be based on a clear statement of the objects of the breeding programme and a clear understanding of the range of variation present in nature in respect of important characters (Kedharnath and Matthews, 1962).

The selection of plus trees of teak is based on criteria such as superior growth in height and diameter; straight stem, free from buttressing and spiral grain; well developed crown with ample foliage and relatively small branches; freedom from attack of leaf defoliators and skeletoniser; resistance to drought in southern India and to frost in northern India; and ability to bear viable seed. These are obvious features of teak desired by every forester. However, in addition to these characters the plus trees must also be capable of producing timber which is superior to the average in strength, stability, durability, splitting, wearing quality and appearance.

While some preliminary studies have been made on the mechanical and strength properties of teak and on the variation of some of these properties shown by teak originating from different parts of India (Limaye, 1942; Nair and Mukerji, 1957; and Sekhar and Negi, 1961), little or nothing is known of the variation between trees of a given seed origin or between different seed origins in respect of specific gravity, fibre length, lumen diameter, cell wall thickness, fibril angle and so on, which are known to be among the factors determining the quality of wood and its strength properties. Thus if acceptable standards for selection for wood quality are to be prescribed much more must be learnt about this kind of variation in wood characters and suitable sampling techniques devised so that a speedy assessment can be made of wood characters and used as additional criteria in the selection of plus trees.

Thus the objects of the study reported here are: —

1. To study the pattern of variation in fibre length across the stem of individual trees from pith to periphery.
2. To study the variation in fibre length between individual trees of the same age growing on the same site.
3. To study the variation in fibre length between trees belonging to different geographic origins or provenances, but all of the same age and growing on the same site.
4. To obtain an estimate of the number of trees to be sampled for fibre length to achieve precisions of 15 and 20 percent.

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### 2. Material and Methods

The material for the present study was derived from three main sources, namely, one 60 year old teak tree of Nilambur origin; 18 trees selected at random from an even-aged population of North Burma provenance growing at New Forest, Dehra Dun; and 5 trees each selected at random from four different provenance plots — Madras moist (that is, Nilambur), North Bombay, North Burma and South Burma — growing at Haldwani in Uttar Pradesh in a seed provenance experiment.

The data for the 60 year old tree of Nilambur origin were derived from a disc taken at breast height from the tree after felling. The data for the other two main sources were based on increment cores taken from standing trees. Following the method of Mitchell (1958) a Swedish increment borer of 4 mm. bore-size was used and the cores taken at breast height from bark to pith. These increment cores were collected in September 1960, labelled, wrapped in Alkathene sheet and taken to the laboratory at Forest Research Institute, Dehra Dun.

In the laboratory the disc taken from the 60 year old tree and the cores from the standing trees were sampled in various ways according to the development of the study and this will be made clear at appropriate points in the text. However, the method of maceration for fibre length determination was the same throughout and can be described here.

The wood samples representing each growth ring or each part of the increment core were cut into small pellets and put into labelled test tubes containing dilute Nitric acid and small quantity of Potassium chlorate. In this mixture maceration was allowed to proceed at laboratory temperature. The fibres were washed in two or three changes of distilled water and centrifuged with a hand centrifuge. The fibres were then mounted on glass slides in a drop of 50 per cent glycerine, the cover slip was applied and sealed with paraffin wax. Twenty fibres were selected at random from each growth ring, or for each part of the increment core, and measured at a constant magnification using an ocular micrometer. The ocular micrometer scale was calibrated and each division found to equal 20 microns.

### 3. Results from the 60-year-old Teak Tree

The data derived from measurements of fibre length in each growth ring along three radii taken at intervals of 120 degrees from a disc cut at breast height from the 60-year old Teak tree are presented in *Table 1* and the results of statistical analysis are given in the analysis of variance in *Table 2*. It will be seen from these two tables that the differences in fibre length in the corresponding growth rings from the three radii are not significant. This suggests that there are no directional effects and one sample taken at a given level on the stem of the tree would suffice for comparative studies, provided of course the trees are normal in their growth habit.

