NATURE AND DISTRIBUTION OF EXTRACTIVES IN TEAK (TECTONA GRANDIS LINN.) FROM THAILAND

by

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SUMMARY

Special properties of teak – e.g. the low swelling and shrinking rates, great resistance to mechanical and chemical attacks, natural durability, inhibition of varnish-drying, difficulty with adhesives, and the causing of dermatoses – can to a considerable extent be attributed to the type and quantity of certain wood extractives. In the present work, the distribution of such extractives over the cross-section of samples of teak from Thailand was examined. The results permit predictions as to the character of the wood in question. The possibilities of cultivating teak of a desired quality and with the desired properties are to be suspected.

Occurrence, use and properties of the wood

Teak (Tectona grandis Linn., Fam. Verbenaceae) is one of the most valuable woods in the world. The tree occurs in the primary forests of Thailand, Burma and parts of India and also in the form of cultivated forests in Indonesia. In recent years attempts have been made to cultivate teak in other areas with a distinct alternation between dry and rainy seasons, such as Africa and Latin America.

Teak is used as structural timber for internal and external constructions when particularly great strength is required for joints and shape. This has long been the case in the building of ships and decks. The wood is further utilised to a considerable extent in the production of resistant containers in the chemical industry. At present, teak also plays a significant role as outfitting and furniture wood – either as a base or as a veneer.

At an average density of 0.64 the wood possesses good technological properties, swells and shrinks to an extremely low degree and

shows great resistance both to mechanical stress and to chemicals. The natural resistance of teak to vegetable and animal parasites is high. A disadvantage in the use of the wood is an occasional danger to the health (dermatoses) caused by close contact with the wood-dust and also its characteristic inhibition of the drying and film-formation of some varnishes.

The outstanding properties of teak and their likely causes have been the subject of wood research for a long time. CAMPBELL & BAMFORD (1939) provided a close relationship between the low shrinkage degree of the wood and it's small content of hemicellulose. At present it is proved, that many peculiarities of teak are caused by the type and amount of some extractives (SANDERMANN & SIMATUPANG 1966).

Table 1

Analyses of teak (CAMPBELL & BAMFORD 1939)

Solubility in cold water	= 4,1%
,, in warm water	= 6,8%
,, in 1% NaOH	= 21,1%
Extract content (alcohol-benzene 1 : 1)	= 10,9%
Cellulose	= 45,2%
α-cellulose	= 36,5%
Lignin	= 30,5%
Methoxyl	= 6,2%
Total pentosan	= 13,3%
Pentosan in cellulose	= 3,9%
Pentosan, not in cellulose	= 9,4%

Teak extractives and their effect

Teak has an extract content of an average of 10%, based on kiln-dry wood. ROMANIS (1887) isolated from the extract tectoquinone (A) as the first chemically uniform compound. The chemical structure of the new material was defined by KAFUKU & SEBE (1932) as 2-methly-anthraquinone. As a result of the research carried out by WOLCOTT (1947, 1949), tectoquinone was found to have a deterrent effect on termites. According to SANDERMANN & DIETRICHS (1957), the resistance of various teak samples rises with increasing tectoquinone concentration.

Besides tectoquinone, further anthraquinones were isolated from teak in the following years : 3-hydroxy-2-methylanthraquinone (B) (PAVANARAM & ROW 1957), 1-hydroxy-2-methylanthraquinone (C) (ROW 1960), 2-hydroxymethylanthraquinone (D) (RUDMAN 1960), and 1.4-dihydroxy-2-methylantraquinone (G) (SANDERMANN & SIMATUPANG, (1966). The presence of anthraquinone-aldehyde -(2) (E) and anthraquinone-carboacid-(2) (F) is likely (RUDMAN 1960). The chemical structure of other anthraquinones found in teak-wood have not yet been elucidated. The aforementioned compounds–as far as they have been examined–demonstrate repellent and toxic effects on termites and–in some cases–on fungi (RUDMAN & DA COSTA 1959). Because of their average low content in the wood they presumably play a subsidiary role in the wood's natural durability.

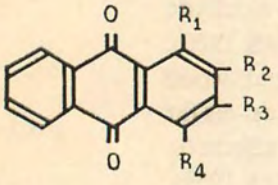
The naphthoquinones found in teak-wood besides others, which chemical structure has not yet been elucidated, are lapachol (H) (SANDERMANN & DIETRICHS 1957) and desoxylapachol (J) (SANDERMANN & SIMATUPANG 1963). Both compounds have a toxic effect on termites. Contact allergies are produced by desoxylapachol and lapachol; but the effect of the latter is 100 to 200 times less. Only desoxylapachol inhibits the drying of some varnishes (SANDERMANN et al. 1963, 1966).

