Wood Quality in Plus Trees of Teak (Tectona grandis L. F.)

An Assessment of Decay and Termite Resistance

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Introduction

In recent years, considerable attention has been directed to the need, in any programme of tree breeding or selection, to select trees on the basis of wood quality as well as on the more obvious characters of growth and form. This paper reports the results of an attempt to assess wood quality in a selection programme for the improvement of teak being carried out by the Department of Forests of the Territory of Papua and New Guinea.

Teak has been grown in New Guinea for some sixty years, the seed having come from Burma and India. The present programme included the establishment of a seed orchard of second generation New Guinea teak 11–13 years old at Keravat in New Britain. A number of "plus" trees were selected on the basis of vigour and form and the remainder felled. It was then decided that a further selection of these plus trees should be made on the basis of wood quality, as far as this could be determined on samples which could be removed without unduly affecting the growth of the tree. In the case of teak the desirable wood properties are high durability, low shrinkage, good appearance, straightness of grain and strength (MATTHEWS, 1961; KEDHARNATH and MATTHEWS, 1962). The present paper is concerned only with the assessment of durability.

Although the increased use of teak for decorative purposes means that only a small proportion of the New Guinea product will be used for heavy outdoor construction, variation in durability is still of great importance. Much teak will still be used for applications such as boat decking where resistance to decay is important. The early thinnings from the plantations will be used locally for general construction. Though these thinnings will consist largely of sapwood which can be given a preservative treatment, the durability of the heartwood is also important, especially as the hazards from decay fungi and both subterranean and dry-wood termites are very high in the producing areas. Moreover, it seems likely that these fast-grown, second crop trees may suffer from heart rots and fungal discolourations, and the incidence of these will be affected by the decay resistance of the inner heartwood in particular.

Previous work by the authors (DA COSTA, RUDMAN and GAY, 1958, 1961; RUDMAN and DA COSTA, 1959) showed that whilst plantation-grown teak was not necessarily inferior in durability, teak trees like most other trees investigated, showed a marked radial variation for this character, with the innermost growth rings being much less resistant to decay and termite attack. With fast-grown plantation trees these early growth rings could form a very large non-durable core, which would affect the utilisation of the timber and render the tree much more susceptible to heart rot. This earlier work showed a wide variation among trees in the size of this non-durable core, with a few trees producing highly resistant wood (at least to some fungi) even in the first few growth rings. It was suggested that these differences were largely genetic in origin and that, in teak breeding, trees having durable wood even in the innermost growth rings should be sought out and used as parents. These earlier results were obtained largely on older trees, and the work of RUDMAN (1963, 1964, 1965 and RUDMAN and GAY, 1966) on the radial variation of durability in eucalypts suggested that between-tree differences in decay resistance and termite resistance of the innermost growth rings might not be apparent when the heartwood was first formed. Such differences might develop as the tree grew older through ageing and detoxification of the heartwood extractives. Since teak produces heartwood and seed at a very early age the ability to base a breeding prognamme on the first-formed heartwood would enable great savings in time. The present investigation on uniformly young trees is thereforc an important extension to our knowledge of between-tree variations.

Materials and Methods

Nineteen of the plus trees remaining in the seed orchard were selected for the examination of wood properties and from each tree a bark-to-bark sample was taken at breast height, the sample measuring approximately 6 inches along the grain and 3 inches tangentially. Each sample was divided into halves, each 3 in. X 3 in., one of which was air-dried prior to durability testing, the other half being kept green and examined for different wood characters. From one radius of the air-dried half, heartwood samples ¾ in. (long.) X 3/8 in. (tang.) X ¼ in. (rad.) for decay tests and 1¼ in. (long.) X 3/8 (tang.) X ¼ in. (rad.) for termite tests were sawn at ½ in., 1 in., 2 in., 3 in., 4 in., etc. from the pith, with an extra sample of the heartwood from immediately adjacent to the sapwood; a sample was also taken from a central position in the sapwood.

Decay resistance was determined using the brown rot fungus *Coniophora olivacea* (FR. ex PERS.) KARST. DFP 1779 and the white rot fungus *Coriolus versicolor* (FR.) QUEL. DFP 2666, in a soil block test described previously by RUDMAN (1963a) with an incubation time of 18 weeks. Termite resistance was determined using laboratory colonies of the subterranean termite Coptotermes *lacteus* (FROGG.) and the technique described previously by RUDMAN and GAY (1964).