*Table 1.* — Fibre Length in Microns from Three Radii of a 60-year-old Teak Tree.

| Ring No. | Radius I | Radius II | Radius III | Average for Three radii |
|---|---|---|---|---|
| 1 | 662 | 776 | 1000 | 812.7 |
| 2 | 808 | 993 | 1006 | 935.7 |
| 3 | 1027 | 1059 | 1136 | 1074.0 |
| 4 | 1036 | 1196 | 1244 | 1158.7 |
| 5 | 1118 | 1120 | 1155 | 1131.0 |
| 6 | 1168 | 1193 | 1071 | 1144.0 |
| 7 | 1185 | 1190 | 1184 | 1186.3 |
| 8 | 1196 | 1225 | 1329 | 1250.0 |
| 9 | 1261 | 1306 | 1264 | 1277.0 |
| 10 | 1267 | 1442 | 1248 | 1319.0 |
| 11 | 1283 | 1367 | 1322 | 1324.0 |
| 12 | 1381 | 1388 | 1327 | 1365.3 |
| 13 | 1439 | 1307 | 1316 | 1354.0 |
| 14 | 1339 | 1401 | 1287 | 1342.3 |
| 15 | 1344 | 1339 | 1328 | 1337.0 |
| 16 | 1350 | 1385 | 1320 | 1351.7 |
| 17 | 1335 | 1369 | 1323 | 1342.3 |
| 18 | 1273 | 1360 | 1315 | 1316.0 |
| 19 | 1336 | 1383 | 1327 | 1348.7 |
| 20 | 1421 | 1447 | 1373 | 1413.7 |
| 21 | 1503 | 1450 | 1492 | 1481.7 |
| 22 | 1461 | 1472 | 1342 | 1425.0 |
| 23 | 1465 | 1405 | 1368 | 1411.7 |
| 24 | 1442 | 1416 | 1322 | 1393.3 |
| 25 | 1490 | 1398 | 1429 | 1439.0 |
| 26 | 1458 | 1361 | 1314 | 1377.7 |
| 27 | 1456 | 1412 | 1357 | 1408.3 |
| 28 | 1359 | 1447 | 1354 | 1386.7 |
| 29 | 1366 | 1422 | 1426 | 1404.7 |
| 30 | 1367 | 1472 | 1444 | 1427.7 |
| 31 | 1321 | 1497 | 1521 | 1446.3 |
| 32 | 1444 | 1486 | 1491 | 1473.7 |
| 33 | 1571 | 1487 | 1524 | 1527.3 |
| 34 | 1401 | 1454 | 1421 | 1425.3 |
| 35 | 1454 | 1442 | 1465 | 1453.7 |
| 36 | 1333 | 1549 | 1439 | 1440.3 |
| 37 | 1519 | 1443 | 1497 | 1486.3 |
| 38 | 1407 | 1513 | 1449 | 1456.3 |
| 39 | 1507 | 1517 | 1431 | 1485.0 |
| 40 | 1437 | 1519 | 1491 | 1482.3 |
| 41 | 1494 | 1441 | 1469 | 1468.0 |
| 42 | 1487 | 1373 | 1483 | 1447.7 |
| 43 | 1424 | 1383 | 1479 | 1428.7 |
| 44 | 1456 | 1339 | 1481 | 1425.3 |
| 45 | 1374 | 1383 | 1476 | 1411.0 |
| 46 | 1463 | 1372 | 1428 | 1421.0 |
| 47 | 1430 | 1337 | 1372 | 1379.7 |
| 48 | — | 1370 | 1505 | 1437.5 |
| 49 | 1365 | 1332 | 1495 | 1397.3 |
| 50 | 1443 | 1350 | 1456 | 1416.3 |
| 51 | 1540 | 1426 | 1557 | 1507.7 |
| 52 | 1510 | 1429 | 1340 | 1426.3 |
| 53 | 1454 | 1484 | 1373 | 1437.0 |
| 54 | 1520 | 1451 | 1494 | 1488.3 |
| 55 | 1479 | 1387 | 1449 | 1438.3 |
| 56 | 1505 | 1484 | 1578 | 1522.3 |
| 57 | 1577 | 1420 | 1518 | 1505.0 |
| 58 | 1545 | 1457 | 1539 | 1513.7 |
| 59 | 1544 | 1509 | 1421 | 1491.3 |

From the graph in *Fig. 1* where fibre length in microns is plotted against the corresponding annual rings for all three radii, it will be seen that there is a sharp rise in fibre length up to about the ninth ring from the pith. Further increase is then gradual and tends to level off; but from around the 49th ring there is a further rise in fibre length. From the 49th ring the sap wood region begins and is easily recognised because of its distinct lighter colouration. Thus in the heartwood two distinct regions may be recognised, one from 1—9 rings from the pith and the second from 10—48 rings.