There are two other interesting extractives in teak, called tectol (K) and dehydrotectol (L) (SANDERMANN et al. 1959, 1964). The very dark violet-coloured dehydrotectol forms the black stripes, sometimes occurring on teak timber surface. Both compounds inhibit drying of varnish (SANDERMANN et al. 1960), but have no effect on fungi and insects.

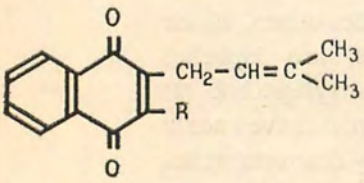
A hydrocarbon in teak, already established by MATTHES & SCHREIBER (1914), represents caoutchouc (M) according to SANDERMANN & DIETRICHS (1959). Probably the caoutchouc content of teak is responsible to the resistance of the timber to water and chemical attacks, and perhaps to a low rate of shrinkage too. (NARAYANAMURTI et al, 1960, 1962, SANDERMANN et al. 1963).

Certain properties of teak are thus closely connected with the chemical constitution of some extractives; furthermore they are depending on the content of these extractives in the wood, as has already been pointed out. Although in practice some contradictory evidences concerning the character of teak are currently observed,

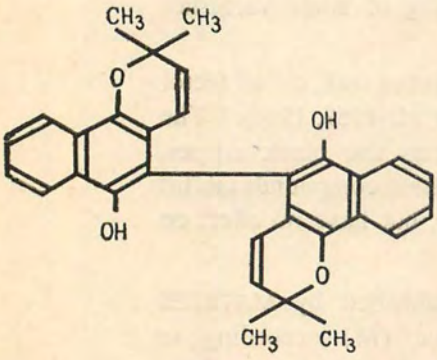
Formulae



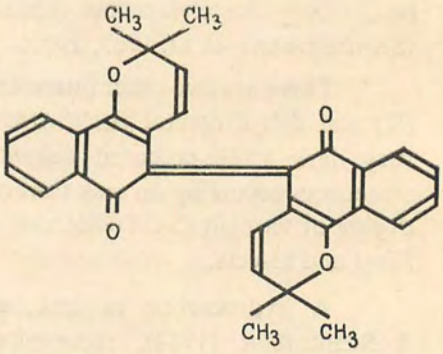
R_1	R_2	R_3	R_4	
H	CH_3	H	H	A (Tectoquinone)
H	CH_3	OH	H	B
OH	CH_3	H	H	C
H	CH_2OH	H	H	D
H	CHO	H	H	E
H	COOH	H	H	F
OH	CH_3	H	OH	G



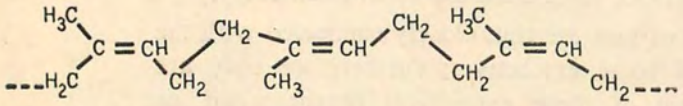
R	
OH	H (Lapachol)
H	J (Desoxylapachol)



K (Tectol)



L (Dehydrotectol)



M (Caoutchouc)

these can be explained by the irregular distribution of the responsible extractives. The varied concentration of extractives is not only to be found in the wood from different trees but also–and often to a pronounced degree–in that from the same tree (SANDERMANN et al. 1959, 1966).

The distribution of extractives in the cross-section of a trunk

The quantitative distribution of the extract in teak has been the object of various investigation (NARAYANAMURTI et al. 1962, RUDMAN 1961). From the point of view of individual extractives, only the caoutchouc content has been considered (NARAYANAMURTI & SINGH 1960) and in two other examinations the distribution of tectoquinone, tectol, dehydrotectol and desoxylapachol are being observed (SANDERMANN et al. 1959, 1966).

To obtain a uniform picture, the distribution of those extractives occurring in greater quantities and hitherto recognised as affective was ascertained by taking a cross-section of four teak trunks from Thailand. Two of the samples (I, IA) came from the district of Kanchanaburi, about 100 km north-west of Bangkok. The other two samples (II, IIIA) were taken from Chiengmai and Lampang in the northern part of Thailand (Fig. 1). All the samples were collected in December 1962; their diameters can be seen from the distribution diagrams. Samples I and II are trunk-wood, whereas IA and IIIA are first branch-wood.

