THE STUDY OF THE FACTORS AFFECTING THE NATURAL RESISTANCE OF THE WOOD OF *TERMINALIA IVORENSIS* AGAINST TERMITE ATTACK

THE STUDY OF THE FACTORS AFFECTING THE NATURAL RESISTANCE OF THE WOOD OF *TERMINALIA IVORENSIS* AGAINST TERMITE ATTACK

A thesis presented by
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in fulfilment of the requirement for the
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From: The Department of Botany,
University of Ghana,
Legon.

The work presented in this thesis is my own, unless otherwise acknowledged in the appropriate place; it has not previously been published or submitted to this or any other university for the award of any degree.

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ABSTRACT

The natural radial and axial variations in the resistance of the wood of Terminalia ivorensis A. Chev. against damage by subterranean termites were investigated for two trees from the same locality. The damage was studied in relation to specific gravity, the modulus of elasticity, the cross-sectional area of vessels in the wood, and the water soluble extractives. The correlation between termite damage and these physical, mechanical and anatomical properties have been reported.

It was found that the termite resistance of the wood varied significantly in the radial direction. The outer-heartwood was less susceptible to damage than the sapwood and the inner-heartwood. The sapwood was less resistant to damage than the inner-heartwood. The termite resistance of the inner-heartwood increased near the top of the tree. Axial variations in the intensity of termite damage were not very pronounced.

Termite damage to the wood was inversely correlated with the specific gravity and cross-sectional area of the vessels generally. The susceptibility to damage by termites generally increased with the modulus of elasticity. The specific gravity, modulus of elasticity and the cross-sectional area of the vessels were inter-correlated and no one of them could be used alone to predict the termite resistance of T. ivorensis. The water soluble extractives appeared not to improve on the resistance of the wood.

The two trees tested showed significant differences in their resistance to termite attack. This means that naturally growing trees of T. ivorensis obtained from different Forest Reserves in Ghana could be expected to vary widely in their resistance against attack by subterranean termites.

CONTENTS

1. INTRODUCTION

1.1 THE OBJECT OF THE STUDY

The aim of the project was to investigate various properties of the tree *Terminalia ivorensis* A. Chev. (Idigbo, Amire), namely

(a) The natural variability in the resistance to termite attack of heartwood and sapwood cut at different heights in the same tree and the variability between trees of the same age.

(b) The natural radial variation in the resistance of the wood to termite attack.

(c) The correlation of the resistance with physical, chemical and anatomical properties such as specific gravity, modulus of elasticity, pore number and size and chemical extractives in different parts of the tree.

In many tropical countries, wood is one of the most important products both for domestic use and for export. However, wood and wood products are the staple food for most termites, hence the need to protect wood, whenever used, against termites. These destructive insects will in time destroy any unprotected timber used in construction work or as fittings unless the wood has been rendered unpalatable or is naturally resistant to termite attack. A knowledge of termite resistance and susceptibility of timbers is thus of importance when designing buildings which incorporate wood.

Because of possible differences in structure and quality of wood in the same tree and variation between trees, it can be expected that these differences would affect in one way or another, the resistance of different pieces of wood to termite attack. The differences in intensity of termite attack may be closely linked with differences in the physical and chemical properties of the wood. As the concentration of chemicals, inedible, repellent or poisonous to termite, varies in the heartwood with the growth of the tree, the heartwood may show some degree of variation in the intensity of termite attack at different parts of the same tree. Variation in the type and concentration of chemicals in the tree will affect its density which might also be related to its resistance to destruction by termites. The strength of a material depends on the amount of substance it contains and since density is indicative of the amount of substance contained in a material, it means the strength of a piece of wood is related to its density. Thus the strength of a piece of wood may also be related to its resistance against termites.

The number of pores and their sizes will determine the amount of moisture and air available for fungal growth in a piece of wood. Since some species of termites require some fungal action on wood before they can use it as food (Hendee, 1934, 1935; Williams, 1965 and Becker, 1969), it means the pores in a piece of wood may affect its resistance against termite attack.

The work that has been done on the natural resistance of some of the tropical African woods to termites has not attempted either to relate the termite resistance to the position in the tree (radial or axial), or to the physical properties of the wood. Such studies have, however, been carried out on a few species, notably those being used or grown in Australia (Rudman _et al_., 1967). The aim of this study, therefore, was to investigate the termite resistance of the wood of one of the tropical species, _T. ivorensis_ in relation to the position in the tree, and to attempt to relate the termite attack to some of the physical, anatomical and chemical properties.

T. ivorensis was selected for this project for the following reasons:

a. It is one of the timbers readily available locally;

b. It is used for constructional purposes;

c. Its general utilization will increase in future and will be enhanced by the many plantations of the species which have been established in recent years.

d. It is the object of considerable research in Ghana by the Forest Products Research Institute (Silvicultural Research, Projects III - 57; III - 88).

e. Results of earlier attempts at investigating its resistance are variable (see Literature Review).

The results of this study will be of practical importance to the timber industry. The parts of the tree to be rejected as unsuitable for any constructional work due to their susceptibility to termite attack may be assessed from the results of this study.

Ghana earns much foreign currency through export of her timbers but has done little to study the durability of her timbers with respect to termite. She has quite a wide range of species of subterranean termites destructive to wood and wood products and is in good position to carry out a survey of the natural resistance of her woods against termite attack. As she develops technologically her use of wood and wood products will increase. It is therefore beneficial that studies of this sort are carried out on her timbers.

1.2 LITERATURE REVIEW

Termites in the tropics cause the most serious damage of all the wood-feeding insects. The menance of termites to buildings is greater in the tropical and subtropical regions of the world than in the temperate regions. Though it is not immediately possible to quote the annual loss caused by termite attack on buildings throughout the world, an idea of the magnitude of the problem can be got from the figures available for selected countries and areas. According to Ebeling (1968), "termites cost the U.S. public approximately half a billion dollars" per year". Hickin (1969) estimated the annual cost in Australia to be around A$*7 million, of which A$3 million goes to termite control operators mainly in the state of Queensland (a subtropical region). A questionnaire sent out by the West African Building Research Institute in 1954 showed that termite damage amounted to about a quarter of a million pounds* (£250,000) annually in Ghana, Nigeria, Sierra Leone and Gambia. This figure for West Africa represented the damage done to buildings controlled by Government departments and did not take into account the damage to privately owned buildings, which without doubt would have increased the loss to several millions of pounds. With the increased use of timber in buildings and other constructional works in West Africa over the past two decades, and without a commensurate increase in wood protection, the total cost of termite damage would be expected to have increased considerably.

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* £1 = 2.426 U.S. dollars) Figures as given by Bank of
A$1 = 0.737 U.S. dollars) Ghana on 3rd March, 1975.

Dr. E. Glesinger, one time Director of the Forestry and Forest Products Division of F.A.O. was quoted to have said that the consumption of timber increases with improvement in living standards, so that growing home demand for timber for buildings, furniture, railway sleepers, telegraph poles, bridges, harbours and other purposes can be expected (Becker, 1963). But ironically, the tropical regions are beset with wood damaging termites which present a great hazard to the use of timber. Sperling (1967) noted "The tiny termite in its quiet determined way damages countless homes and saps the resources of nations and peoples throughout the tropical and subtropical regions of the world. No community can afford to allow this wastage to continue." To reduce this wastage, designers and builders have used timbers of natural durability in addition to other preventive methods against termites. This has led to the classification of timbers by some workers into three classes, namely: Resistant, Less Resistant, and Not Resistant (e.g., Small *et al*., 1960).

The resistance of a piece of wood to destruction by termites is partially governed by the amount of cellulose that it contains. The presence of extractives in heartwood, and in some hardwoods the formation of tyloses, materially reduces the permeability of the heartwood (Alexis and de Zeeuw, 1970). This loss in permeability reduces the amount of available air and moisture for fungal growth and thus increases the durability of the heartwood to fungal and termite attack. The main reason, however, for the increased durability of the heartwood of some species of wood is the presence of extractives, such as essential oils, tannins, and phenolic substances, that are toxic, to some degree, to the wood deteriorating organisms (Alexis and de Zeeuw, 1970). Thus the heartwood is usually more resistant to termites. The relatively high starch content of the sapwood also makes it more attractive to many biological destructive organisms.

In the United States, Eldon (1972) found from laboratory studies that the heartwood of northern white cedar was more resistant to attack by subterranean termites than the sapwood. In his study, Eldon used 23 white cedar trees obtained from two sources and found wide variations in the termite resistance of the inner heartwoods among the trees. He also found that the inner heartwood was less resistant to termite attack than the outer heartwood in a number of trees.

In the tropics, radial variation in resistance to termite attack has been investigated in _Tectona grandis_ (Rudman _et al_., 1967) obtained from New Guinea. It was found that there was a marked radial variation in durability/resistance of the heartwood of the tree. The innermost heartwood was found to be much less resistant to decay and termite attack than the outermost heartwood. However, no such termite resistance study has been reported on any African indigeneous species. Only the natural decay resistance of _Khaya ivorensis_ (African mahogany) had been reported in some detail by Findlay (1957). He found from laboratory studies that the outer heartwood was more decay resistant than the inner heartwood and that the decay resistance of the heartwood was related to the amount of Water-soluble extractives in the wood.

In Ghana, there are nearly 250 timber species (F.P.R.I. Information Bulletin No.2). Of these, only 32 species have been tested against termites (Small _et al_., 1960) and the results of the studies on these species are rather variable. For example, the data available on the natural resistance of _T. ivorensis_ to damage by subterranean termites are very variable: Small _et al_., (1960) classified the wood as not resistant to termites; In the "Gold Coast (Ghana) Timbers" (Anon., 1949, 1966) T. ivorensis is again recorded as non-resistant to attack by termites. But in another report (Ministry of Supply, Tropical Testing Establishment Report 317, 1954) the wood was said to show some appreciable resistance to termite attack. Williams (1973) found that the tree has an appreciable degree of resistance against Pseudacanthotermes militaris. Brampton et al., (1966) considered the wood to be more resistant to termite attack than Chlorophora excelsa (Iroko) which is normally considered resistant. Brampton et al. (op. cit) gave T. ivorensis a slightly above-average rating (a score of 49 - their most resistant species, Piptadeniastrum africanum (Dahoma) had 26 and the least resistant, Pycnanthus angolensis (Illomba) had 120). Ayensu and Bentum (1974) discussing the termite resistance of T. ivorensis noted that "Data on its resistance to termite attack in West Africa are conflicting." On susceptibility to decay, King et al.(1955) classified T. ivorensis as resistant.

It would appear that more work has been done on the natural decay resistance of wood than on its resistance to termites. Scheffer and Cowling (1966) offered the following generalization in reference to natural decay resistance of wood:

a. Decay resistance decreases progressively from the outer heartwood to the pith;

b. Decay resistance of the outer heartwood decreases progressively from the base of the tree upward, whereas the opposite is true for the inner heartwood;

c. Outer heartwood at the base of the tree is more resistant and inner heartwood at the base is less resistant, heartwood in the upper bole being intermediate between these extremes, and

d. The larger the tree, the more resistant is the outer heartwood and less resistant is the inner heartwood.

This generalization seems to follow the pattern of resistance found by Eldon (1972) and Rudman _et al_.(1967) for termite resistance in white cedar and teak.

According to Alexis and de Zeeuw (1970) the progressive reduction in the decay resistance of heartwood from the outside to the pith is due to the degradation of the toxic substances to less active compounds by enzymatic or microbial action or through leaching.

2. MATERIALS AND GENERAL METHODOLOGY

2.1 MATERIALS

2.1.1 Termites

In this study, the samples of *T. ivorensis* were tested against subterranean termites in the field. The termites found in association with the test samples belong to the subfamilies Amitermitinae, Macrotermitinae and Coptotermitinae. The Amitermitinae and Macrotermitinae belong to the major family Termitidae (Snyder, 1949; Emerson, 1955) and rely on bacteria for the digestion of the wood which they ingest. The subfamily Macrotermitinae are commonly referred to as the fungus growing termites because of their habit of constructing within their nests sponge-like masses of mixed vegetable and mineral material which support basidiomycete fungi of the genus *Termitomyces* (Noirot and Noirot-Timothee, 1969). The Coptotermitinae belongs to the major family Rhinotermitidae (Snyder, 1949; Emerson, 1955) and are sometimes referred to as "Moist-wood termites" (Harris, 1961). Unlike the Amitermitinae and Macrotermitinae, the Coptotermitinae possesses intestinal protozoa (Harris, 1961) which help in the digestion of cellulose.

2.1.2 The Wood of *Terminalia ivorensis*

The study was made on two trees of *T. ivorensis* cut from one Forest Reserve (Tinte Bepo Forest Reserve) to reduce site differences on wood. The two trees were growing about 100 metres apart and of mean girth of 3.35 metres. The study is thus limited to mature wood from merchantable size trees.

The trees, each of which had a clear bole of about 22 metres, were felled on 27th January and 1st February, 1972 by the felling gang of Ghana Wood Supply Limited, Kumasi.

2.2 GENERAL METHODOLOGY

2.2.1 Sampling and specimens preparation

Circular discs of wood of *T. ivorensis*, 30cm thick, were cut at regular intervals of 4.88m along each tree with the first one being cut at 1.22m above the ground. Five such discs were obtained from each tree and were serially numbered from the first to the fifth(see Fig.1a).