*Table 3.* — Mean Fibre Length in Three Regions of Eighteen Trees of North Burma Origin grown at New Forest, Dehra Dun. *(Age 29 years).*

| Tree No. | Girth at b. h. in inches. | Mean fibre length in microns JH | AH | Sap |
|---|---|---|---|---|
| 1 | 39 | 904 | 1113 | 1187 |
| 2 | 39 | 960 | 1287 | 1427 |
| 3 | 32 | 1001 | 1244 | 1365 |
| 5 | 37 | 919 | 1230 | 1204 |
| 6 | 28 | 930 | 1135 | 1362 |
| 7 | 24 | 1054 | 1169 | 1065 |
| 8 | 37 | 1032 | 1068 | 1126 |
| 9 | 36 | 1072 | 1140 | 1267 |
| 10 | 36 | 1106 | 1193 | 1368 |
| 11 | 36 | 1000 | 1093 | 1211 |
| 12 | 27 | 1062 | 1205 | 1297 |
| 13 | 36 | 1089 | 1136 | 1288 |
| 14 | 28 | 1043 | 1160 | 1238 |
| 15 | 27 | 1038 | 1186 | 1285 |
| 16 | 39 | 1180 | 1386 | 1406 |
| 17 | 36 | 1139 | 1309 | 1256 |
| 18 | 25 | 1105 | 1224 | 1339 |
| 19 | 30 | 1109 | 1182 | 1397 |
| Standard Error | | 47.50 | 46.12 | 51.68 |
| Significance | | *** | *** | *** |

### 4. Results from Trees of North Burma Seed Origin Grown in New Forest, Dehra Dun

The observations on the 60-year-old tree suggested that one increment core could be taken at breast height from normally-grown trees, and that the increment core could, to simplify subsequent measurements, be divided into three parts. These three parts consisted of the juvenile heartwood (J. H.) comprising the first nine rings from the pith; the adult heart-wood (A. H.) comprising the remaining portion of the heartwood; and finally, the sap wood (Sap) which is easily distinguished from the heartwood by its lighter colour.

When all other factors were equated it was found that significant differences existed in fibre length between the three regions sapwood, adult heartwood and juvenile heartwood among the eighteen trees sampled in the stand

*Table 2.* — Analysis of Variance in Fibre Length.

| Source of Variation | Degres of Free-dom | Sum of Squares | Vari-ance | Variance Ratio Observed | Expected at 5% | 1% | 0.1% |
|---|---|---|---|---|---|---|---|
| Between radii | 2 | 29.84 | 14.92 | N.S. 0.16 | 2.99 | | 6.91 |
| Between rings | 57 | 163798.84 | 2873.66 | *** 31.30 | | | 1.00 |
| Interaction (Radii × rings) | 114 | 22540.29 | 197.72 | *** 2.15 | | | 1.00 |
| Error | 3306 | 303364.85 | 91.76 | | | | |
| Total | 3479 | 489733.82 | | | | | |