For the semi-quantitative determination of teak extractives the samples, taken radially from the cross-section, were cut up into shavings and hot-extracted with ethyl-alcohol in quantities of 5 g each. The extracts obtained were evaporated to a volume of 50 ml of which 20 mm^3 was used for chromatographic spotting (tectoquinone, lapachol, desoxylapachol). After the evaporation of the alcohol and the determination of the content of extracts by weighing, a small amount of ethyl-alcohol and xylol was added to make a total of 15 ml. After the addition of a spatula-tip of p-quinone-tetrachloride to each of the extracts, the solutions were kept in the drying oven at a temperature of 80° C for 8 hours; during this time tectol changes to dehydrotectol. After cooling off, the solutions were topped up to 25 ml with ethyl-alcohol; 20 mm^3 of each solution were used for the paper chromatographic spotting.

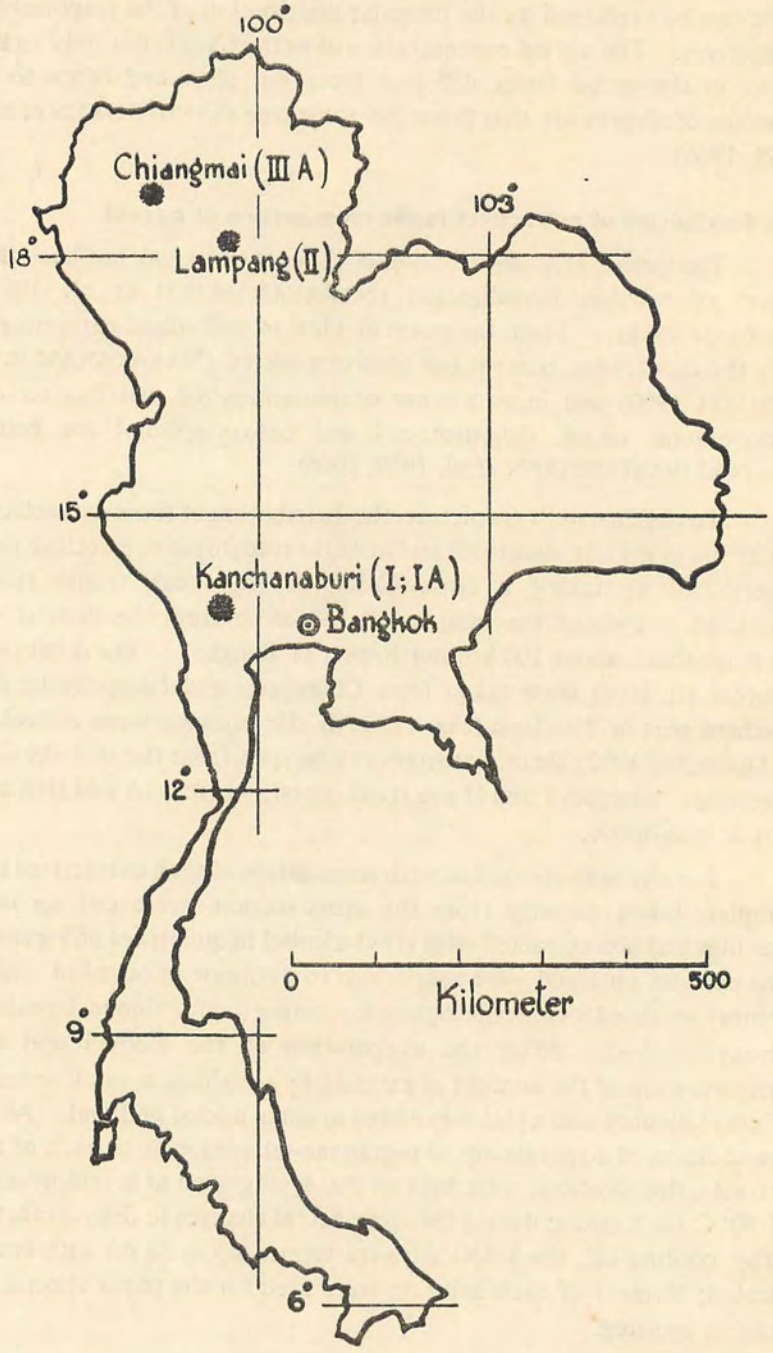


Fig. 1. Areas of origin of the wood-samples examined

Chromatographic separation proved to be descending on the papers S. & S. 2043 bMgl on use of petrol ether (80° to 100°C) saturated with methyl-alcohol as mobile phase and on use of methyl-alcohol saturated with petrol ether as stationary phase. The running-times amounted to 4 to 5 hours.