The discs were air dried for a week. One of the circular faces of each disc was then planed to expose the growth rings and also to better define the sapwood and the heartwood. Eight radial boards in four perpendicular directions radiating from the pith were then marked and cut (see Fig. 1b). The distance spanned by the sapwood and the inner heartwood (excluding the pith) was divided into eight radial zones as follows: Zone 1 = Sapwood, Zones 2,3,4 = Outer heartwood, Zones 5,6,7,8 = Inner heartwood (zones 4,5 and 6 clearly being transitional in nature between the outer and inner heartwoods). A test sample was distinguished with a three-digit number denoting the tree number, disc number and zone number. Thus a number 213 indicated a sample from tree two, disc one, zone three. Table 2.1 gives summaries of the characteristics of the discs. The mean girth of each disc was computed from the mean of four diameter measurements. Each radial zone measured 30cm (axially) x 5cm (tangentially) x 3cm (radially).

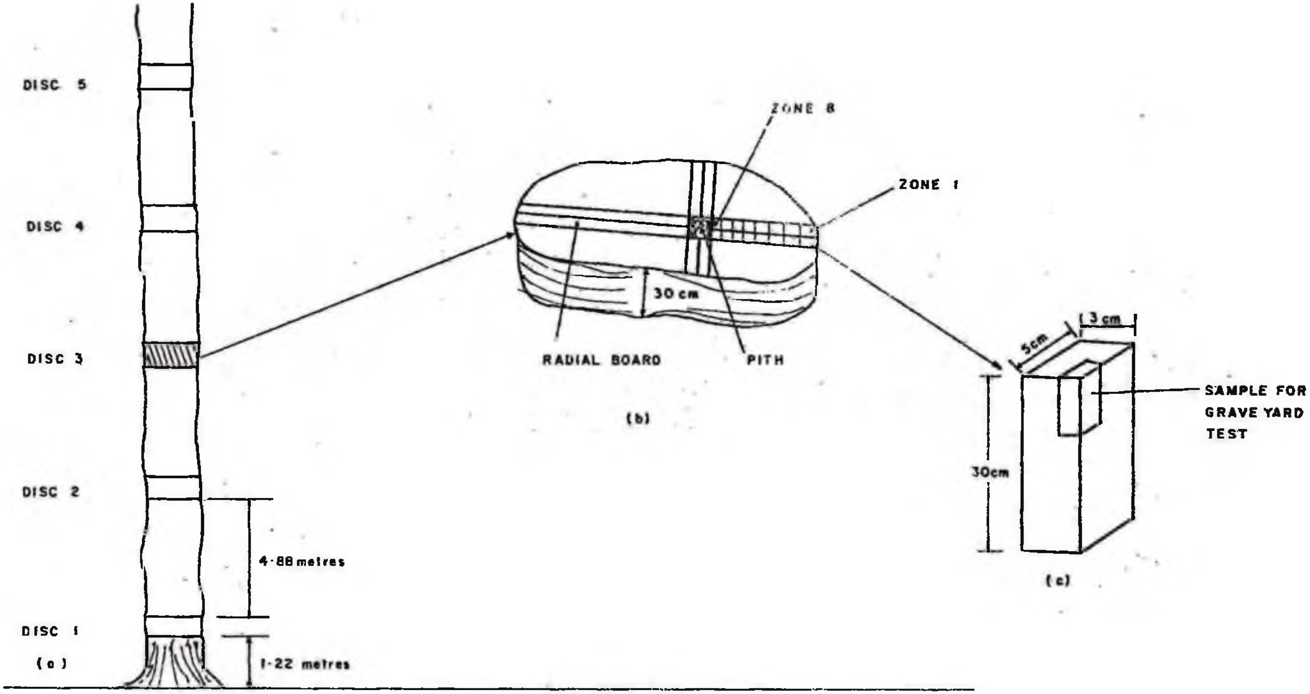

FIG. 1 a) DIAGRAM OF *TERMINALIA IVORENSIS* SHOWING THE POSITIONS OF THE FIVE DISCS FROM WHICH SAMPLES WERE TAKEN

b) ONE DISC SHOWING 8 RADIAL BOARDS AND THE 8 ZONES

c) A ZONE FROM WHICH A TEST SAMPLE WAS CUT

TABLE 2.1

The characteristics of discs of
Tree 1 and Tree 2

Disc No.	Height above ground (metres)		Mean diameter (metres)		Mean girth (metres)	
	Tree 1	Tree 2	Tree 1	Tree 2	Tree 1	Tree 2
1	1.22	1.22	1.14	1.04	3.58	3.27
2	6.40	6.40	1.14	1.12	3.58	3.52
3	11.28	11.28	1.09	1.07	3.42	3.36
4	16.16	16.16	0.97	1.04	3.05	3.27
5	21.04	21.04	0.99	1.07	3.11	3.36

2.2.2 Specimens for the field tests

To reduce variability in the properties of specimens, it was decided to use as small a sample size as possible, 10cm (axially) x 4cm (tangentially) x 2.5cm (radially). One such sample was cut from each of the radial zones.

2.2.3 Specimens for modulus of elasticity tests

From each radial zone, two samples each measuring approximately 10.0 x 1.5 x 0.2cm were prepared for the tensile tests. Exact measures of the width and thickness of each piece were obtained with a micrometer screw gauge while a vernier caliper was used to measure the length.

2.2.4 Specimens for specific gravity tests

These were prepared to the 2cm standard (2.0 x 2.0 x 2.0cm) specified in the British Standard (BS 373, 1957).

2.2.5 Specimens for anatomical studies

Three samples each measuring 1.0 x 1.0 x 1.0cm were prepared from each zone of each disc. Anatomical studies were made on thin sections prepared from these samples.

2.2.6 Specimens for chemical tests

Samples from zones 1, 3 and 8 of each disc of each tree (representing the sapwood, the outer-heartwood and the inner-heartwood respectively) were pulverised in a Wiley mill. Leachates of the pulverised wood were made and used to treat blocks of *Triplochiton scleroxylon* which were then tested against subterranean termites.

2.2.7 Assessment of termite damage

The damage was assessed by finding the percentage weight loss when the blocks were exposed in the field. Before the samples were sent to the field for testing, they were conditioned by oven-drying them for four days at 75°C (± 1°C) and weighed. Preliminary tests had shown that specimens attained constant weights after 80 hours when dried at this temperature. At the end of each test, the samples were washed, air dried for two days, oven dried again and weighed. The difference between the first and second weighings represented the damage caused by fungi and termites. To get the damage due to termites alone, a correction for fungal damage was made to the total damage. Fungal damage to the blocks was assessed from separate tests in which samples were buried in the soil as in the termite tests but with the surrounding ground treated first with a solution of dieldrin which is a termiticide.

The samples were conditioned before weighing to ensure that samples were weighed under similar conditions both prior to and after exposure to termites and fungi.

2.2.8 The Testing Site - Fumesua

The field tests were conducted on the Building and Road Research Institute Termite Testing Site at Fumesua near Kumasi. This site covers an area of approximately 0.85ha and is in a form of a rectangular strip measuring approximately 130m by 65m. Fig.2 shows the site.

The termite species and their distribution over the site had previously been studied by Usher and Ocloo(1975, report in preparation). To do this a total of 826 *Triplochiton scleroxylon* (obeche) blocks were inserted on a grid, 4m between blocks on the long axis of the site, 2m between blocks on the short axis. The blocks were inspected on a four weekly cycle and the termites found in association with the blocks were collected and identified. Thirty-one different species of termites were recorded from the site but not all of them feed on wood. The wood feeding termites found included *Ancistrotermes crucifer* (Sjöstedt), *A. guineensis* (Silvestri), *A. cavithorax*, *Pseudacanthotermes militaris* (Hagen), and *Macrotermes* spp. (*M. bellicosus* (Smeathman) and *M. subhyalinus*(Rambur)) and *Microtermes subhyalinus* Silvestri. A full list of the termites found is attached as Appendix 6. Artificial feeding of the termites was carried out from time to time by scattering bushes chopped into 30 to 50cm lengths. This appeared to favour *Ancistrotermes* and *Macrotermes* since the runways of these species were frequently found on the bushes.

FIG. 2 The termite testing site at Fumesua. A few bushes have been left on the site to cast a shade.

3. EXPERIMENTATION

3.1 'GRAVEYARD' FIELD TEST

The purpose of this experiment was to investigate the natural resistance of T. ivorensis against attack by subterranean termites under conditions similar to that in which the wood is used. The design of the test had to reflect possible differences both in the radial and axial directions in the tree and differences between sample trees.

In 'graveyard' tests by Butterworth and MacNulty(1958), Fougerousse(1969) and Krogh(1969) the stakes were all half buried. Fougerousse (op.cit) said that termites only attack stakes in the surface 15-20cm of the soil and 5cm above the soil level. Gay et al.(1957) indicated that termites are most active in the surface 20cm of the soil. Sands(1960) reported that the attack of the larger Macrotermitinae such as Macrotermes, Pseudacanthotermes and Odontotermes usually commence in the top 6 to 9 inches (i.e. 15.2 to 22.8cm) of the soil. In an investigation of stake size and shape in 'graveyard' field tests for termite resistance, Usher and Ocloo (1974) found that the proportion of wood removed by termites increased as a stake was buried deeper in the soil. It was therefore decided, in the present study, to bury the stakes to a depth of 10cm which amounted to burying them completely.

The test area was divided into 8 plots. 80 samples (8 zones x 5 discs or heights x 2 trees) were randomly assigned to each plot of 8 rows of 10 stakes(see Table 3.1).

The stakes were buried 20cm apart and interconnected with 0.5 x 5.0cm pieces of T. scleroxylon (obeche) sapwood as baits (see Fig.3).

The plots were inspected at 6 monthly intervals for 18 months. The results of the 'graveyard' tests are presented in Tables 3.2-3.7. At each inspection the termites

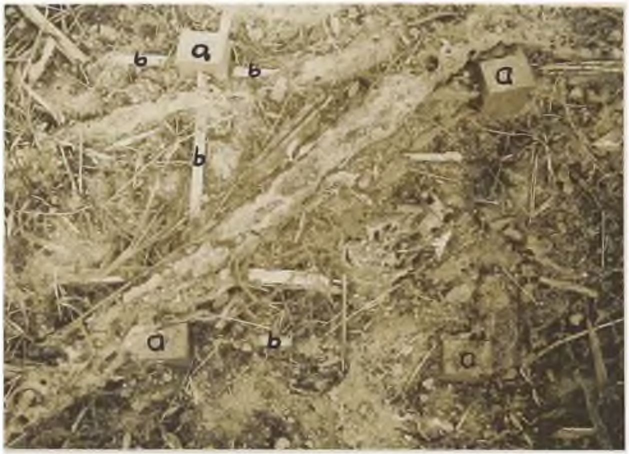

FIG. 3 Portion of the termite testing site showing four of the test blocks(a) interconnected with pieces of bait wood(b) which are partially covered.

found damaging the stakes were collected and identified (see Appendix 6).

TABLE 3.1

Random distribution of stakes in Plot 1. The first digit of each number indicates the tree number, the second digit represents the disc (height) number while the last digit denotes the zone.

113	217	213	251	154	235	216	237	247	236
151	142	128	258	215	234	123	126	122	252
138	243	212	231	134	225	148	155	143	117
223	257	254	242	228	222	256	125	227	232
233	226	124	244	147	115	248	127	135	221
153	238	156	136	121	116	132	214	137	111
146	255	157	131	152	141	133	253	145	112
118	144	245	246	158	218	241	211	114	224

3.1.1 Results of 'Graveyard' Tests

Tables 3.2-3.7 below give the total damage due to fungi and termites to stakes from the eight radial zones in each disc of the two trees. The percentages represent the mean total damage from the 8 test plots after 6, 12 and 18 months exposure.

TABLE 3.2

Fungal and termite damage (expressed as mean percentage weight loss) to TREE 1 of *Terminalia ivorensis* after 6 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	2.42	1.21	0.61	0.72	1.23	0.85	1.30	1.40	1.22
2	3.63	0.83	0.65	0.53	0.49	0.94	0.69	0.81	1.07
3	4.62	0.94	0.69	0.57	0.69	0.97	1.04	0.92	1.30
4	5.20	1.34	0.87	1.26	0.74	0.86	1.06	1.26	1.57
5	3.88	1.24	1.19	0.85	1.11	1.24	1.18	0.84	1.44
ZONE MEAN	3.95	1.11	0.80	0.79	0.88	0.97	1.05	1.04	

APPROX. S.E* ± 0.003

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* Each of the 40 means in this table (2.42, 1.21, ..., 1.18, 0.84) has an approximate standard error (Approx. S.E) of 0.003. The same S.E applies to all means since in the analysis of variance the homogeneity of treatment means is assumed. Analysis of variance would be inappropriate if the variances of each treatment mean were non-homogeneous. All 40 means are calculated as the average of 8 timber samples (see pages 26 and 27). The S.E. in the other tables (Tables 3.3-3.7 and Tables 3.14-3.19) were similarly estimated.