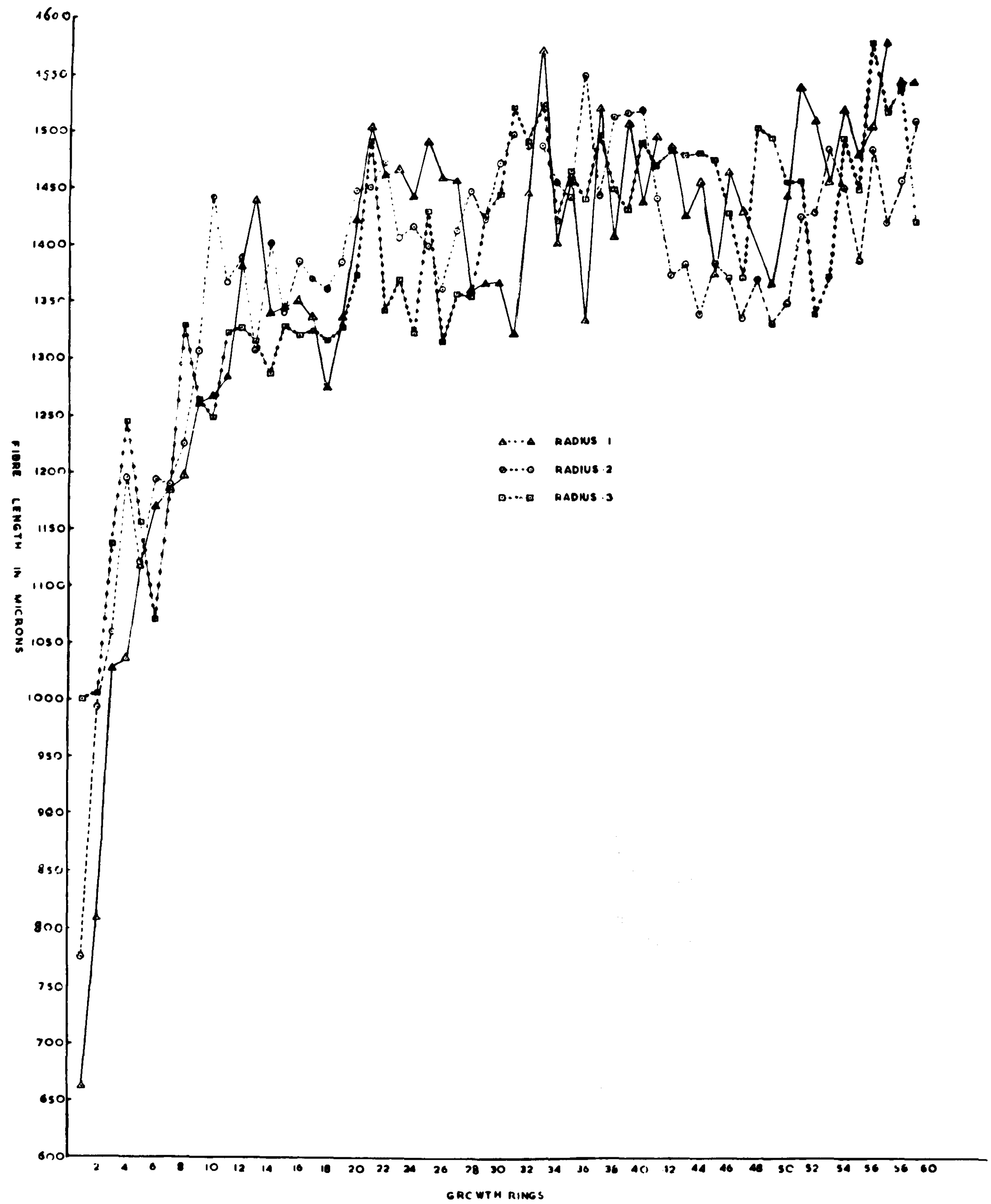


*Fig. 1.* — Graph Showing Mean Fibre Length at Successive Growth Rings.

of North Burma origin at New Forest, Dehra Dun. In general the fibres in the sap wood region were significantly longer than those in the adult-heartwood region, and those in adult-heartwood region were significantly longer than those in the juvenile-heartwood region. Significant differences in fibre-length were also observed between trees within each region of the sample cores. The data on fibre length are presented in *Table 3* and the results of the analysis of variance in *Table 4.*

**5. Results from the Teak Provenance Test at Haldwani, Uttar Pradesh**

The increment cores from the third main source used in this study were also collected in September 1960. These cores were taken from five trees selected at random in each of four provenance plots at Haldwani in Uttar Pradesh. One of the plots consisted of trees of the North Burma provenance previously sampled in New Forest. Dehra Dun.

The trees at Haldwani were all 29 years old at the time of sampling.

Consistent results were obtained for all four seed origins in that the fibre lengths were significantly different in the three regions across the stem (see last column of *table 5).*

During the analysis of fibre length between trees within the same region of the core it was noticed that in the North Burma seed origin significant differences existed between the trees sampled for all three regions of the increment

*Table 4.* — Analysis of Variance.

| Source of Variation | Degrees of Freedom | Sum of Squares | Variance | Variance ratio Observed | expected at 5% | 1% | 0.1% |
|---|---|---|---|---|---|---|---|
| | | | *Juvenile Heartwood* | | | | |
| Between trees | 17 | 5082.6806 | 298.9812 | 2.649*** | 1.65 | 2.02 | 2.49 |
| Within trees | 342 | 38596.8500 | 112.8563 | | | | |
| Total | 359 | 43679.5306 | | | | | |
| | | | *Adult Heartwood* | | | | |
| Between trees | 17 | 5394.3556 | 317.3150 | 2.98*** | 1.65 | 2.02 | 2.49 |
| Within trees | 342 | 36387.2000 | 106.3953 | | | | |
| Total | 359 | | | | | | |
| | | | *Sap Wood* | | | | |
| Between trees | 17 | 8411.7000 | 494.8059 | 3.707*** | 1.65 | 2.02 | 2.49 |
| Within trees | 342 | 45655.9000 | 133.4968 | | | | |
| Total | 359 | | | | | | |

*Table 5.* — Fibre Length for the Three Regions JH, AH and S in Four Seed Origins.

| Seed Origin | Mean Fibre Length (Microns) JH | AH | S | Significance | Standard Error | Bar Diagram at 5% Level of Probability |
|---|---|---|---|---|---|---|
| North Burma | 1015.4 | 1199.6 | 1328.0 | *** | 21.62 | S > AH > JH |
| South Burma | 976.8 | 1266.6 | 1341.8 | *** | 18.74 | S > AH > JH |
| Madras Moist | 972.8 | 1179.0 | 1275.8 | *** | 19.26 | S > AH > JH |
| North Bombay | 980.0 | 1092.6 | 1302.0 | *** | 21.12 | S > AH > JH |

*Table 6.* — Fibre Length by Sample Trees in each Region for Four Seed Origins.