Extractive	R_f	Ascertainment
Lapachol	0,45	+ NH_3 steaming in daylight=red
Tectoquinone	0,67	in UV light=yellow-green
Dehydrotectol	0,78	in daylight=blue-green
Desoxylapachol	0,82	after UV exposure in daylight=brown

The semi-quantative determination of teak extractives was done by measuring of their spot-sizes in the chromatogram and the comparison of calibration curves (Fig. 2) which were drawn up with

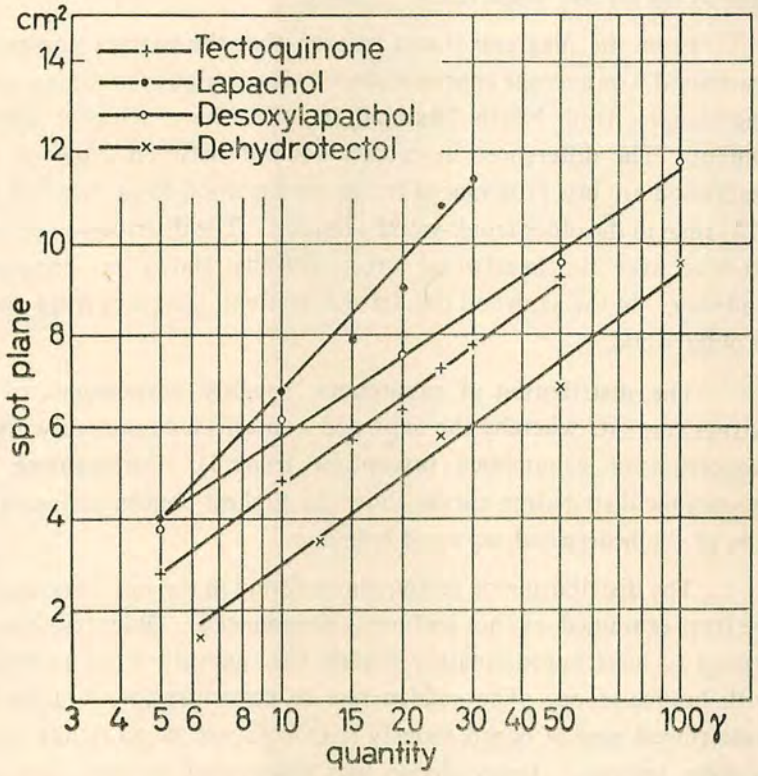


Fig. 2. Calibration curves for the semi-quantitative determination of teak extractives.

the aid of authentic substances. The margin of error of such procedures is given as ± 10% (CRAMER 1958).

To ascertain the total extractive and caoutchouc contents, the wood-shavings, already extracted with ethyl-alcohol and then dried, were again exhaustively extracted with chloroform. After the evaporation of chloroform the extracts were weighed; the total made up of chloroform extract and the already ascertained ethyl-alcohol extract are given in the diagrams as total extract. The caoutchouc, present only in the chloroform extracts, was determined in its bromide form after the method already used for teak (SANDERMANN & DIETRICHS 1959).

The results are given in the form of trunk cross-section diagrams (Figs 3 to 6). The quantity given for total extracts and extractives refer to the air-dry wood (u=8 ... 10%).

From the diagrams it can be seen that the extract content of heartwood is on average approximately twice as high as in the sapwood. The samples from North Thailand (II, IIIA) have a higher extract content. The differences in extract content between sapwood and heartwood are less pronounced in the young wood (branch-wood, IA, IIIA) than in the older trunk-wood samples. The distribution of total extracts over the heartwood cross-sections shows no congruous tendency. In the sapwood the extract content increases from young to older wood.

The distribution of caoutchouc roughly corresponds to the extract content, whereby the sapwood contains a comparably higher proportion of caoutchouc (exception trunk I). Furthermore, the caoutchouc distribution curves show the highest concentration in the area of the heartwood-sapwood boundary.

The distribution of tectoquinone found in the heartwood of all the trees examined was not uniformly pronounced. Older trunk-wood proved to have approximately double the quantity when compared with branch-wood. The sudden rise in concentration to 1.2% in a wide-ringed zone of conspicuously light-coloured wood (trunk I) was of some interest. Tectoquinone was discovered in very low concentration in the sapwood of the only trunk II.