Table 3.2 shows the sapwood to be more susceptible to fungi and termites than the outer-heartwood and the inner-heartwood. The susceptibility of the sapwood generally increased with height. The outer-heartwood also was more resistant to decay and termite attack than the inner-heartwood. Analysis of variance of the damage indicated significance differences in the radial direction ($0.001 \leq p$). Axial variations in termite resistance were not significant($p > 0.05$).

TABLE 3.3

Fungal and termite damage (expressed as mean percentage weight loss) to TREE 1 of *Terminalia ivorensis* after 12 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	4.92	2.82	1.71	2.00	4.80	3.68	5.95	5.18	3.88
2	10.80	2.35	1.84	1.98	2.13	2.97	2.36	4.35	3.60
3	9.05	1.56	1.70	1.99	3.22	4.45	3.47	5.68	3.89
4	9.55	3.30	2.11	3.40	2.03	3.51	3.98	4.52	4.05
5	10.70	3.23	2.53	2.45	1.90	3.05	3.33	2.38	3.70
ZONE MEAN	9.00	1.68	1.98	2.36	2.82	3.53	3.82	4.42	

APPROX. S.E. = ± 0.011

Table 3.3 shows the sapwood to be less resistant to decay and termite damage than the outer and inner heartwoods. The durability of the outer-heartwood slightly decreased with height in the upper half of the tree but the inner-heartwood showed an increase in durability from Disc 3 upwards. Differences in damage in the radial directions were significant ($p \leqslant 0.001$). Differences in the longitudinal directions were not significant ($p > 0.05$).

TABLE 3.4

Fungal and termite damage (expressed as mean percentage weight loss) to TREE 1 of *Terminalia ivorensis* after 18 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	18.80	7.15	4.76	6.60	10.07	8.24	9.73	17.63	10.37
2	20.32	8.13	5.98	6.13	7.65	11.74	8.19	16.46	10.58
3	43.54	5.48	5.59	15.34	6.17	14.16	11.81	15.40	14.69
4	34.09	7.93	5.78	8.24	6.80	8.54	8.29	10.19	11.23
5	40.55	12.16	5.65	5.48	4.82	5.02	7.90	5.81	10.92
ZONE MEAN	31.46	8.17	5.52	8.36	7.10	9.54	9.18	13.10	

APPROX. S.E. = ± 0.051

Table 3.4 shows the outer-heartwood to be more durable than the sapwood and the inner-heartwood. The outer-heartwood close to the butt (Disc 1) was on the whole more resistant to decay and termite damage than the outer-heartwood towards the top of the tree (Discs 4 and 5). The durability of the inner-heartwood increased in the last two discs of the tree (i.e. in Discs 4 and 5). The analysis of variance of the damage showed that the radial variations in durability were significant ($p \leq 0.001$). Axial differences in durability were not important($p > 0.05$).

TABLE 3.5

Fungal and termite damage (expressed as mean percentage weight loss) to TREE 2 of *Terminalia ivorensis* after 6 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	2.44	0.82	0.63	0.97	0.77	1.02	0.74	0.88	1.03
2	1.85	0.66	0.70	0.63	0.65	0.61	0.74	1.37	0.90
3	1.85	0.67	0.62	0.75	0.98	0.70	0.92	1.41	0.99
4	10.40	0.93	1.01	1.09	0.83	1.19	1.00	1.23	2.21
5	2.13	0.80	0.67	0.95	0.72	0.82	0.84	1.22	1.02
ZONE MEAN	3.73	0.78	0.73	0.88	0.79	0.87	0.85	1.22	

APPROX. S.E. = ± 0.011

The table shows that the outer-heartwood was more resistant to decay and termite damage than the sapwood and the inner-heartwood. The wood of Disc 4 was the most susceptible. Analysis of variance of the damage indicated significant difference between radial zones ($p \leqslant 0.001$).

TABLE 3.6

Fungal and termite damage (expressed as mean percentage weight loss) to TREE 2 of *Terminalia ivorensis* after 12 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	9.45	2.72	1.98	3.88	4.92	8.14	23.80	14.80	8.71
2	6.60	1.89	3.04	4.12	7.86	4.28	7.65	15.70	6.39
3	9.45	2.27	4.50	2.67	3.88	16.60	7.45	14.85	7.71
4	22.30	2.09	2.43	3.38	2.72	8.06	14.00	11.20	8.27
5	8.21	1.59	2.50	2.57	4.88	2.08	5.10	8.50	4.43
ZONE MEAN	11.20	2.11	2.89	3.32	4.85	7.83	11.60	13.01	

APPROX. S.E. = ± 0.051

The 12 months results in Table 3.6 also show the outer-heartwood to be more durable than the sapwood and the inner-heartwood. Analysis of variance of the damage again indicated significant difference between zones ($0.001 < p < 0.01$).

TABLE 3.7

Fungal and termite damage (expressed as mean percentage weight loss) to TREE 2 of *Terminalia ivorensis* after 18 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	31.77	5.86	5.06	8.90	12.92	17.70	44.07	30.77	19.63
2	22.22	6.84	15.20	9.33	14.68	9.60	21.79	49.72	18.67
3	22.27	7.80	11.65	8.41	10.75	24.11	27.62	44.53	19.64
4	45.78	7.68	6.90	8.95	9.15	26.29	27.32	22.73	19.35
5	21.13	4.80	5.75	5.82	10.06	6.55	12.76	22.00	11.11
ZONE MEAN	28.63	6.60	8.91	8.28	11.51	16.85	26.71	33.95	

APPROX. S.E. = ± 0.07

The outer-heartwood was more durable than the sapwood and the inner-heartwood within the 18 months exposure to subterranean termites as shown in Table 3.7. Zone 2 of the outer-heartwood was slightly more resistant to decay and termites than zones 3 and 4. The table also shows the wood of Disc 5 to be the most durable part of Tree 2. The analysis of variance of the damage showed that the radial variations in durability were significant ($p \leq 0.001$). Differences in durability along the tree were not important ($p > 0.05$).

3.2 Test for fungal decay

The weight loss recorded in the 'Graveyard' tests was due to the combined activity of fungi and termites on the wood. Since the project strictly concerned the termite damage component, it was necessary to correct for the loss in weight due to fungi. This experiment was therefore carried out to determine the contribution of decay to the total damage.

The test for decay required the exclusion of termites from the test plot by creating an effective termite barrier around the experimental plots. This was done as follows:

A pit, 1m wide, 4m long and 20cm deep was dug not far away from the termite test plots. The soil removed was heaped on a tarpaulin. The inside of the pit and the soil surrounding it were treated with 0.5 per cent water emulsion of dieldrin, a termiticide, applied at a rate of 5.4 litres per square metre. The soil removed was then replaced and the edges of the pit marked with _Chlorophora excelsa_ pegs. A border of 1m was then marked all round the pit with another set of _C. excelsa_ pegs and the border treated with the same water emulsion of dieldrin applied at the rate of 5.4 litres per square metre.

Two samples from each of the zones 1, 3 and 8 (representing the sap, the outer-heartwood and the inner-heartwood respectively) and from each disc of the two trees were tested on two plots on the pit. The samples were of same sizes as those used in the termite tests and were buried 10cm in the soil and 10cm apart and without baits. The tests lasted for 18 months and were also inspected after six month intervals. The decay was assessed in a manner similar to that used in assessing the termite attack, that is, using the loss in weight method. The results of this study on the fungal decay are presented in Tables 3.8 to 3.13. These results were then used below in working out a correction factor for the total damage in the 'Graveyard' tests.

3.2.1 Correction for fungal decay

The mean percentage weight loss by samples from the sap, the outer-heartwood and the inner-heartwood was computed from the data collected in the fungal test.

The weight loss due to termites alone was calculated as follows:

Let X = Initial weight of test sample

X_n = Weight of sample at end of test period

X_f = Weight decomposed by fungi, etc. (i.e. sources other than termites)

X_t = Weight removed by termites, and

P_f = Mean percentage weight loss due to fungi, etc.

Weight lost over the test period = $X - X_n$ which is due to termites, fungi, etc., so

$$X - X_n = X_f + X_t \quad \ldots\ldots\ldots\ldots\ldots \quad \text{I}$$

X and X_n in equation I are known but we must solve for X_f and X_t.

The average weight of wood available to fungi, etc., over the test period is

$$\tfrac{1}{2}\left[X + (X - X_t)\right] = X - \tfrac{1}{2}X_t$$

$$P_f = \frac{X_f}{X - \frac{1}{2}X_t} \cdot 100 \text{ which gives}$$

$$X_f = (X - \tfrac{1}{2}X_t)P_f/100$$

$$= P(X - \tfrac{1}{2}X_t), \text{ where } p = P_f/100$$

Substituting for X_f in equation I,

$$X - X_n = p(X - \tfrac{1}{2}X_t) + X_t$$

which when re-arranged, gives

$$X_t = \left[X(1 - P) - X_n\right]\left[\frac{2}{2 - P}\right] \quad \ldots\ldots\ldots \quad \text{II}$$

Average weight of wood available to termites is

$$\tfrac{1}{2}\left[X + (X - X_f)\right]$$

percentage weight loss due to termites = $\frac{100X_t}{X - \frac{1}{2}X_f}$

Substituting for X_t and X_f,

Percentage weight loss due to termites = $\frac{4\left[X(1 - P) - X_n\right]}{4X - 3pX - pX_n}$ 100

If equation II gives a negative answer (due to biological variability, and the fact that P_f is a mean) then X_t is scored as zero.

Overall mean percentage weight loss due to termites at the end of a given test period is

$$\frac{\sum_{i=1}^{8} Xti}{\sum_{i=1}^{8} Xi - \frac{1}{2}\left(\sum_{i=1}^{8} X_{fi}\right)} \quad 100 \quad \ldots\ldots\ldots\ldots \text{III}$$

Average percentage weight loss from plots

$$= \frac{1}{8} \sum_{i=1}^{8} \left(\frac{100X_{ti}}{Xi - \frac{1}{2}X_{fi}}\right) \quad \ldots\ldots\ldots\ldots \text{IV}$$

where X_{ti} = Weight removed by termites from a sample on plot i.

X_i = Initial weight of sample on plot i.

X_{fi} = Weight decomposed by fungi, etc. on plot i.

3.2.2 Results of fungal test

TABLE 3.8

Decay (expressed as mean percentage weight loss) due to fungal action on TREE 1 of *Terminalia ivorensis* after 6 months exposure.

DISC	SAPWOOD	OUTER-HEARTWOOD	INNER-HEARTWOOD
1	2.39	0.83	2.59
2	3.67	0.48	1.92
3	2.44	0.77	1.23
4	3.38	1.03	1.81
5	3.59	0.75	1.04

The results in Table 3.8 shows that the outer-heartwood at any height (i.e. in any disc) was more resistant to decay than the sapwood and the inner-heartwood. The inner-heartwood was less susceptible to decay than the sapwood except in Disc 1.

TABLE 3.9

Decay (expressed as mean percentage weight loss) due to fungal action on TREE 1 of *Terminalia ivorensis* after 12 months exposure.

DISC	SAPWOOD	OUTER-HEARTWOOD	INNER-HEARTWOOD
1	10.03	6.08	9.05
2	10.98	4.56	8.54
3	6.35	4.48	8.88
4	10.42	5.31	7.74
5	9.17	5.13	5.71

TABLE 3.10

Decay (expressed as mean percentage weight loss) due to fungal action on TREE 1 of *Terminalia ivorensis* after 18 months exposure.

DISC	SAPWOOD	OUTER-HEARTWOOD	INNER-HEARTWOOD
1	11.87	7.74	10.82
2	13.45	4.93	9.83
3	8.38	5.32	11.09
4	11.14	5.99	9.50
5	10.29	6.06	6.35

Tables 3.9 and 3.10 show that after 12 and 18 months respectively, the outer-heartwood in Tree 1 was still the most resistant to decay. The inner-heartwood was also more resistant than the sapwood. Differences in decay along the tree were not significant.

TABLE 3.11

Decay (expressed as mean percentage weight loss) due to fungal action on TREE 2 of *Terminalia ivorensis* after 6 months exposure.

DISC	SAPWOOD	OUTER-HEARTWOOD	INNER-HEARTWOOD
1	1.66	0.33	0.87
2	2.23	1.06	1.07
3	1.38	0.75	0.90
4	3.97	0.25	1.15
5	3.43	0.61	2.09

TABLE 3.12

Decay (expressed as mean percentage weight loss) due to fungal action on TREE 2 of *Terminalia ivorensis* after 12 months exposure.

DISC	SAPWOOD	OUTER-HEARTWOOD	INNER-HEARTWOOD
1	6.72	5.15	9.25
2	8.80	6.42	6.26
3	6.15	5.85	5.23
4	11.01	4.76	7.13
5	12.87	5.88	7.03

TABLE 3.13

Decay (expressed as mean percentage weight loss) due to fungal action on TREE 2 of *Terminalia ivorensis* after 18 months exposure.