| Seed Origin | Tree No. / Region | Mean Fibre Length (microns) 12 | 27 | 37 | 43 | 52 | Sig. | Standard Error | Bar Diagram at 5% level of Probability |
|---|---|---|---|---|---|---|---|---|---|
| North Burma | JH | 941 | 881 | 1159 | 1001 | 1095 | *** | 35.16 | 37 52 43 12 27 |
| | AH | 1252 | 1091 | 1283 | 1112 | 1260 | ** | 46 30 | 37 52 12 43 27 |
| | S | 1401 | 1158 | 1296 | 1566 | 1219 | *** | 51.68 | 43 12 37 52 27 |

| Seed Origin | Tree No. / Region | Mean Fibre Length (microns) 10 | 20 | 38 | 52 | 66 | Sig. | Standard Error | Bar Diagram at 5% level of Probability |
|---|---|---|---|---|---|---|---|---|---|
| South Burma | JH | 927 | 1017 | 1036 | 948 | 956 | N. S. | 37.40 | |
| | AH | 1201 | 1248 | 1322 | 1279 | 1283 | N. S. | 39.76 | |
| | S | 1326 | 1528 | 1255 | 1316 | 1284 | *** | 44.72 | 20 10 52 66 38 |

| Seed Origin | Tree No. / Region | Mean Fibre Length (microns) 1 | 13 | 25 | 49 | 63 | Sig. | Standard Error | Bar Diagram at 5% level of Probability |
|---|---|---|---|---|---|---|---|---|---|
| Madras Moist (Nilambur) | JH | 909 | 1132 | 1068 | 920 | 835 | *** | 38.10 | 13 25 49 1 63 |
| | AH | 1084 | 1211 | 1352 | 1069 | 1179 | *** | 38.82 | 25 13 63 1 49 |
| | S | 1200 | 1253 | 1369 | 1207 | 1250 | N. S. | 48.22 | |

| Seed Origin | Tree No. / Region | Mean Fibre Length (microns) 29 | 42 | 50 | 80 | 93 | Sig. | Standard Error | Bar Diagram at 5% level of Probability |
|---|---|---|---|---|---|---|---|---|---|
| North Bombay | JH | 912 | 1049 | 1045 | 973 | 921 | N. S. | 50.42 | |
| | AH | 1090 | 1085 | 1131 | 1045 | 1112 | N. S. | 43.14 | |
| | S | 1354 | 1210 | 1352 | 1321 | 1271 | N. S. | 46.86 | |

core. By contrast, in the Madras moist (Nilambur) seed origin the differences were significant only in the juvenile and adult heartwood regions. For South Burma seed origin significant differences were found only for the sap wood region. In the North Bombay seed origin no differences were noted in any of the three regions.

An additional point concerns the consistency of results noticed for the plots of North Burma provenance grown at Dehra Dun and Haldwani. The results in *table 3* (which are based on 18 trees) and those in *table 6* (based on 5 trees) show similar trends. Significant differences were obtained between regions and between trees within each region of the cross section of the stem.

In general this provenance test at Haldwani confirms that fibre length in teak increases across the stem from pith to periphery and the results show a general pattern which is common to all the trees sampled. However, the differences in this character between the trees are highly significant only for North Burma seed origin for all the three regions, while the differences in fibre length between trees are not significant for any of the regions in North Bombay seed origin. This raises the question of whether the sample size was sufficient to bring out the variability in fibre length between trees in the North Bombay seed origin. It would appear from the results that North Burma seed origin is more variable than the North Bombay seed origin and should therefore prove a promising material for selection for fibre length.

It is also instructive to note that in the other two seed origins — Madras moist and South Burma — the significant differences in fibre length between trees only apply to certain regions of the cross section of the stem.

**6. Indication of Sample Size Required for a given Level of Precision**

The number of sample trees and the number of determinations of fibre length to be made for each region across the stems of the selected plus trees depend on the variation between trees of the same provenance and within regions across the stem at the same height; and the desired precision of the estimates. If 'n' trees in one provenance are selected at random and 'm' observations are made in each of the three regions across the stem to determine fibre length, and the average of the 'n' 'm' observations is taken as the estimate of fibre length for each region, then the estimates of variation between trees and within regions can be used to determine the values of 'n' and 'm' corresponding to a desired precision of the estimate.

It was noted that increasing the value of 'm' above 20 had no appreciable influence on the accuracy of the estimates so, keeping the value of 'm' at 20, values of 'n' for different provenances were computed for precisions of 15 and 20 per cent. The results of this analysis are presented in *table* 7.