The severity of decay or termite attack was measured by the percentage loss in weight of each specimen. In addition, the percentage survival of the termites at the end of the test was used as an indication of the existence of any termiticidal activity in the wood as distinct from deterrent activity.

To enable comparison with earlier work, and a general assessment of the overall durability of these New Guinea trees a limited number of other wood species was included in the test. The relevant details are: –

Tectona grandis L. f. Tree TK 97, ex virgin forest Burma, 168 years old, (DA COSTA, RUDMAN and GAY, 1961).

Tectona *grandis* L. f. Tree TK 75, ex plantation Indonesia, 14 years old, (DA COSTA, RUDMAN and GAY, 1958, 1961; RUDMAN and DA COSTA, 1959).

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Eucalyptus marginata SM. Tree J 30, ex virgin forest, Nowra, Western Australia, mature tree, (RUDMAN, 1964; RUDMAN and GAY, 1966).

Eucalyptus obliqua L'HERIT. Tree EO 18. Used as a control in decay tests (RUDMAN, 1965).

Eucalyptus delegatensis R. T. BAKER. Used as an example of a highly termite susceptible timber.

Callitris columellaris F. MUELL. Tree WCP 13, ex virgin forest Baradine, New South Wales, Australia (RUDMAN, 1963; RUDMAN and GAY, 1964).

Pinus radiata D. DON. Used as an example of highly termite susceptible timber.

The New Guinea teak samples retain the code numbers used by the Department of Forests, Territory of Papua and New Guinea.

Results

General information relating to the teak trees is reported in *Table 1; Table 2* presents the results obtained with the reference timbers that were included with the teak test as well as a summarised form of the results given in *Figure 1.*

Table 1. — General data for the New Guinea teak.[1])

Tree Number	Origin of Seed[2])	Breast High Diameter (in.)	Sample Radius (in.)
TG 1	Burma	15.25	7.62
2	Burma	13.25	7.75
5	Burma	11.62	6.75
7	Burma	11.82	7.00
8	Burma	15.50	10.00
9	Burma	13.25	7.12
12	Burma	12.62	6.50
13	Burma	11.75	6.75
14	Burma	12.75	6.50
15	Burma	11.75	6.50
16	Burma	13.25	6.75
20	India	13.00	7.00
23	India	9.50	5.12
24	India	13.00	8.00
26	Burma	8.62	4.37
27	Burma	9.50	5.25
28	Burma	7.50	4.37
30	India	9.50	5.00
31	India	12.00	6.50

[1]) Many of the trees had a highly eccentric pith.
[2]) The Indian seed came from the State of Madras.

All the experimental results obtained with the nineteen plus trees of teak have been presented graphically for ease of comparison (see *Figure 1*). The percentage survival figures for the termite colonies at the conclusion of the test are not given, but they were similar to those in the unfed and control colonies (50 per cent. on average), indicating that teak wood is not toxic but merely deters the termites.

A most outstanding feature of the results is the similarity that exists between the decay resistance pattern and the termite resistance pattern for the individual tree. Teak is a timber in which there is a considerable concentration of quinones and related extractives, which possess both antitermitic activity and antifungal activity (RUDMAN, 1961 a and b) so that the general similarity of the curves is not unexpected.

A further point of considerable interest is the overall level of durability in the trees *(Table 2)*. These trees may be said to be moderately durable whereas most virgin teak would be classed as highly durable. This difference does not, however, imply any genetic or climatic differences but arises almost entirely from the fast growth of the teak in its early years. Because of this, virtually all the heartwood of these medium sized trees is confined to the first few growth rings from the pith and comparison with analogous growth rings of the older trees tested in our earlier works *(loc. cit.)* shows that the New Guinea wood is only slightly, if at all, less durable.

A consideration of the graphs showing the amounts of decay and termite attack *(Fig. 1)* indicates that in all trees the inner heartwood is much less durable than the outer heartwood (as was expected from earlier work on this and other species) but that the variation in durability within a tree varies widely among trees. In all trees the innermost heartwood is very susceptible to attack, often more susceptible than sapwood but in some trees the outer heartwood is quite resistant whereas in others it is only slightly better than the inner heartwood. Because of this variation in the radial pattern and because of slight differences in the results for the two decay fungi and the termite species, it is difficult to assign to each tree a single-figure assessment of durability or even to rank them for this property.

Trees containing durable wood in the innermost growth rings may occur, but be rare, and hence would not be ex-

Table 2. — Durability of reference timbers.