DISC	SAPWOOD	OUTER-HEARTWOOD	INNER-HEARTWOOD
1	7.81	5.91	15.12
2	9.87	6.99	7.57
3	8.93	7.01	8.99
4	12.86	5.39	8.09
5	16.40	6.38	7.64

In Tree 2 (see Tables 3.11-3.13) the trend in radial variation of decay is similar to that in Tree 1, namely the outer-heartwood being more resistant than the inner-heartwood and the sapwood. Except in the heartwood there seemed to be a general increase in susceptibility from Disc 1 to Disc 5. The 12 and 18 months damage were greater than the 6 months damage but the general trends in radial and axial variations were the same as for the 6 months.

3.2.3 CORRECTED VALUES FOR DAMAGE DUE TO TERMITES ALONE

Tables 3.14 to 3.19 give the estimated damage due to termites after correcting for the damage due to fungi (see 3.2.1). Analyses of variance of the damage were carried out for the six and twelve months data. Summaries of the analyses are provided under each table. The 18 months damages were also analysed and the full analyses given in Appendix 1.

To analyse the percentage weight losses, they were transformed into angles by means of the angular transformation (see Snedecor, 1956).

$$P^1 = \arcsin\left(\sqrt{P/100}\right)$$

where P is the percentage, and P^1 is the transformed variable expressed as an angle.

After the analyses, the data were backtransformed, thus Tables 3.14 to 3.19 give the percentage weight losses after calculation had been based on data subjected to an arcsin transformation.

TABLE 3.14

Termite damage (expressed as mean percentage weight loss) to TREE 1 of *Terminalia ivorensis* after 6 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	0.35	0.62	0.07	0.05	0.00	0.00	0.00	0.21	0.16
2	1.28	0.49	0.29	0.26	0.00	0.26	0.01	0.00	0.32
3	14.15	0.31	0.18	0.18	0.10	0.29	0.21	0.21	1.95
4	2.72	0.54	0.21	0.46	0.00	0.00	0.02	0.05	0.50
5	1.17	0.56	0.56	0.35	0.26	0.35	0.51	0.26	0.50
ZONE MEAN	3.93	0.50	0.26	0.26	0.07	0.18	0.15	0.15	

APPROX. S.E. = 0.05*

Table 3.14 shows that the sapwood was the least resistant part of the tree. Analysis of variance of the damage indicated significant difference ($p \leqslant 0.001$) between zones.

---

* The assumption of uniformity of both variance and S.E. is stated beneath Table 3.2

TABLE 3.15

Termite damage (expressed as mean percentage weight loss) to TREE 1 of <u>Terminalia ivorensis</u> after 12 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	0.00	0.00	0.00	0.00	1.49	0.08	0.11	0.00	0.21
2	1.49	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.19
3	1.89	0.00	0.00	0.00	0.00	1.03	0.00	2.10	0.63
4	3.71	0.00	0.00	0.99	0.00	0.00	0.36	0.65	0.71
5	2.50	0.24	0.20	0.00	0.00	0.00	0.18	0.00	0.39
ZONE MEAN	1.92	0.05	0.04	0.20	0.30	0.22	0.13	0.55	

APPROX. S.E. = ± 0.03

Table 3.15 shows the sapwood to be more susceptible to termite damage than the outer and inner heartwoods. Zone 3 of the outer-heartwood was the most resistant part of the tree. The pattern of termite damage was similar to the decay pattern exhibited by the tree in 12 months (see Table 3.9). Analysis of variance of the damage again showed significant difference ($0.01 < p \leqslant 0.05$) between radial zones.

TABLE 3.16

Termite damage (expressed as mean percentage weight loss) to TREE 1 of <u>Terminalia ivorensis</u> after 18 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	9.14	1.17	0.00	0.40	2.29	1.17	0.92	8.55	2.91
2	8.35	3.71	1.40	2.18	1.44	3.84	2.29	7.97	3.90
3	38.07	0.95	0.89	0.73	0.21	6.79	4.32	6.52	7.31
4	25.30	2.34	2.18	3.64	0.22	1.84	1.20	2.84	4.95
5	33.40	5.53	0.92	0.62	0.16	0.15	2.67	0.42	5.48
ZONE MEAN	22.85	2.74	1.08	1.51	0.86	2.76	2.28	5.26	

Table 3.16 shows the sapwood portion of the tree to be the most susceptible part. The analysis of variance of the damage in the table indicated significant difference ($p \leq 0.001$) in the radial direction. The standard error of the means is 0.10 per cent. The analysis of variance of the damage from the 8 test plots shows the differences in the radial direction to be significant at all heights (see Appendix 1, Table A1.1-A1.15). Generally, differences in the termite damage to the wood were not significant in the axial direction. The sapwood of Disc 1, however, was significantly less susceptible than the sapwoods of Discs 3 and 5 (see Appendix 1, Table A1.16). Though in Table 3.16 the sapwood of Disc 2 was slightly more resistant to termite damage than the sapwood of Disc 1, the mean percentage weight loss from the 8 plots shows the reverse. The

apparent difference may be due to the fact that the values in Table 3.16 were obtained using equation III on page 28 while equation IV on the same page gave the values in Table A1.16. The outer-heartwood of Disc 1 was significantly more resistant than the outer-heartwoods of Discs 2 and 4 (see Appendix 1, Table A1.17). The differences in the damage to the inner-heartwoods were not significant in the axial direction (see Table A1.18 of Appendix 1). Figs. 3.2(a), (b), (c) illustrate the variation of termite damage in Tree 1.

TABLE 3.17

Termite damage (expressed as mean percentage weight loss) to TREE 2 of <u>Terminalia ivorensis</u> after 6 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	0.95	0.40	0.30	0.60	0.22	0.45	0.15	0.40	0.43
2	0.20	0.13	0.04	0.05	0.30	0.08	0.15	0.55	0.19
3	0.70	0.20	0.22	0.40	0.20	0.10	0.20	0.66	0.39
4	7.64	0.68	0.73	0.85	0.08	0.24	0.20	0.33	1.34
5	1.50	0.37	0.35	0.45	0.00	0.03	0.00	0.10	0.35
ZONE MEAN	2.20	0.36	0.33	0.47	0.16	0.18	0.14	0.41	

APPROX. S.E. = ± 0.01

Table 3.17 shows that the termite damage to the sapwood was greater than the damage to the outer and inner heartwoods. Analysis of variance of the damage showed significant difference in the radial direction ($0.001 < p \leq 0.01$).

TABLE 3.18

Termite damage (expressed as mean percentage weight loss) to TREE 2 of <u>Terminalia ivorensis</u> after 12 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	4.32	0.00	0.00	0.64	1.00	2.10	12.30	13.96	4.29
2	0.75	0.00	1.30	0.15	4.10	0.50	3.24	10.83	2.61
3	4.68	0.00	1.40	0.00	0.30	12.61	2.95	10.75	4.09
4	15.20	0.00	0.04	0.29	0.00	2.39	9.90	5.93	4.22
5	1.60	0.00	0.00	0.00	2.50	0.00	1.80	4.30	1.28
ZONE MEAN	5.31	0.00	0.55	0.21	1.58	3.52	6.04	9.15	

The 12 months results also showed the outer-heartwood to be less susceptible to termite damage than the sapwood and the inner-heartwood. Analysis of variance of the damage indicated significant differences in the termite resistance of the wood in the radial direction ($p \leqslant 0.001$). Variation in termite resistance along the tree was not significant ($p > 0.05$). The standard error of the means is 0.09 per cent.

TABLE 3.19

Termite damage (expressed as mean percentage weight loss) to TREE 2 of <u>Terminalia ivorensis</u> after 18 months exposure.

DISC	RADIAL ZONES								DISC MEAN
	SAPWOOD	OUTER-HEARTWOOD			INNER-HEARTWOOD				
	1	2	3	4	5	6	7	8	
1	25.91	0.64	0.51	3.45	4.32	6.61	33.40	19.35	11.77
2	13.79	1.49	9.75	2.95	8.45	3.26	15.64	45.47	12.60
3	15.26	1.44	5.77	2.56	2.84	16.93	20.33	38.93	13.01
4	37.22	3.77	2.29	3.77	2.03	19.17	21.46	16.02	13.29
5	10.71	0.42	0.59	0.37	5.37	0.76	7.05	16.15	5.18
ZONE MEAN	20.58	1.55	3.78	2.62	4.60	9.47	19.58	27.18	

Table 3.19 shows the sapwood to be more susceptible to termite damage than the outer and inner heartwoods. Analysis of variance of the damage shows significant difference in the radial direction ($p \leqslant 0.001$). The standard error of the means is 0.13 per cent. The analysis of variance of the damage from the 8 test plots shows the differences in the radial direction to be significant at all heights. Differences in the termite resistance of the wood were not pronounced in the axial direction. However, the sapwood of Disc 5 was significantly more resistant to termite damage than the sapwood of Disc 4 (see Appendix 1, Table A1.19). The outer-heartwood also of Disc 5 was significantly more resistant to termites than those of Discs 2 and 4 (see Appendix 1, Table A1.20). Similarly, the inner-heartwood of Disc 5 was significantly less susceptible to termites than the inner-heartwoods of Discs 2,3 and 4 (see Appendix 1, Table A1.21).

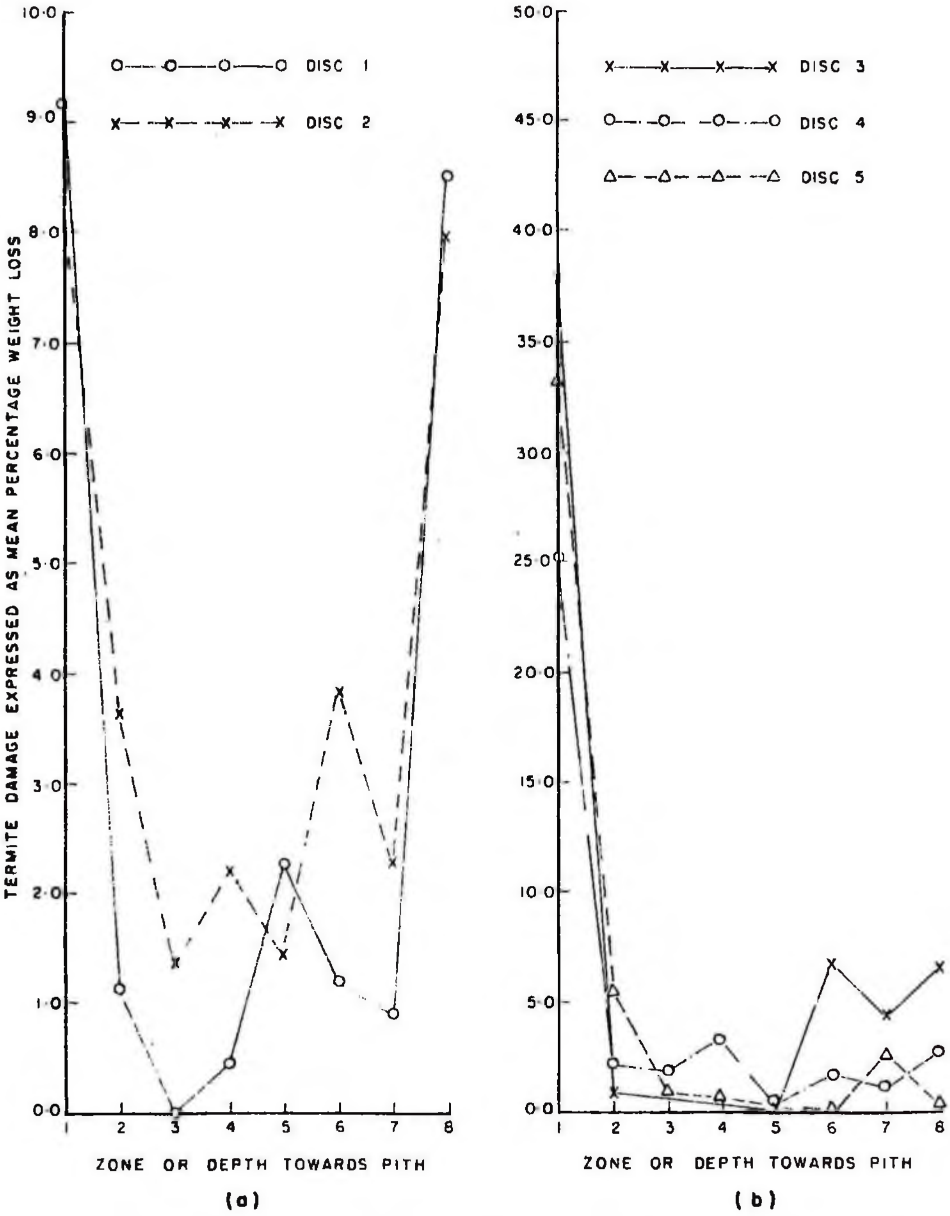


FIG. 3.2 RADIAL VARIATION IN MEAN PERCENTAGE WEIGHT LOSS OF TREE I OF *T. IVORENSIS* AT DIFFERENT HEIGHTS.