It is natural to expect that estimates of the sample size required for a given precision will be more efficient when based on a larger sample. Two such estimates are available for the North Burma provenance, one based on 5 trees and the other on 18 trees. From *table* 7 it will be seen that about 20 trees would be a sufficient sample for 15 per cent precision and 10 trees if only 20 per cent precision is desired. In the other provenances where the tree-to-tree variation in respect of fibre length appears to be low when compared with the North Burma seed origin, a smaller sample would be expected to give the same accuracy.

*Table* 7. — Values of 'n' for Four Provenances for 15 and 20 per cent accuracies (The value of 'm' is kept constant at 20).

| | 15% Precision | | | 20% Precision | | |
|---|---|---|---|---|---|---|
| Region of the stem Provenance | JH | AH | S | JH | AH | S |
| North Burma (Growing at New Forest) | 19 | 16 | 21 | 11 | 9 | 12 |
| North Burma (Growing at Haldwani) | 42 | 20 | 51 | 24 | 11 | 28 |
| South Burma (Growing at Haldwani) | 8 | 4 | 22 | 5 | 3 | 13 |
| Madras moist or Nilambur (Growing at Haldwani) | 55 | 32 | 8 | 31 | 18 | 5 |
| North Bombay (Growing at Haldwani) | 16 | 3 | 8 | 9 | 2 | 4 |

**7. The Variation in Fibre Length from Pith to Periphery at Breast Height**

The results presented in this paper are in agreement with those of other investigators on a number of different species — that is, the length of the fibres in the growth rings nearest the pith is relatively short and increases rapidly in the first few rings. Then the rate of increase declines until a maximum fibre length is reached. A study of the literature (see Dinwoodie, 1961) shows that there is considerable disagreement as to whether this initial increase in length outwards from the pith is associated with ring-number or with linear distance from the pith and whether fibre length then settles down to a constant length or fluctuates. As regards teak *(Tectona grandis),* so far as the authors are aware the only published report on changes in fibre length is that of Bisset *et al* (1950) who dealt mainly with fibre length variation within one growth ring. These workers found that the increase in fibre length was rapid and a more or less constant value was reached quite quickly.

The data presented in this paper suggest that significant differences generally exist in length between fibres in the juvenile-heartwood region comprising the first nine annual rings from the pith, the adult heartwood-region comprising that part of the stem from the tenth ring outwards, and in the sapwood region.

**8. Tree to-Tree Variation in Fibre Length**

Considerable evidence is available in the literature concerning the variation in fibre length in different species of the same genus but less work appears to have been done on the variation in fibre length between provenances and individuals within a species. Echols (1958) found highly significant variation in fibre length between provenances of Scots pine *(Pinus sylvestris).* He also observed highly significant correlations of latitude with fibre length. In addition the high correlation between fibre length and tree height led to the suggestion that prediction factors could be established for these trees based on the length of the fibres in the juvenile stage.

Nylinder and Hagglund (1954) studied the variation in fibre length in *Picea abies* and found that the longest fibres occurred in the 'broom' form and the shortest in the 'band' form. Kennedy and Wilson (1954) working in *Abies lasiocarpa* found that trees with smooth bark had significantly longer fibres than trees with rough corky bark. Echols (1955) was able to suggest that average fibre length of *Pinus elliottii* could be altered by controlled crosses between selected parents and the same conclusion was reached by Jackson and Greene (1958) for both *P. elliottii* and *P. taeda.* Dadswell and Nicholls (1959) working with *Pinus elliottii* worked out correlation-coefficients for a number of important wood characters. They found that two structural features, namely, cell length and cell wall thickness (the latter revealed by the percentage of late wood and basic density) gave in this species much of the information on wood characters required for tree breeding. Cell length and micellar angle were found to be highly correlated and both were correlated to the same degree with longitudinal shrinkage. Dadswell and Nicholls concluded that for the development of cultivars of trees of Slash pine with desirable wood characters it would appear sufficient to have a knowledge of the fibre length and basic density of the selected parents. These characters can be expected, on available evidence, to be transmitted from parent to progeny and further, data on these characters can be readily obtained from smallwood samples taken from standing trees.

### 9. The Sampling of Trees for Assessment of Fibre Length

The number of trees to be sampled and the number of determinations of fibre length to be made for each region across the stem were examined. It was found that increasing the number of observations above 20 had no appreciable influence on the accuracy of the estimates. It was also noted that only about 20 trees need be sampled for 15 per cent precision and about 10 trees if only 20 per cent precision is desired.

As for the number of sample cores to be taken from a tree at breast height it was found that there was no directional effect and the average fibre length in the corresponding rings obtained from three different radii at breast height did not show significant differences. From this it would seem that one sample from each tree (provided it shows normal growth) would suffice for comparative studies of variation between trees.