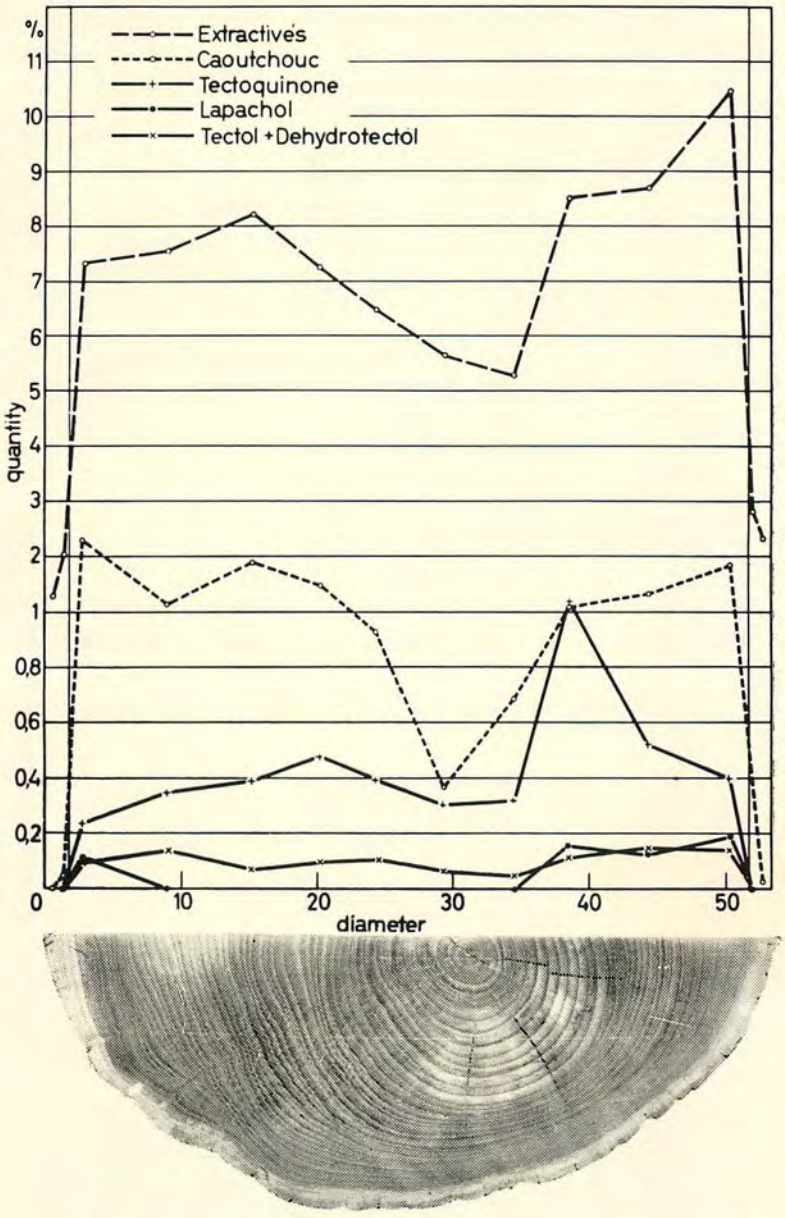


Fig. 3. Distribution of the extractives in the trunk-wood of teak from Kanchanaburi (Sample I).