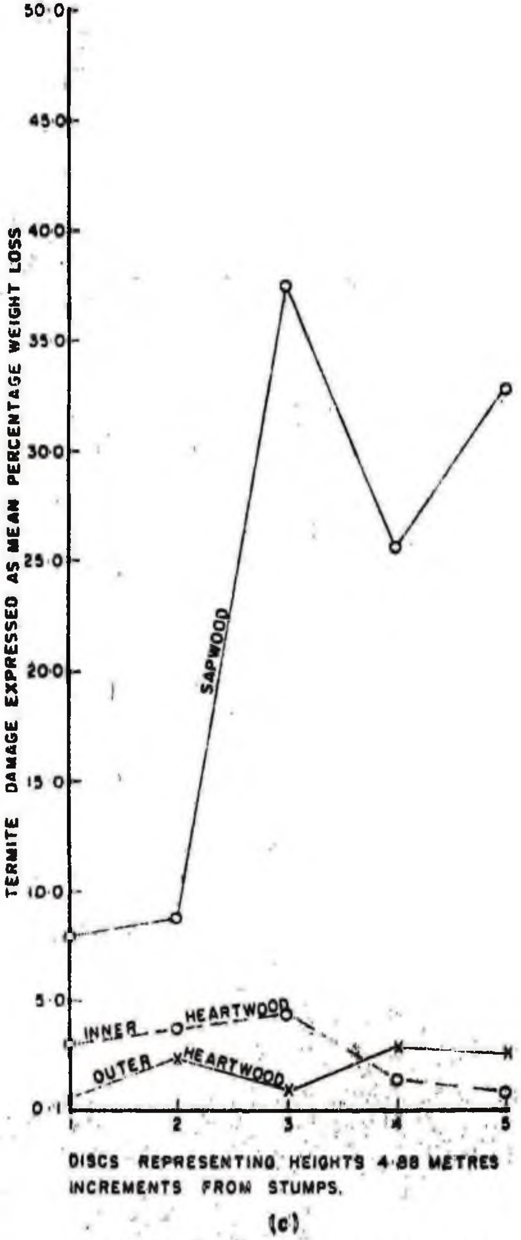
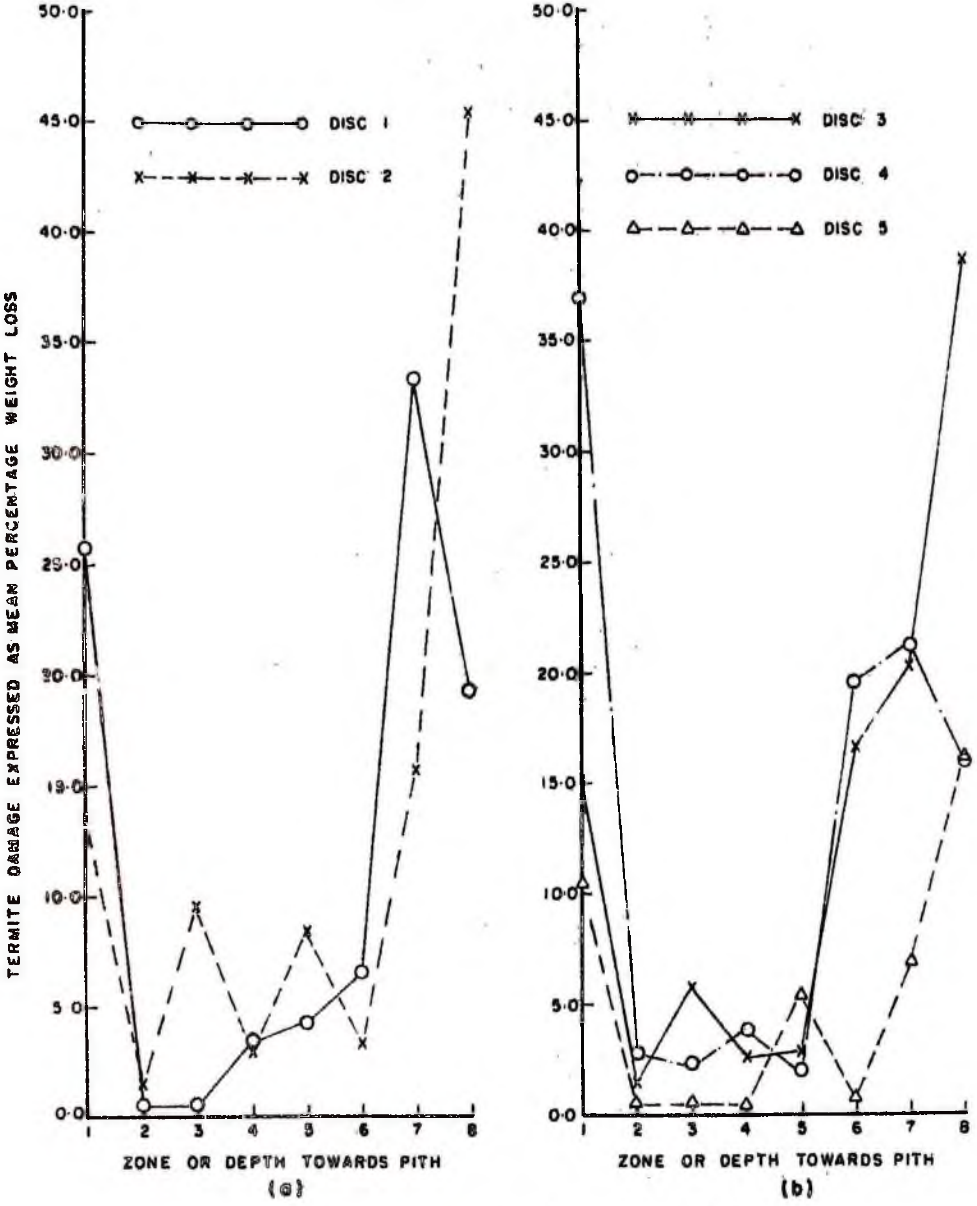


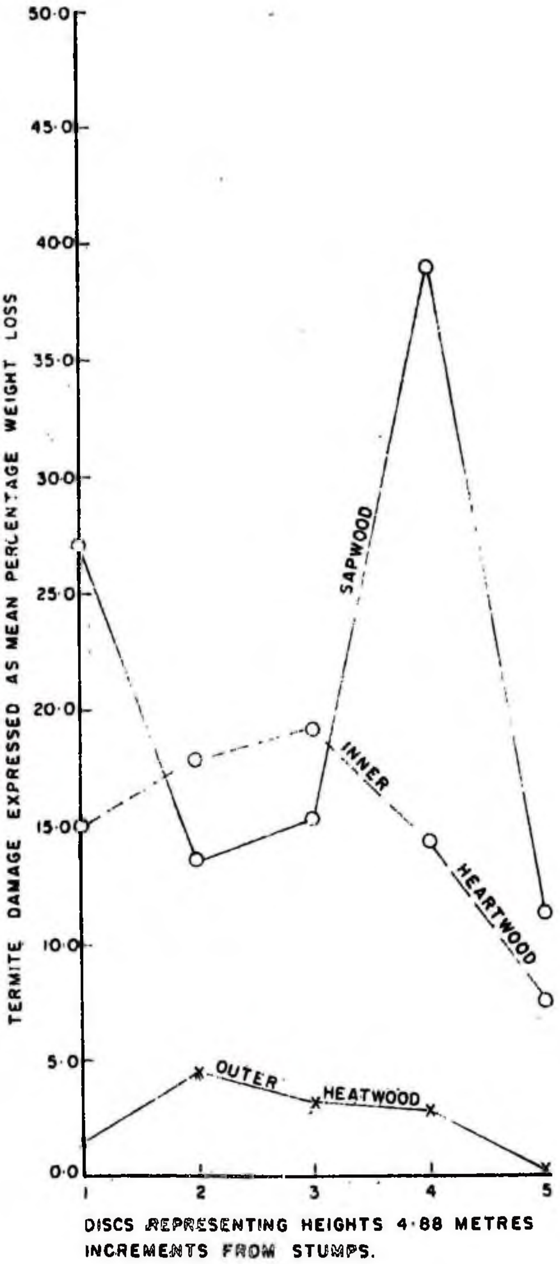
FIG. 3.2 VARIATION IN MEAN PERCENTAGE WEIGHT LOSS OF TREE 1 OF I. IVORENSIS ALONG ITS LENGTH



(a)

(b)

FIG. 3.3 RADIAL VARIATION IN MEAN PERCENTAGE WEIGHT LOSS OF TREE 2 OF I *IVORENSIS* AT DIFFERENT HEIGHTS.



(c)

FIG. 3.3 VARIATION IN MEAN PERCENTAGE WEIGHT LOSS OF TREE 2 OF I. IVORENSIS ALONG ITS LENGTH.

3.3 CONCLUSIONS FROM THE 'GRAVEYARD' TESTS

The 'graveyard' tests showed that the natural termite resistance of *T. ivorensis* varied considerably in different parts of the tree. The tests also showed that the total damage scored in the field tests was not due to termites alone. Fungi also contributed to the damage. In some cases the fungal decay was as high as 16.40 per cent in the sapwood, 7.01 per cent in the outer-heartwood and 11.09 per cent in the inner-heartwood. The decay pattern at all heights in the two trees followed the pattern of the total damage. There was also a strong similarity in the patterns of fungal decay and termite damage.

At all heights (i.e., in all 5 discs) in Tree 1, there were significant differences in the termite resistance of the wood in the radial direction. The outer-heartwoods of the first three discs of Tree 1 were more resistant to damage by termites than the inner-heartwoods of those discs. But the inner-heartwoods of Discs 4 and 5 were more resistant than the outer-heartwoods of those discs (see Fig. 3.2(c)). Similar results were obtained for Tree 2 only that the outer-heartwood was more resistant against attack by termites than the inner-heartwood at all heights (see Fig.3.3(c)). Matching the radial zones of Tree 1 against corresponding zones in corresponding discs of Tree 2, it is observed that the zones differ significantly at all heights in resistance to termite attack. The overall differences in susceptibility of the trees to damage by subterranean termites were also significant at all heights except near the top of the trees (i.e. in Disc 5). See Tables 3, 6, 9, 12 and 15 of Appendix 1.

These results agree with those obtained by Da Costa *et al*.(1958, 1961); Rudman and Da Costa(1959); and Rudman *et al*.(1967) with teak (*Tectona grandis*). For example, they found a marked radial variation in the resistance of teak to fungal decay and to termite damage. They also observed striking similarity between the decay and termite resistance patterns in that species. Eldon (1972) also reported a similar variation in the termite resistance of northern white cedar from northern U.S.

According to Alexis and de Zeeuw (1970), the greater durability of heartwood, in comparison with the sapwood of the same species, is attributable largely to the presence in the former of toxic materials, such as essential oils, tannins, and phenolic substances. When these are present in sufficient amounts, they may prevent or at least considerably minimize the severity of the attack by destructive organisms. The progressive reduction in the decay resistance of heartwood from the outside to the pith is explained by them to be due to the degradation of the toxic substances to less active compounds by enzymatic or microbial action or through leaching. These chemical changes may also affect the density of the wood in the radial direction and this formed the object of another test in which the termite damage was studied in relation to the specific gravity.

The axial variation in the intensity of termite damage to the sapwood, the outer and inner heartwoods of the trees were not very pronounced. The sapwood at all heights was, however, more susceptible to termite damage than the outer-heartwoods of the two trees. The sapwood of Tree 1 was also much more susceptible than the inner-heartwood at all heights (see Fig. 3.2(c)). The inner-heartwoods of Discs 2 and 3 of Tree 2 were less resistant to termite attack than the sapwood of those discs (see Fig. 3.3(c)).

The implication of these results is that care must be taken in selecting samples of *T. ivorensis* for tests of natural resistance against termites. Though the differences in the assessment of the natural resistance of the wood against termite attack by earlier workers might be due to differences in localities from which the test samples were obtained, they might actually have been due to within tree variations.

3.4 SPECIFIC GRAVITY TESTS

Many heavy woods are highly durable (Alexis and de Zeeuw, 1970) suggesting that the density of wood may be correlated to its durability. The aim of this experiment therefore was to find out if there is any variability in the density, hence specific gravity, of the wood of *T. ivorensis*, and how the specific gravity affects the resistance of the wood against attack by termites.

The specific gravity of each sample was determined from the oven dry weight and volume. Four samples were prepared from each of the eight radial zones to the 2cm British Standard Specification (BS 373, 1957). The experimental procedures recommended by Brown *et al*.(1952) were followed.

The samples were oven dried at 105°C for 40 hours at which time the samples had attained constant weight. They were then cooled in a desiccator and quickly weighed on a Mettler Analytical Balance. After weighing, the samples were returned to the oven and dried for a further one hour. They were removed and while still warm, each block was immersed in hot melted paraffin wax and quickly removed to keep the coating of paraffin wax as thin as possible. This was done to seal the pores of the wood and thereby prevent any absorption of water when its volume was being determined by the water displacement method. The volume of each block was determined by the following procedure.

Distilled water was poured into a beaker to a depth that will permit the complete immersion of the sample without its touching the sides and without run off. The beaker of water was placed on the Mettler balance and the latter adjusted to give the weight of the beaker and water. This was recorded. The block whose volume was to be measured was fixed to the end of a dissecting needle and lowered into the water in the beaker (see Fig.4.0) without touching the sides or bottom of the container. The balance was again adjusted and the new reading noted. The difference between this reading and the weight of beaker with water gave the weight of water displaced by the wood block and the portion of the dissecting pin that was submerged (which was taken as negligible). Since 1 cubic centimetre of water weighs 1 gram, the figure as obtained represented the volume of the block in cubic centimetres.