Species	Code Number	Percentage Weight Losses					
		Inner Heartwood			Outer Heartwood		
		Termites	Fungi[1])		Termites	Fungi[1])	
		C. lacteus	1779	2666	*C. lacteus*	1779	2666
Tectona grandis[2]) (New Guinea) 13 years old	TG 1—31 incl.	66	44	54	20	12	21
Tectona grandis (Indonesia) 14 years old	TK 75	79	54	55	13	22	21
Tectona grandis (Burma) 168 years old	TK 97	15	4	8	4	4	3
Eucalyptus marginata (Jarrah)	J 30	100	50	24	31	1	2
Eucalyptus obliqua (Messmate stringybark)	EO 18	—	3	11	—	4	5
Eucalyptus gigantea (Alpine ash)	—	—	—	—	99	—	—
Callitris columellaris (Cypress pine)	WCP 13	1	1	1	0	2	1
Pinus radiata	—	—	—	—	100	—	—

[1]) 1779, *Coniophora olivacea;* 2666, *Coriolus versicolor.*
[2]) Means derived from the results for all the New Guinea teak are given.

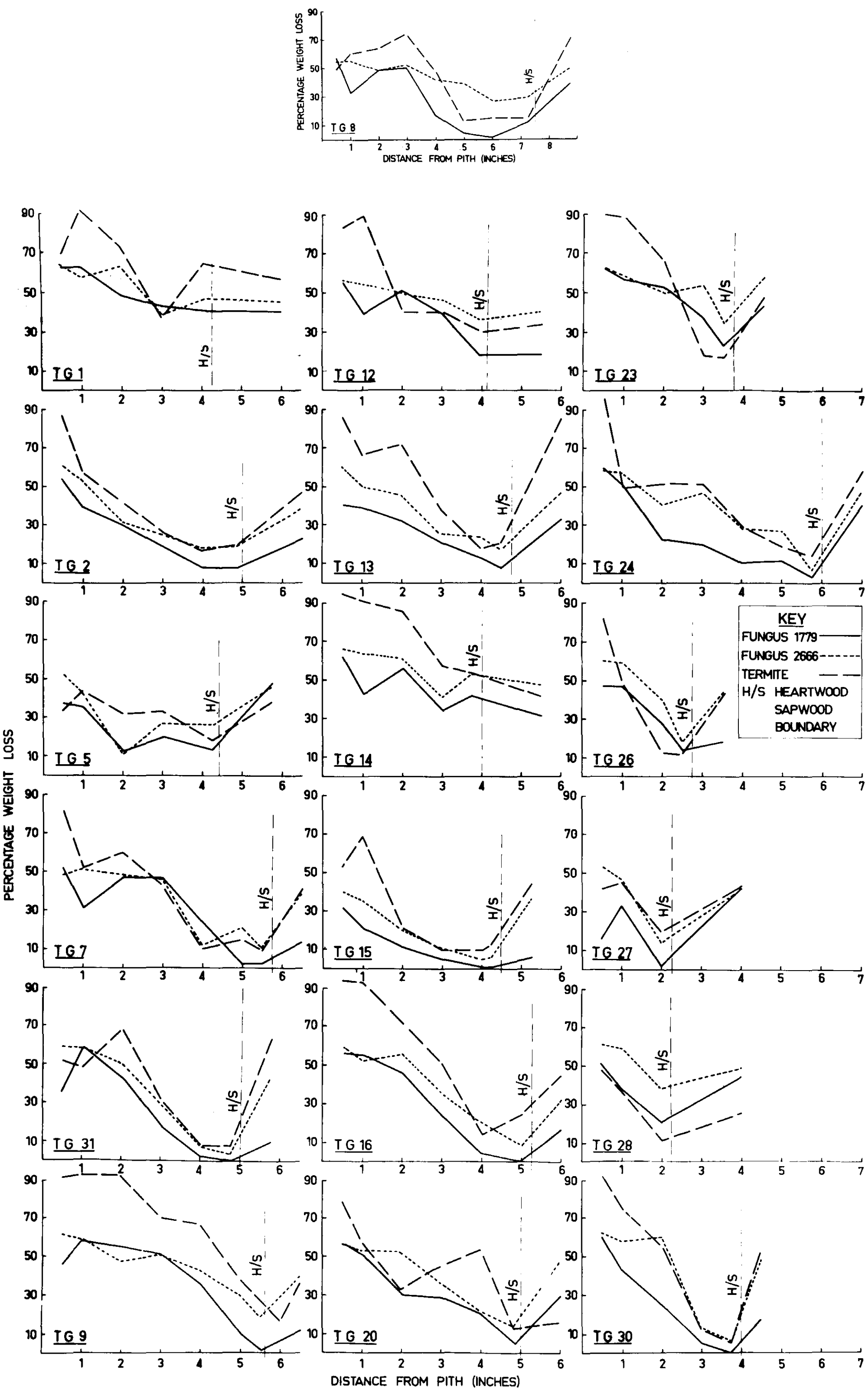

Figure 1. — The radial variation in durability of New Guinea teak. 1779, *Coniophora olivacea;* 2666, *Coriolus versicolor,* termite, *Coptotermes lacteus.*