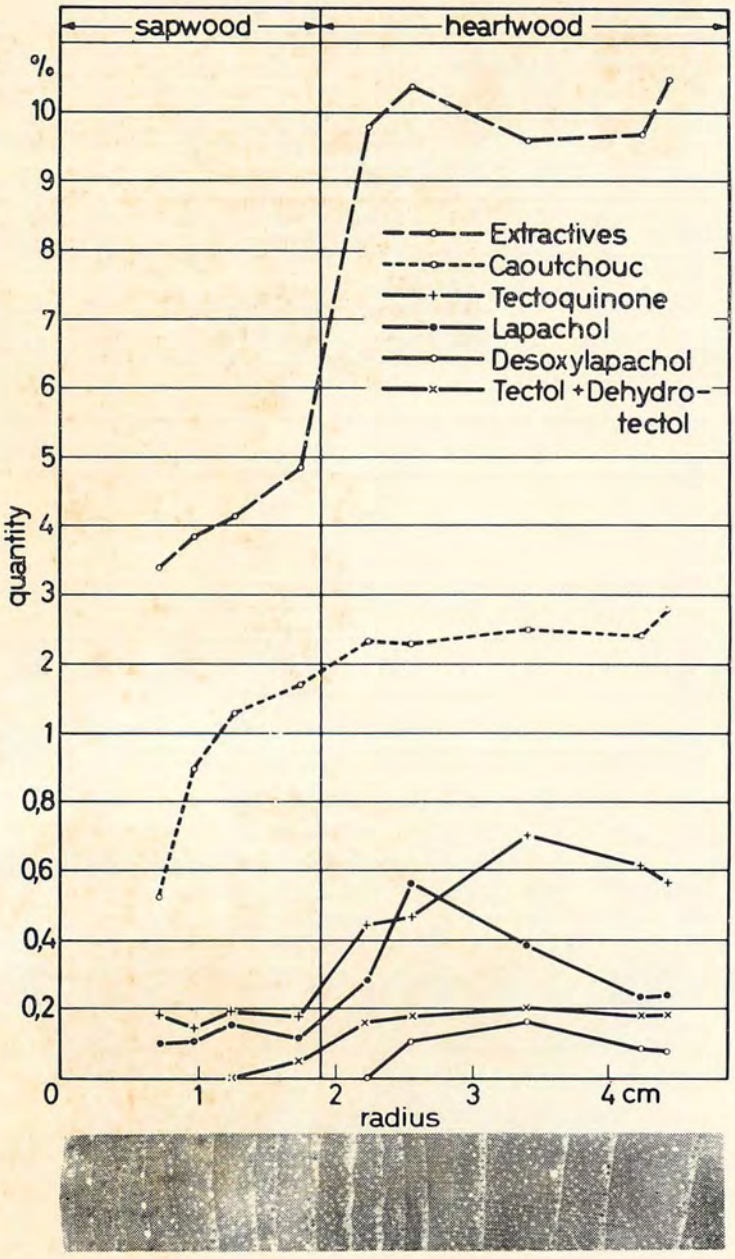


Fig. 7. Distribution of the extractives in individual growth-rings in the trunk-wood of teak from Lampang (Sample II).

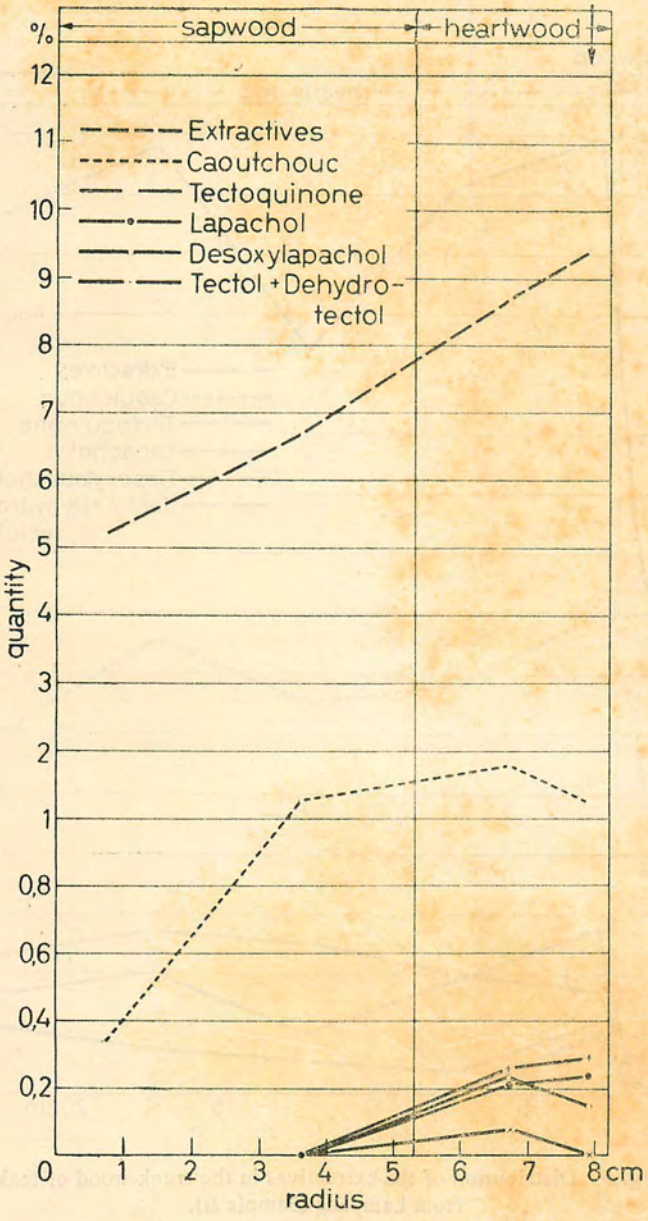


Fig. 4. Distribution of the extractives in the branch-wood of teak from Kanchanaburi (Sample IA)