The specific gravity of each sample was calculated as follows:

$$\text{Specific gravity} = \frac{\text{weight of sample}}{\text{weight of an equal volume of distilled water}}$$

$$= \frac{\text{weight of samples in grams}}{\text{weight in grams of water displaced by sample}}$$

$$\text{or } S = \frac{W_o}{V}$$

where S is the specific gravity, W_o is the oven-dry weight of the specimen. S thus obtained represented the specific gravity at 0% moisture content.

Regression analysis of the specific gravity in the radial direction of each disc was carried out (see Appendix 4). The results of the specific gravity tests are presented in Tables 4.1 to 4.5. The parameters a_o, a_1 and a_2 in the Tables are the coefficients of the polynomial $S = a_o + a_1z + a_2z^2$, which approximates the relationship between the specific gravity, S, and the radial zone, z, at a given height.

3.4.1 Results of Specific Gravity Tests

Tables 4.1 to 4.5 give the experimental values of the specific gravity in the radial direction. The 95 per cent confidence limits are attached to each value.

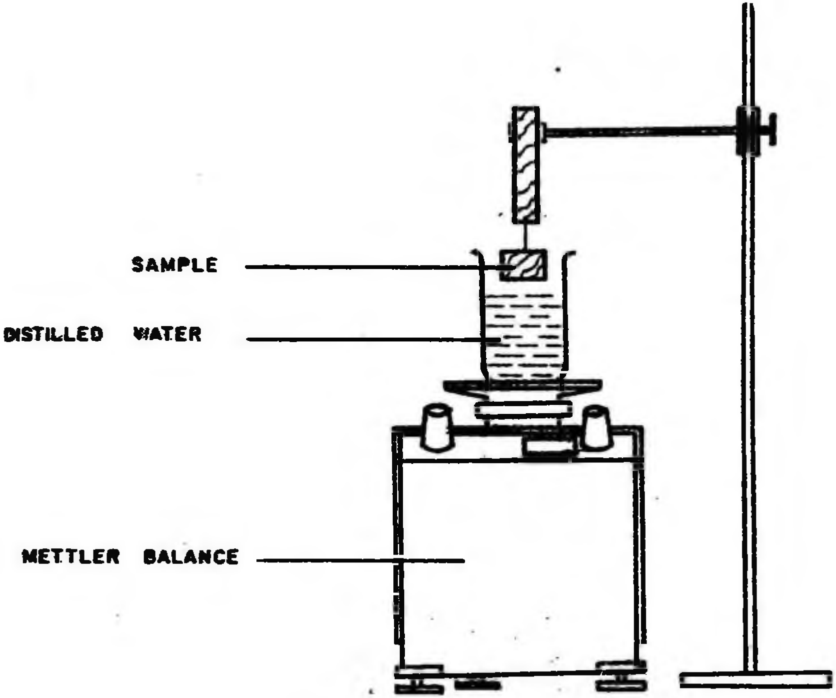


FIG. 4.0 EXPERIMENTAL ARRANGEMENT FOR MEASURING THE VOLUME OF A WOOD SAMPLE

TABLE 4.1

Specific gravity of Disc 1 of Trees 1 and 2

ZONE	SPECIFIC GRAVITY	
	TREE 1	TREE 2
1	0.566 ± 0.016	0.595 ± 0.016
2	0.571 ± 0.011	0.632 ± 0.018
3	0.568 ± 0.060	0.564 ± 0.010
4	0.579 ± 0.009	0.546 ± 0.026
5	0.600 ± 0.006	0.506 ± 0.008
6	0.523 ± 0.008	0.514 ± 0.010
7	0.523 ± 0.041	0.399 ± 0.003
8	0.497 ± 0.043	0.400 ± 0.013
	$a_0 = 0.542$ $a_1 = 0.239 \times 10^{-1}$ $a_2 = -0.377 \times 10^{-2}$	$a_0 = 0.621$ $a_1 = -0.570 \times 10^{-2}$ $a_2 = -0.296 \times 10^{-2}$

Table 4.1 and Fig.4.1(a) show that the specific gravity of Tree 2 Disc 1 increased progressively from the pith towards the sapwood. The specific gravity of Disc 1 of Tree 1 also increased from zone 8 near the pith to a maximum of 0.58 at $Z = 3.2$ (estimated from polynomial), a zone located in the outer-heartwood. Except for zones 1 and 2, the specific gravity of Tree 2 Disc 1 was less than that of Tree 1 Disc 1.

TABLE 4.2

Specific gravity of Disc 2 of Trees 1 and 2

ZONE	SPECIFIC GRAVITY	
	TREE 1	TREE 2
1	0.551 ± 0.070	0.590 ± 0.030
2	0.574 ± 0.031	0.590 ± 0.016
3	0.590 ± 0.008	0.583 ± 0.008
4	0.589 ± 0.020	0.570 ± 0.010
5	0.599 ± 0.083	0.503 ± 0.008
6	0.571 ± 0.036	0.530 ± 0.017
7	0.496 ± 0.009	0.514 ± 0.010
8	0.513 ± 0.026	0.487 ± 0.009
	$a_o = 0.517$ $a_1 = 0.401 \times 10^{-1}$ $a_2 = -0.539 \times 10^{-2}$	$a_o = 0.612$ $a_1 = -0.123 \times 10^{-1}$ $a_2 = -0.400 \times 10^{-3}$

Table 4.2 and Fig.4.1(b) show that the specific gravity of Tree 2 Disc 2 increased almost linearly from zone 8 in the inner-heartwood to zone 1, the sapwood. The variation of specific gravity in Tree 1 Disc 2 was more curvi-linear. The estimated maximum specific gravity occurred in the outer-heartwood (at Z = 3.7).

TABLE 4.3

Specific gravity of Disc 3 of Trees 1 and 2

ZONE	SPECIFIC GRAVITY	
	TREE 1	TREE 2
1	0.580 ± 0.008	0.553 ± 0.016
2	0.616 ± 0.019	0.570 ± 0.019
3	0.678 ± 0.039	0.622 ± 0.018
4	0.598 ± 0.027	0.579 ± 0.020
5	0.616 ± 0.019	0.569 ± 0.018
6	0.550 ± 0.014	0.560 ± 0.010
7	0.548 ± 0.050	0.510 ± 0.020
8	0.480 ± 0.016	0.482 ± 0.018
	$a_o = 0.554$ $a_1 = 0.459 \times 10^{-1}$ $a_2 = -0.696 \times 10^{-2}$	$a_o = 0.523$ $a_1 = 0.397 \times 10^{-1}$ $a_2 = -0.572 \times 10^{-2}$

Table 4.3 and Fig.4.1(c) show that the variation of specific gravity in Disc 3 of the two trees was curvilinear. The wood of Tree 1 at this height (11.28m above ground level) was denser than that of Tree 2. The estimated maximum specific gravity of T1D3 occurred at $Z = 3.3$ and that of T2D3 was at $Z = 3.5$, both located in the outer-heartwood.

TABLE 4.4

Specific gravity of Disc 4 of Trees 1 and 2

ZONE	SPECIFIC GRAVITY	
	TREE 1	TREE 2
1	0.597 ± 0.017	0.599 ± 0.016
2	0.652 ± 0.027	0.604 ± 0.030
3	0.686 ± 0.084	0.647 ± 0.098
4	0.604 ± 0.029	0.617 ± 0.008
5	0.595 ± 0.003	0.620 ± 0.051
6	0.552 ± 0.027	0.568 ± 0.021
7	0.564 ± 0.011	0.542 ± 0.028
8	0.540 ± 0.008	0.552 ± 0.025
	$a_o = 0.618$ $a_1 = 0.137 \times 10^{-1}$ $a_2 = -0.318 \times 10^{-2}$	$a_o = 0.584$ $a_1 = 0.232 \times 10^{-1}$ $a_2 = -0.373 \times 10^{-2}$

As was observed in the first three discs, the specific gravity variation in Disc 4 of Tree 1 followed a curvilinear relationship. The specific gravity reached its maximum value at Z = 2.2. The specific gravity of Tree 2 Disc 4 also increased non-linearly from the inner-heartwood to a maximum at Z = 3.1 in the outer-heartwood. After this point the specific gravity decreased.

TABLE 4.5

Specific gravity of Disc 5 of Trees 1 and 2

ZONE	SPECIFIC GRAVITY	
	TREE 1	TREE 2
1	0.584 ± 0.026	0.596 ± 0.027
2	0.608 ± 0.025	0.611 ± 0.019
3	0.651 ± 0.028	0.616 ± 0.003
4	0.712 ± 0.061	0.653 ± 0.031
5	0.646 ± 0.050	0.647 ± 0.009
6	0.664 ± 0.011	0.622 ± 0.004
7	0.547 ± 0.083	0.522 ± 0.070
8	0.522 ± 0.070	0.534 ± 0.058
	$a_o = 0.494$ $a_1 = 0.893 \times 10^{-1}$ $a_2 = -0.109 \times 10^{-2}$	$a_o = 0.540$ $a_1 = 0.526 \times 10^{-1}$ $a_2 = -0.679 \times 10^{-2}$

Table 4.5 and Fig.4.1(e) show that the specific gravity of Disc 5 of the two trees increased progressively from the inner-heartwood to an estimated maximum in the outer-heartwood at Z = 4.1 and Z = 3.9 for Tree 1 and Tree 2 respectively.

The maximum specific gravity at any height occurred in the outer-heartwood of the two trees except in the first two discs of Tree 2 in which there were no clear maxima. The specific gravity on the whole increased with height in the trees.

TABLE 4.6

Correlation between termite damage and specific gravity in the radial direction.

Disc	Correlation coefficients	
	Tree 1	Tree 2
1	-0.321 n.s	-0.585 n.s
2	-0.478 n.s	-0.621 n.s
3	-0.199 n.s	-0.853 **
4	-0.052 n.s	-0.614 n.s
5	-0.248 n.s	-0.711 *

TABLE 4.7

Correlation between termite damage to outer and inner heartwoods and specific gravity in the axial direction.

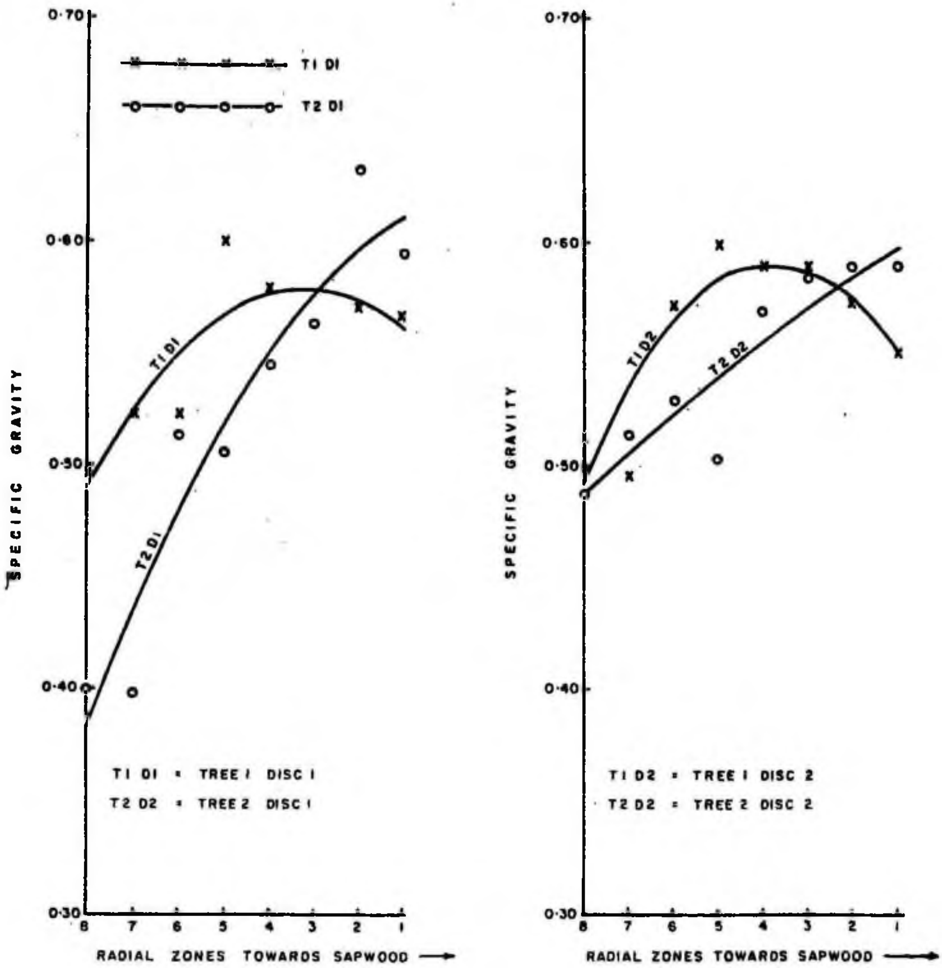
Tree	Correlation coefficients	
	Outer-Heartwood	Inner-Heartwood
1	-0.102 n.s	-0.588 **
2	-0.196 n.s	-0.577 **

The following symbols are used in the tables for significance:

**, $0.001 < p \leqslant 0.01$

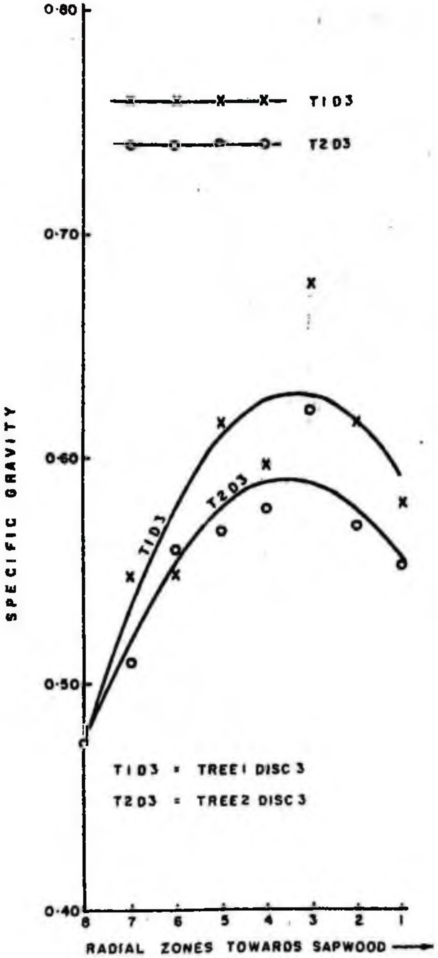
*, $0.01 < p \leqslant 0.05$

n.s, $p > 0.05$



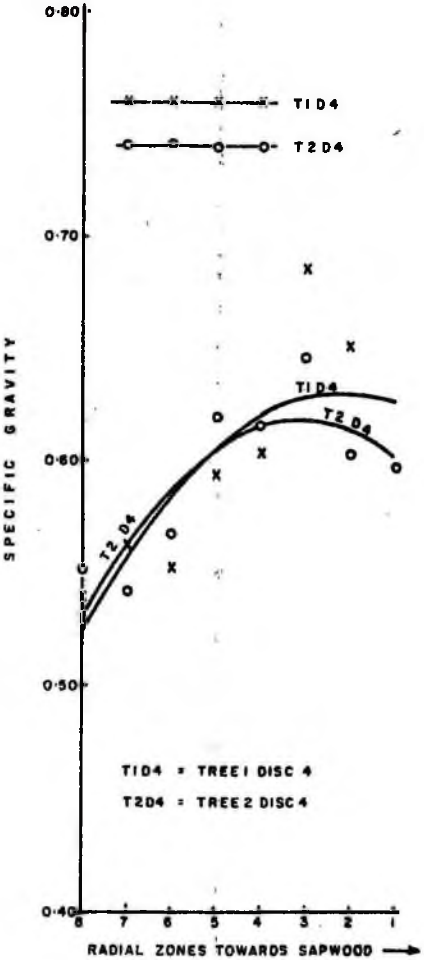
(A) (B)

FIG. 4·1. RADIAL VARIATION IN SPECIFIC GRAVITY OF *TERMINALIA IVORENSIS*



(C)

FIG. 4·1. RADIAL VARIATION IN SPECIFIC GRAVITY OF <u>TERMINALIA IVORENSIS.</u>



(D)

FIG. 4·1. RADIAL VARIATION IN SPECIFIC GRAVITY OF <u>TERMINALIA IVORENSIS.</u>

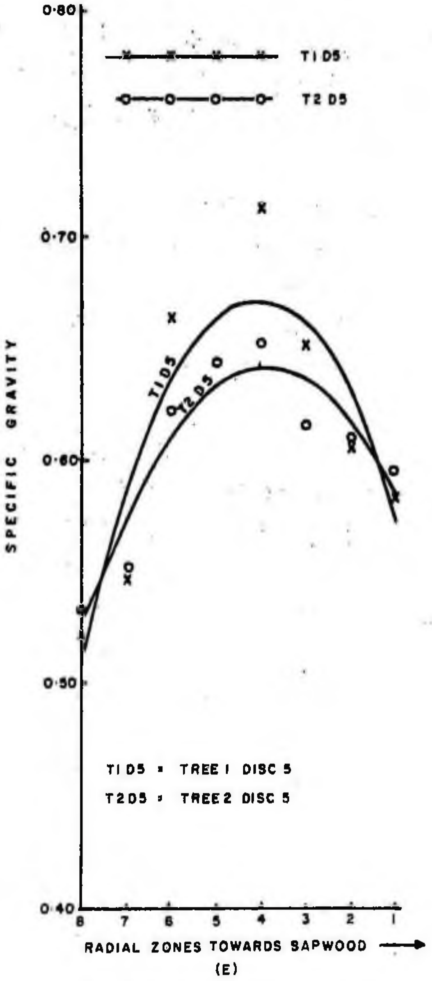


FIG. 4·1. RADIAL VARIATION IN SPECIFIC GRAVITY OF TERMINALIA IVORENSIS.

3.4.2 General conclusions from the specific gravity tests

One of the aims of this study was to find out if there was any correlation between termite damage and specific gravity. With this end in view, the results of the graveyard and specific gravity tests were tested for correlation.

In both trees, the damage was found to be inversely correlated to the density of the wood at all heights. The correlation between the two quantities was, however, not high at all heights in the two trees. Table 4.6 gives the correlation coefficients between termite damage and specific gravity.

The correlation between termite damage and specific gravity as shown in Table 4.6 is in accordance with other published results for wood (Alexis and de Zeeuw, 1970).

As noted earlier, the specific gravity varied in the radial direction, attaining a maximum value in the outer-heartwood almost at all heights. This variation may be due to differences in size of pores, the thickness of the cell walls and the presence of gums, resins and extractives in the wood (U.S. Department of Agric. Handbook No.72, 1955).

Table 4.7 gives the correlation between termite damage and the specific gravity of the outer and inner heartwoods. The damage was inversely correlated to the density of the heartwood. Since the accumulation of materials, toxic or poisonous to termite occurs in the heartwood and this is accompanied by increase in specific gravity, the decrease in the termite damage to the wood with increase in specific gravity could be expected. The termite susceptibility of the inner-heartwood of Tree 1 decreased significantly with increase in specific gravity in the axial direction. In Tree 2, the inverse correlation between damage to the inner-heartwood and the specific gravity in the axial direction was significant.

The inverse correlation between termite damage and specific gravity is also reflected in the overall termite resistance of the two trees. The wood of Tree 1 which was slightly heavier than the wood of Tree 2 was more resistant to termite damage than the wood of Tree 2 (see mean percentage weight losses in Tables 3.16 and 3.19).

These results confirm the findings of Alexis and de Zeeuw (1970) that variation in density in a given tree does not affect its durability much unless the higher durability is correlated with the greater accumulation of toxic substance.

The correlation between specific gravity and termite damage can be applied when using T. ivorensis under conditions in which it will come into contact with subterranean termites. It will then be necessary to use the part of the tree which will resist attack by termites. As every part of the tree cannot be tested for termite resistance, some other means of establishing termite resistance must be applied and the relationship between specific gravity and termite damage can be used in such a case.

In practice, this will mean using the part of the tree of high density or outer-heartwoods from logs near the butt of the tree. Since the specific gravity is also slightly correlated to strength of the wood, this will imply using the high strength portion of the tree.

3.5 MODULUS OF ELASTICITY TESTS

The strength of a particular material generally depends on the amount of substance it contains per unit volume. Since the amount of substance determines the density of the material and the durability of some species of wood is known to be related to density (Alexis and de Zeeuw, 1970), it was decided to examine the strength of *T. ivorensis* in relation to its resistance against termite attack. This experiment was to determine the modulus of elasticity at different heights in different radial positions. A cantilever method (Tyler, 1958; Worsnop and Flint, 1950) was used.

Two specimens, of size 10cm x 1.5cm x 0.2cm approximately, were prepared from each of the eight radial zones in a disc. The point on each specimen where the deflection was to be measured was marked. Similarly the points of loading and fixing the specimen as a cantilever were also marked. The average thickness of each specimen was determined from ten readings taken with a micrometer screw gauge along the length between the points of loading and fixing. The mean breadth of specimen was similarly measured.

The samples were then oven dried at 105°C. It was found that at this temperature the samples attained constant weight after 3 hours. After this time they were transferred into a desiccator and kept in a cold room where the tests were carried out. The mean relative humidity of the room was 60 per cent and its temperature was 26°C.

The experimental set-up was as shown in Fig.5.1. One end of the test piece was rigidly held between the edge of a heavy table and a wooden block by means of a G-clamp. Mercer strain gauge calibrated to read 0.001in.(0.00254cm) was used to measure the deflection at a point 6cm from the fixed end. The load was placed 8.0cm from the fixed end. Preliminary tests showed that for the specimens used, loads between 40gm and 80gm gave deflections within the elastic limits. For this range of loads, the depressions ranged between 0.0305 and 0.1346cm.

Five different loads were used for each sample and the corresponding deflection for each load recorded. Fig.5.2 shows the graphs of load against deflection for two of the test samples. Similar graphs were obtained for the other samples.

The theory of the experiment shows that for small deflections, the deflection is directly proportional to the load (see Appendix 2). The constant of proportionality was determined from a regression equation for each sample. The regression coefficient, b, represents the constant of proportionality. The correlation (correlation coefficient, r) between the deflection and the load for each specimen was also computed. There was a large correlation between the loads used and the deflection measured ($0.9905 < r \leq 1.00$) showing that the loads used were within the elastic limit. The modulus of elasticity, E, parallel to the grain was then found. A computer programme, written for calculating b, r and E, is shown in Appendix 3. The values of E are given in Tables 5.1-5.5. The percentage moisture pick up by the samples during the tests ranged from 0 to 1.43 with a mean of 0.40.

3.5.1 Results

Tables 5.1 to 5.8 give the values of the modulus of elasticity of *T. ivorensis* at 0% moisture content. The figures represent Young's moduli in the radial direction parallel to the grains in the wood.

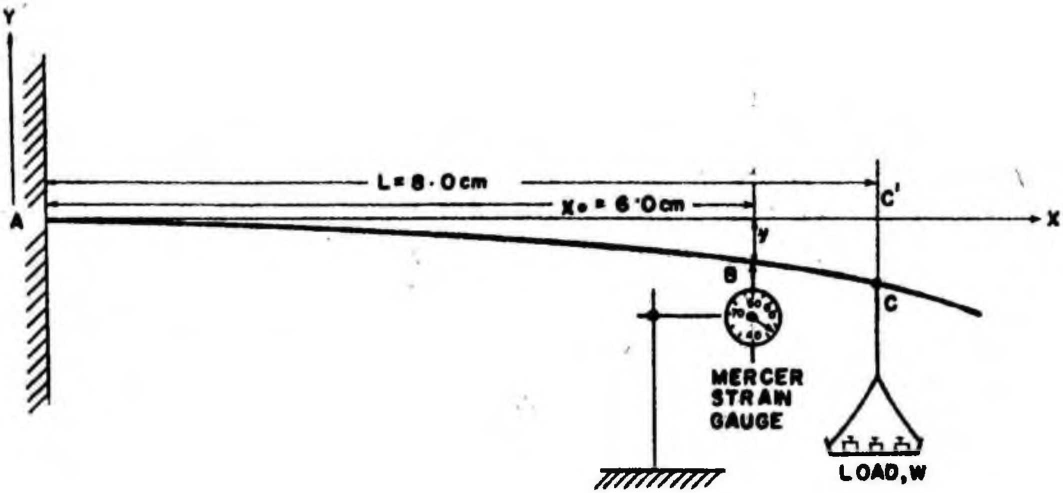


FIG. 5.1 ARRANGEMENT FOR MEASURING MODULUS OF ELASTICITY

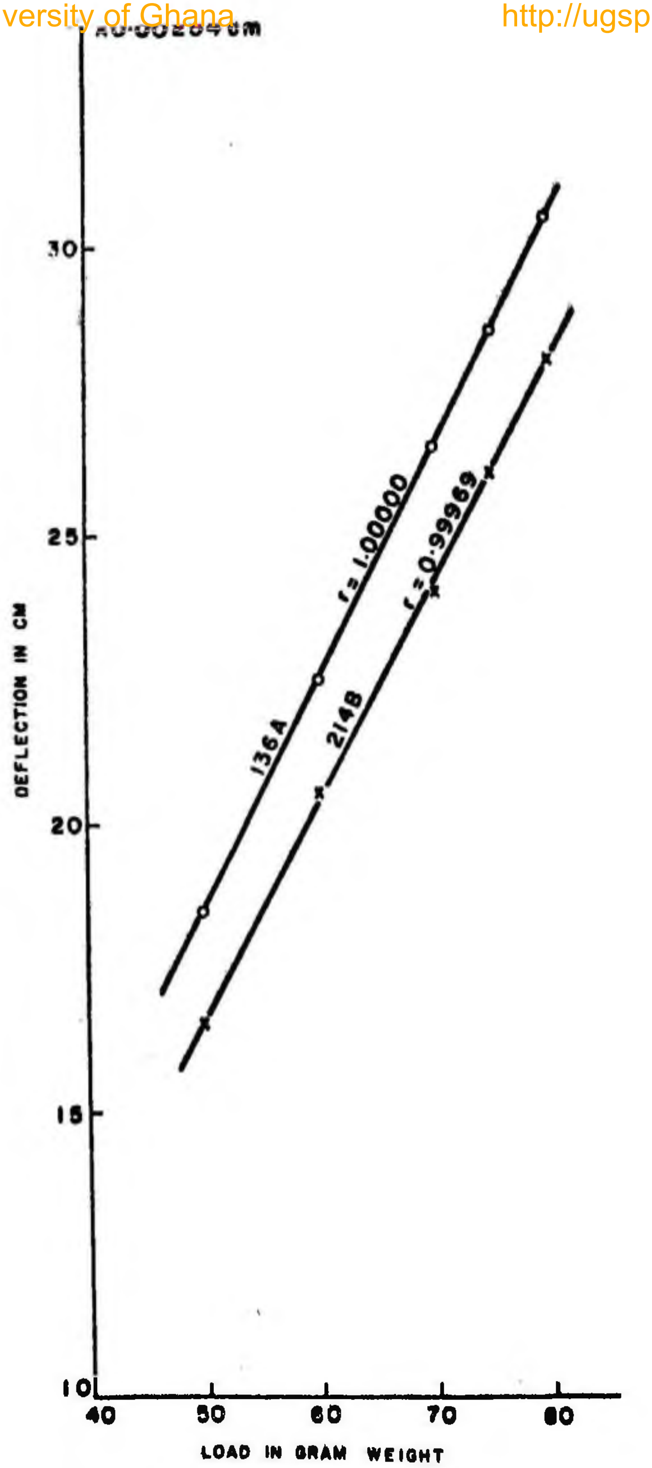


FIG. 5.2 GRAPH OF DEFLECTION AGAINST LOAD.