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### Summary

As part of a programme of breeding improved cultivars in teak, a valuable timber species, variation in fibre length was assessed from increment core samples of trees belonging to 4 different seed origins viz. Madras moist (syn. Nilambur), North Bombay, North Burma and South Burma. As with several other woody species, fibre length in the ring nearest the pith was very short and increased rapidly in first few rings and thereafter the rate of increase declined gradually. It was found that significant differences exist in the relative lengths of the fibres in the juvenile heartwood region comprising the first nine annual rings from the pith, the adult heartwood from the 10th ring onwards and in the sapwood region. Significant differences in fibre length were found between trees in North Burma seed origin. In the case of North Bombay seed origin such differences in fibre length between trees were not significant. In the two other seed origins i. e. Madras moist and South Burma, only in certain regions of the sample such differences were significant. The number of trees to be sampled and the number of determinations of fibre length to be made for each region was examined. It was found that increasing the number of observations above 20 had no appreciable influence on the accuracy of the estimates. As for the number of samples to be taken from a tree at a given height it was found that there was no directional effect and the average fibre length in the corresponding rings obtained from 3 different radii at 120° interval at breast height did not show significant differences. From this it would seem that one sample per tree, provided the tree is normal grown would suffice for comparative studies.



### Résumé

Titre de l'article: *Variation individuelle et variation géographique de quelques caractères du bois de Teck (Tectona grandis). I. Longueur des fibres.*

Dans le cadre d'un programme pour l'amélioration du Teck, important producteur de bois d'oeuvre, on a étudié la variation de la longueur des fibres à partir de bâtonnets de tarière de Pressler, prélevés sur des arbres de 4 provenances différentes: Zone humide de Madras (ou Nilambur), Nord de Bombay, Birmanie du Nord et Birmanie du Sud. De même que chez plusieurs autres espèces ligneuses, la longueur des fibres dans le premier anneau, près de la moëlle, est très courte, puis elle augemente rapidement dans les anneaux suivants et beaucoup plus lentement ensuite.

On a trouvé des différences significatives dans la longueur des fibres pour la région du bois de coeur juvénile comprenant les 9 premiers anneaux, pour le bois de coeur adulte à partir du 10ème anneau et pour l'aubier. On a également trouvé des différences significatives entre les arbres de la provenance Birmanie du Nord; ces différences ne sont pas significatives pour la provenance Nord-Bombay. Elles ne sont significatives que dans certaines zones de l'échantillon, pour les deux autres provenances. On a étudié l'échantillonnage: nombre d'arbres et nombre de mesures de longueur des fibres pour ces régions. L'augmentation du nombre des observations au délà de 20 n'a pas d'influence appréciable sur la précision des résultats. En ce qui concerne le nombre d'échantillons à prélever sur un arbre à une heuteur donnée, on n'a constaté aucun effet de direction et aucune différence significative dans la longueur moyenne des fibres pour les anneaux correspondants sur 3 rayons différents pris à hauteur d'homme à intervalles de 120°. Il semble donc qu'un seul échantillon par arbre soit suffisant pour les études comparatives à condition que la croissance de l'arbre soit normale.



### Zusammenfassung

Titel der Arbeit: *Geographische und individuelle Baumvariation einiger Holzmerkmale bei Teak (Tectona grandis) I. Faserlänge.*

Als Teil eines Züchtungsprogrammes auf verbesserte Eigenschaften bei Teak, einer wertvollen Holzart, wurden Messungen zur Schätzung der Faserlängenvariation an Bohrkernen durchgeführt. Untersucht wurden Bäume aus den 4 Herkünften: Madras moist (syn. Nilambur), Nord-Bombay, Nord-Burma und Süd-Burma. Die Faserlänge ist ähnlich wie bei vielen anderen Holzarten im ersten Jahrring am Mark sehr kurz und steigt in wenigen folgenden Jahrringen in Richtung Rinde sehr stark an, danach nimmt der Längenanstieg allmählich ab. In der relativen Länge der Fasern zwischen der marknahen Kernholzzone der ersten 9 Jahrringe, dem reifen Kernholz vom 10. Jahrring bis zur Splintholzgrenze und dem Splintholz wurden signifikante Unterschiede festgestellt. Signifikante Baumunterschiede wurden nur bei der Herkunft Nord-Burma gefunden, zwischen den Bäumen der Herkunft Nord-Bombay waren die Faserlängenunterschiede nicht statistisch gesichert. In den beiden anderen Herkünften (Madras moist und Süd-Burma) bestanden nur innerhalb einiger Teilgebiete signifikante Faserlängenunterschiede zwischen Bäumen. Untersucht wurde die für Faserlängenbestimmungen erforderliche Zahl der Probebäume je Teilgebiet. Eine Erhöhung der Zahl der Beobachtungen über 20 brachte keinen wesentlichen Gewinn an Genauigkeit der Schätzgrößen. Es wurde gefunden, daß bei einer gegebenen Baumhöhe die Zahl der entnommenen Proben unerheblich war. Die mittleren Faserlängen von korrespondierenden Jahrringen aus 3 verschiedenen Richtungen bei einem Winkelabstand von 120° zeigten keine signifikanten Unterschiede. Hieraus wird vermutet, daß bei normal gewachsenen Bäumen eine Probe je Baum für vergleichende Untersuchungen ausreicht.