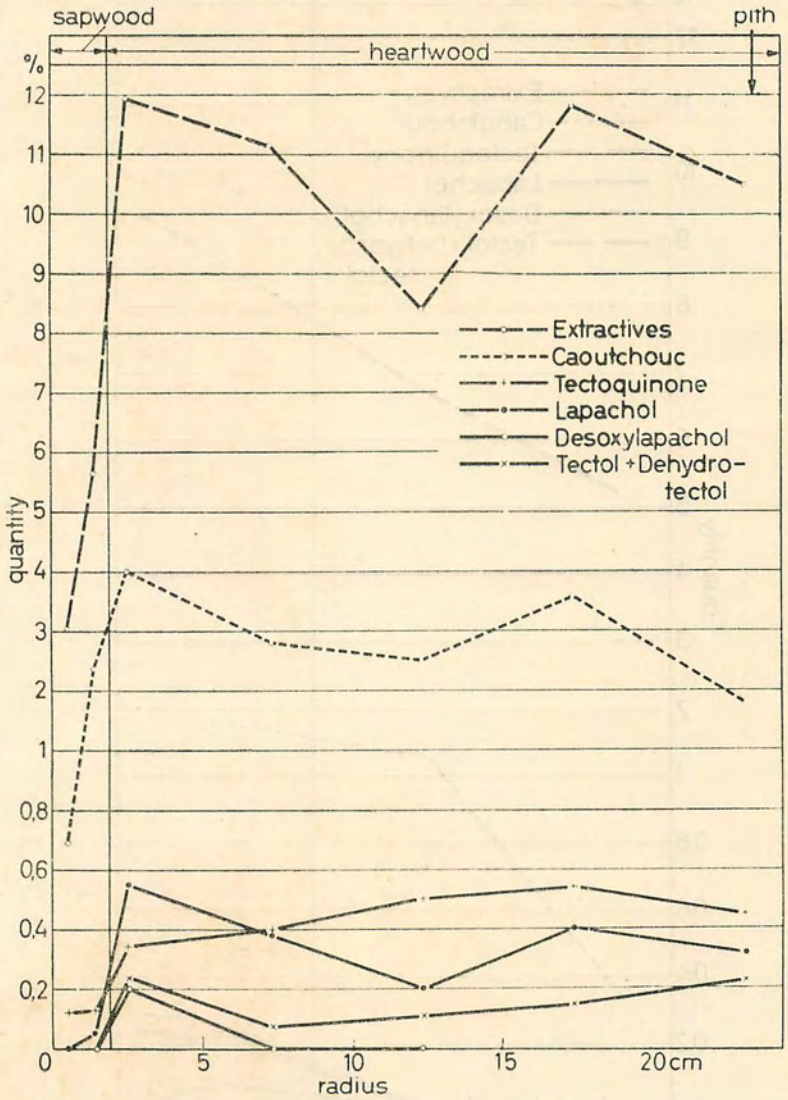


Fig. 5. Distribution of the extractives in the trunk-wood of teak from Lampang (Sample II).