pected to be found in a sample of nineteen trees. A much more extensive sampling should eventually locate such trees (Da Costa, Rudman and Gay, 1961) and they would be particularly valuable for any breeding programme.

An examination of the data does not show any consistent difference between trees derived from Indian seed (*i. e.* trees 20, 23, 24, 30 and 31) and those from Burmese seed. Inspection of the teak samples suggests that there is some degree of association between colour and durability, with those trees with dark brown heartwood tending to be more resistant to both decay and termites, but this is by no means consistent because one of the poorest trees (tree 23) had reasonably dark heartwood.

Discussion

The results of this experiment clearly indicate the advantages of making assessments of wood quality when selecting trees for propagation purposes. All trees involved had already been selected as being suitable for breeding purposes, yet if the resistance of the heartwood or the amount of heart rot likely in the trees has any significance in the utilisation of the timber, then it is quite clear that over half of the plus trees initially chosen are unsatisfactory.

The information obtained could be put to use in several different ways. For the rapid production of large quantities of seed for mass planting of better than average teak, it may be sufficient to eliminate only the poorest trees (trees 1, 12, 14 and 23) from the seed orchard. For a select seed orchard, for progeny trials, or for experimental crosses, it is desirable to select the best trees. Here the variation in the within-tree pattern of durability makes the choice difficult. Thus trees 15, 30 and 31 have achieved a high resistance to attack in their outermost heartwood almost comparable to that of the best Burmese teak from the virgin forest (*Table 2* and previous papers); if production is aimed mainly at large trees (say three times the diameter of the trees tested) then these three trees would seem to be the obvious choice. On the other hand, the middle heartwood of trees 30 and 31 (about a point midway between pith and sapwood) is more susceptible to attack than the middle heartwood of trees 2 and 15. This difference may be unimportant in the utilisation of large trees, but it must be remembered that durability will be a more important property in determining the susceptibility of the stands to heart rot and in the utilisation of thinnings. In these applications, a difference between moderately susceptible and highly susceptible inner and middle heartwood of trees of the size tested or inner heartwood of larger trees may be of critical importance. Because both the utilisation of thinnings and the production of large trees are important, neither choice is completely satisfactory, and trees which exhibit superior resistance to decay and termites in all radial zones must be sought. If no further assessment of the relative importance of the alternative is possible, then all four trees (trees 2, 15, 30 and 31) should be considered since they represent a considerable improvement over the existing nineteen plus trees. Because rate of growth is also important, this choice could be narrowed down if necessary to trees 2 and 31, that is one from each category.

Another difficulty in selecting from young trees, which is now becoming evident, is in forecasting to what extent the observed differences will persist as the trees grow older. The most important question is whether or not what is now high durability wood will age in the growing tree so that eventually it is low durability wood. If ageing and detoxification of the extractives occurs in teak (as shown in eucalypts by Rudman, 1963, 1964, 1965, Rudman and Gay, 1966) then this would affect the assessments. If rate of ageing is uniform for the species, then the trees which are initially more durable will retain this superiority, but it is possible that trees vary widely in rate of ageing.

It is to be hoped that some of these problems may be partly solved by a re-examination of the present trees in about ten years time. It is also hoped that progeny and clonal trials can be arranged to establish the extent to which these differences are inherited.

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Summary

Nineteen young "plus" trees being used for the propagation of teak (*Tectona grandis* L. f.) in New Guinea have been examined for decay and termite resistance, and quantitative assessments of each made at inch intervals outwards from the pith. An outstanding feature of the results is the similarity between the decay and termite resistance patterns. The overall level of durability may be said to be moderate rather than high, but this is probably because all the heartwood of these 13 year old trees (average d. b. h. 11.9 inches) is within a few growth rings of the pith. Four of the trees are considered completely unacceptable, the remainder are acceptable but four trees are shown to be superior.

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