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# The Austrian × Red Pine Hybrid

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The genetic improvement of red pine (*Pinus resinosa* AIT.) presents tree breeders with one of their most difficult problems. Not only is this valuable species remarkably uniform, but until 1955 it resisted all attempts to cross it with other pines. In that year red pine and Austrian pine (*P. nigra* var. *austriaca* [HOESS] ASCHERS. & GRAEBN.) were successfully crossed at the Institute of Forest Genetics, Placerville, California. The few hybrid trees from this cross have been mentioned and illustrated by DUFFIELD and SNYDER (1958) and RIGHTER (1962).

This cross is the first successful hybridization between hard pines of the Eastern and Western hemispheres. It is also one of the few interspecific crosses in *Pinus* that has been studied developmentally (MCWILLIAM 1959), and we know at what point the reproductive processes usually break down. The hybrids may prove to be of economic value in increasing red pine's resistance to its most serious pest, the European pine shoot moth (*Rhyacionia buoliana* [SCHIFF]). Finally, the hybrids are heterotic, greatly exceeding either parent species in early height growth at Placerville.

Austrian and red pines are grouped together in all modern classifications of the pines. SHAW (1914) places them in the *Lariciones*, a well defined group that includes most of the hard pines of the Eastern Hemisphere. The only Western Hemisphere members of this group are red pine, a native of northeastern North America, and *P. tropicalis* MORELET, a Cuban species.

Austrian pine, in contrast to red pine, has been successfully crossed with several other species in the *Lariciones*. The first authentic pine hybrid, produced by A. F. BLAKESLEE in 1914, was *P. nigra* × *densiflora* (AUSTIN 1927). Austrian pine has since been crossed with *P. sylvestris* L. and several East Asian species. These crosses and unsuccessful attempts to cross Austrian pine are summarized by WRIGHT and GABRIEL (1958).

The cross between Austrian and red pines has been tried on a much larger scale than any other cross involving either species (JOHNSON and HEIMBURGER 1946; DUFFIELD 1952; HOLST and HEIMBURGER 1955; WRIGHT and GABRIEL 1958). Between 1948 and 1955 WRIGHT and his coworkers pollinated more than 300 female strobili in attempts to make this cross, using both species as female parents. Unsuccessful attempts at the Institute of Forest Genetics since 1940 total more than 30 tree × tree combinations and 500 female strobili.

The developmental stage at which this cross fails has been described by MCWILLIAM (1959). Ovules of Austrian pine pollinated by red pine collapse toward the end of the first season after pollination and at the beginning of the second season. Breakdown of the ovule is initiated in the megaspore and later in the developing female gametophyte. MCWILLIAM found red pine pollen growing normally in about 30 percent of the ovules of Austrian pine. These ovules are the last to break down, and some of them remain intact until seed coats are formed at about the time of fertilization, early in the second season of development.

### Production and Crossing of the Hybrids

The only successful cross of these two species was made in May, 1955, between two trees growing in the Eddy Arboretum at Placerville (*table 1*). The parents were a 30-year-old Austrian pine of unknown origin and a 27-year-old red pine from an unspecified Maine source. The cross yielded 45 sound seed, 42 of which produced seedlings.

During their first growing season, the seedlings were not readily distinguishable from their Austrian pine half-sibs growing in adjacent rows (products of the *P. nigra* × *nigra* cross listed in *table 1*). The following year F. I. RIGHTER singled out four seedlings as possible hybrids. His selection was based on their marked superiority in height growth and on the lighter green of their foliage compared to the Austrian pine controls.

These putative hybrids were outplanted the following spring (1959), together with their Austrian pine half-sibs and unrelated red pines of Wisconsin origin. The outplanted trees were watered only during their first season in the field. Most of the Austrian pines had to be replaced the following year, and nearly all of the red pines have died since outplanting as a result of severe summer droughts.

The majority of seedlings from this cross of *P. nigra* × *P. resinosa* have proved to be nonhybrids. Of the eighteen 5-year-olds surviving in 1961, only six were probable hy-

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