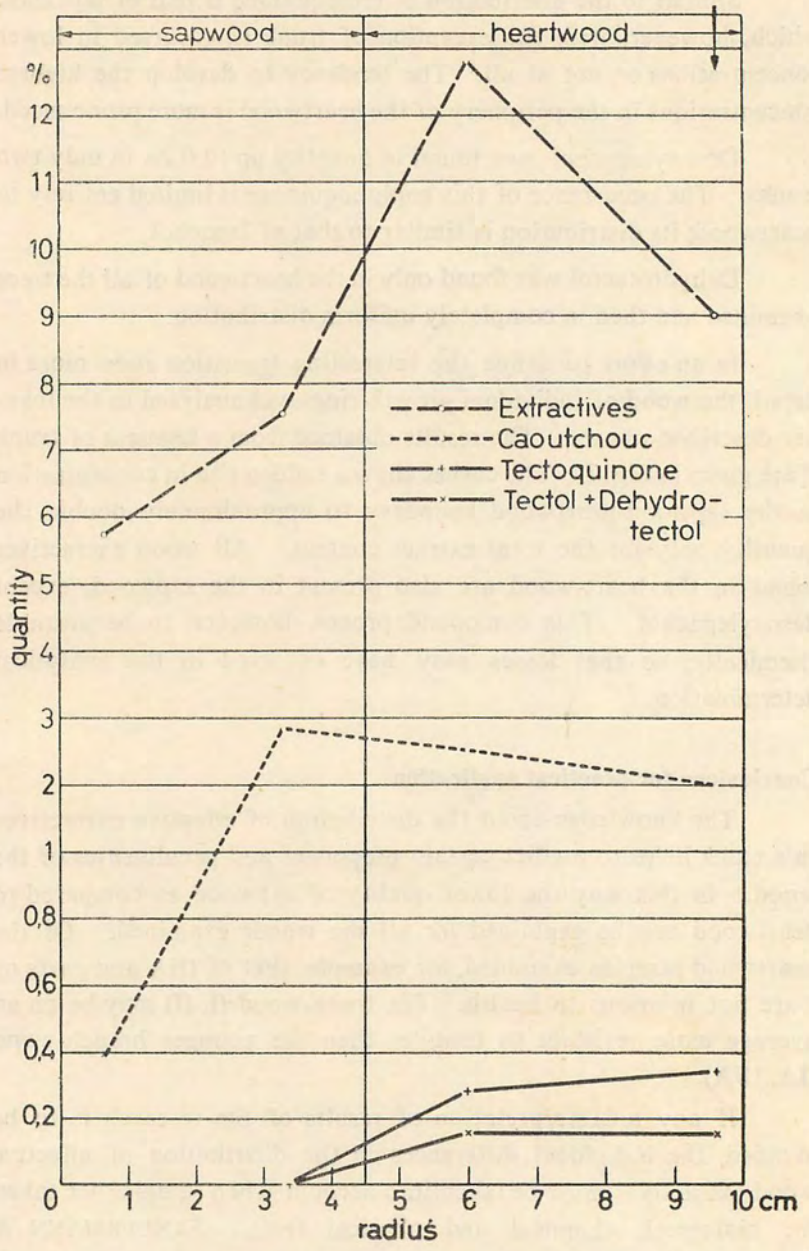


Fig. 6. Distribution of the extractives in the branch-wood of teak from the district of Chiengmai (Sample IIIA).

Similar to the distribution of tectoquinone is that of lapachol, which, however, with the exception of trunk II, occurred in lower concentrations or not at all. The tendency to develop the highest concentrations in the periphery of the heartwood is more pronounced.

Desoxylapachol was found in quantity up to 0.2% in only two trunks. The occurrence of this naphthoquinone is limited entirely to heartwood; its distribution is similar to that of lapachol.

Dehydrotectol was found only in the heartwood of all the trees examined and then in completely uniform distribution.

In an effort to define the interesting transition zone more in detail, the wood of individual growth-rings was analysed in the manner described above. The results obtained from a segment of trunk II are given in Fig. 7. The curves show a sudden rise in concentration at the sapwood-heartwood boundary to approximately double the quantity only for the total extract content. All wood extractives found in the heart-wood are also present in the sapwood, except desoxylapachol. This compound proves, however, to be unstable chemically, so that losses may have occurred in the analytical determination.

Conclusions for practical application

The knowledge about the distribution of effective extractives in a trunk helps to predict certain properties and peculiarities of the wood. In this way the lower quality of sapwood as compared to heartwood can be explained for all the woods examined. Of the heartwood samples examined, for example, that of IIIA and parts of I are not injurious to health. The trunk-wood (I, II) may be on an average more resistant to termites than the younger branch-wood (IA, IIIA).

If any misinterpretation of results of the research is to be avoided, the individual differences in the distribution of effective wood extractives must be taken into account when samples are taken for biological, chemical and physical tests. SANDERMANN & SIMATUPANG (1961) in particular pointed out the interesting possibility of selecting teak-trees as seed bearers, which possess the highest

possible content of desired extractives in a uniform distribution over the trunk cross-section, by analysing thin cores taken from the living tree. Before such a process could be carried out, the question whether the distribution of extractives in teak is hereditary would have to be answered. Perhaps, it would be possible in the future under the forestry practice to cultivate high-quality teak-trees with the aid of such chemical selection.

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