TABLE 5.1

DISC 1

ZONE	YOUNG'S MODULUS IN NEWTON PER SQUARE METRE	
	TREE 1	TREE 2
1	6.063×10^9	9.495×10^9
2	5.722×10^9	8.505×10^9
3	9.109×10^9	10.882×10^9
4	7.941×10^9	7.477×10^9
5	8.019×10^9	6.265×10^9
6	7.591×10^9	7.015×10^9
7	6.249×10^9	7.636×10^9
8	6.882×10^9	7.387×10^9

In Tree 1 Disc 1 the mean values of E for the outer and inner heartwoods are 7.621×10^9 and 7.185×10^9 N m^{-2} respectively. Thus the outer-heartwood was stronger than the inner-heartwood and the sapwood. The outer-heartwood of Tree 2 Disc 1 also was stronger ($E = 8.954 \times 10^9$ N m^{-2}) than the inner-heartwood ($E = 7.046 \times 10^9$ N m^{-2}). The modulus of elasticity of the sapwood of Tree 2 Disc 1 was 9.495×10^9 N m^{-2}, thus the strength of the wood of Tree 2 Disc 1 increased from the inner-heartwood to the sapwood in a manner similar to the specific gravity variation in that Disc (see Fig. 4.1(a)).

TABLE 5.2

DISC 2

ZONE	YOUNG'S MODULUS IN NEWTON PER SQUARE METRE	
	TREE 1	TREE 2
1	7.979×10^9	7.559×10^9
2	7.954×10^9	7.984×10^9
3	8.774×10^9	8.409×10^9
4	7.466×10^9	7.394×10^9
5	7.454×10^9	8.345×10^9
6	7.284×10^9	7.526×10^9
7	7.573×10^9	5.059×10^9
8	6.818×10^9	5.628×10^9

The mean Young's modulus of elasticity of the outer and inner heartwoods of Tree 1 Disc 2 were 8.064×10^9 and 7.282×10^9 respectively. The value for the sapwood was 7.979×10^9 N m^{-2}. Thus the modulus of elasticity was maximum in the outer-heartwood as the specific gravity in that Disc (see Fig.4.1(b)). The strength of the wood of Tree 2 Disc 2 increased progressively from the inner-heartwood to the sapwood as observed with the specific gravity.

TABLE 5.3

DISC 3

ZONE	YOUNG'S MODULUS IN NEWTON PER SQUARE METRE	
	TREE 1	TREE 2
1	6.624×10^9	6.259×10^9
2	7.002×10^9	5.725×10^9
3	10.001×10^9	10.523×10^9
4	8.051×10^9	10.915×10^9
5	8.535×10^9	7.082×10^9
6	8.398×10^9	9.143×10^9
7	8.214×10^9	8.713×10^9
8	8.400×10^9	6.462×10^9

In Tree 1 Disc 3, the value of modulus of elasticity, E, in the sapwood was less than the values in the outer and inner heartwoods. Though the peak value of E occurred in the outer-heartwood, the mean value of E in the outer-heartwood was slightly less than the value in the inner-heartwood. For Tree 2 Disc 3, Table 5.3 shows a clear maximum value of E in the outer-heartwood. The modulus of elasticity thus varied in T2D3 in a manner similar to the specific gravity variation observed in the Disc (see Fig. 4.1(c)).

TABLE 5.4

DISC 4

ZONE	YOUNG'S MODULUS IN NEWTON PER SQUARE METRE	
	TREE 1	TREE 2
1	4.531×10^9	7.435×10^9
2	6.172×10^9	6.789×10^9
3	7.376×10^9	4.527×10^9
4	6.456×10^9	6.902×10^9
5	7.472×10^9	9.759×10^9
6	8.003×10^9	8.152×10^9
7	8.474×10^9	11.566×10^9
8	6.894×10^9	8.168×10^9

As in Disc 3, the modulus of elasticity in the inner-heartwood of Tree 1 Disc 4 was higher than the value in the outer-heartwood. Disc 4 of Tree 2 also showed the inner-heartwood to be stronger than the outer-heartwood.

TABLE 5.5

DISC 5

ZONE	YOUNG'S MODULUS IN NEWTON PER SQUARE METRE	
	TREE 1	TREE 2
1	5.141×10^9	7.316×10^9
2	5.401×10^9	7.401×10^9
3	5.080×10^9	7.645×10^9
4	5.810×10^9	14.795×10^9
5	5.491×10^9	9.696×10^9
6	5.656×10^9	10.535×10^9
7	12.686×10^9	7.466×10^9
8	9.496×10^9	3.929×10^9

Table 5.5 also shows E of the inner-heartwood of Tree 1 Disc 5 to be greater than that of the outer-heartwood. The outer-heartwood of Tree 2 Disc 5 on the other hand was stronger than the inner-heartwood.
The Tables show that the patterns of variation of the modulus of elasticity in the first two discs of Tree 1 were similar to the patterns of specific gravity variations in the discs, that is, both the modulus of elasticity and specific gravity attained their maximum values in the outer-heartwood. From Discs 3 to 5, the inner-heartwood of Tree 1 became stronger than the outer-heartwood (see Table 5.6).

The modulus of elasticity varied in the first two discs of Tree 2 in a manner similar to the specific gravity variations in the discs. Both the modulus of elasticity and specific gravity increased from the inner-heartwood to the sapwood. The modulus of elasticity varied in Disc 3 of the tree as did the specific gravity. The maximum values of E and the specific gravity occurred in the outer-heartwood. In Disc 4, the strength of the inner-heartwood became greater than that of the outer-heartwood (see Table 5.6).

TABLE 5.6

Mean modulus of elasticity of outer and inner heartwoods at the five different heights. Values in N m^{-2}.

DISC	TREE 1		TREE 2	
	OUTER-HEARTWOOD	INNER-HEARTWOOD	OUTER-HEARTWOOD	INNER-HEARTWOOD
1	7.621×10^9	7.185×10^9	8.954×10^9	7.046×10^9
2	8.064×10^9	7.282×10^9	7.110×10^9	6.640×10^9
3	8.351×10^9	8.387×10^9	10.889×10^9	7.850×10^9
4	7.001×10^9	7.711×10^9	6.073×10^9	9.411×10^9
5	5.430×10^9	6.088×10^9	9.947×10^9	7.614×10^9

3.5.2 General conclusion from modulus of elasticity and termite resistance tests

Correlation analysis showed the termite damage to decrease with increase in modulus of elasticity in Discs 1, 2,3 and 5 of Tree 1. The damage was positively correlated to the strength of the wood of Disc 4 of the tree. In Tree 2, the susceptibility of the wood to damage positively correlated with strength at all heights. The correlation between damage and the modulus of elasticity was, however, not significant at all heights in the two trees. Table 5.7 gives the correlation coefficients between damage and modulus of elasticity. The positive correlation between termite and strength of the wood at all heights in Tree 2 as compared to the inverse correlation between damage and strength in Tree 1 (except for Disc 4) exhibited another instance of the differences between the two trees.

TABLE 5.7

Correlation between termite damage and modulus of elasticity in the radial direction. Levels of significance are indicated by the following symbols:

***, $p \leq 0.001$
**, $0.001 < p \leq 0.01$
*, $0.01 < p \leq 0.05$
n.s, $p > 0.05$

Disc	Correlation coefficients	
	Tree 1	Tree 2
1	-0.431 n.s	+0.689 n.s
2	-0.344 n.s	+0.910 **
3	-0.594 n.s	+0.551 n.s
4	+0.992 ***	+0.689 n.s
5	-0.231 n.s	+0.789 *

3.6 CHEMICAL TESTS

It is generally believed that heartwood extractives are important in conferring termite resistance on wood. These extractives are usually extracted with ether, methanol or water. When wood is used outdoor, it is exposed to rains which may dissolve out any water soluble extractives which may be toxic, repellent or poisonous to termites and thereby increase its susceptibility to termite attack. It is possible also that some of the water soluble extractives may render the wood attractive and palatable to the insects. The aim of these experiments therefore was to find out if the water soluble chemical constituents of *T. ivorensis* impart any termite resistance to the timber.

Samples from zones 1, 3 and 8 of Discs 2 and 4 of Tree 1 (representing the sapwood, the outer-heartwood and the inner-heartwood respectively) were pulverised in a Wiley mill. 25 grams of the powder of each sample were added to 500c.c. of distilled water and thoroughly stirred. The solutions were allowed to stand for 30 minutes after which they were filtered. The colour of the leachates indicated that some materials were dissolved by water. Sapwood blocks of wawa (*Triplochiton scleroxylon*) measuring approximately 10.0cm x 4.0cm x 2.5cm were impregnated with the leachates and the treated blocks and controls (untreated blocks) tested against subterranean termites. The treated and control blocks were replicated five times and exposed to the termites for four weeks. The damage was assessed by measuring the volume of wood eaten by the termites (see Ocloo, 1973). The termites found damaging the blocks were *Macrotermes bellicosus*, *M. subhyalinus* and *Pseudacanthotermes militaris*.

3.6.1 Results and discussion

The mean percentage volume losses indicated very little differences in the termite resistance of the blocks treated with leachates of Tree 1 Disc 2. The samples treated with leachates of the outer-heartwood were slightly more resistant to termites than the blocks treated with sapwood and inner-heartwood extractives. The control blocks were more susceptible to termite damage than the treated blocks. Analysis of variance of the damage, however, showed the differences in the treated blocks to be non-significant at the 5 per cent level. Table 6.1 gives the mean percentage volume losses of the treated and control blocks. The value of the least significant difference (LSD) for comparing differences between pairs of means is also provided in the table. No pairs of means show a difference greater than the LSD.

The blocks treated with inner-heartwood extractives of Tree 1 Disc 4 were more susceptible to damage than those treated with sapwood and outer-heartwood extractives and the controls (see Table 6.2).

Thus the termite resistance of the treated blocks had not significantly increased in comparison with the control. This could mean either the water soluble extractives of *T. ivorensis* do not contribute to the termite resistance of the wood or enough of the water soluble materials which impart resistance to the wood had not been used in treating the wawa blocks in the present work. This needs to be investigated.

TABLE 6.1

Mean percentage loss in volume by blocks treated with water soluble extractives of TREE 1 DISC 2. The means and standard error are backtransformed after calculation had been based on data subjected to an arcsin transformation.

	TREATMENT				
	Sapwood Extractive	Outer-heartwood Extractive	Inner-heartwood Extractive	Control	LSD
MEAN % VOLUME LOSS	2.56	2.09	3.45	3.91	12.43

S.E = ± 0.85%

TABLE 6.2

Mean percentage loss in volume by blocks treated with water soluble extractives of TREE 1 DISC 4. The means and standard error are backtransformed after calculation had been based on data subjected to an arcsin transformation.

	TREATMENT				
	Sapwood Extractive	Outer-heartwood Extractive	Inner-heartwood Extractive	Control	LSD
MEAN % VOLUME LOSS	6.52	7.41	25.00	9.55	42.52

S.E = ± 0.46%

3.7 ANATOMICAL STUDIES

One of the objectives of this project was to relate the natural termite resistance of *T. ivorensis* to some of its anatomical properties such as the number of pores per unit area and the sizes of the pores. Since the deposition of extractives in the wood is greater in the vessels, it means the number of pores and their sizes is likely to affect the susceptibility of the wood to termite attack. The purpose of this section is to examine the termite damage in relation to the vessel sizes and their number per unit area.

Thin sections were prepared from the sapwood, outer and inner-heartwoods of each disc of the two trees. The average number of vessels per unit area and the maximum tangential diameter were determined from ten measurements in the transverse sections.

3.7.1 Results of anatomical studies

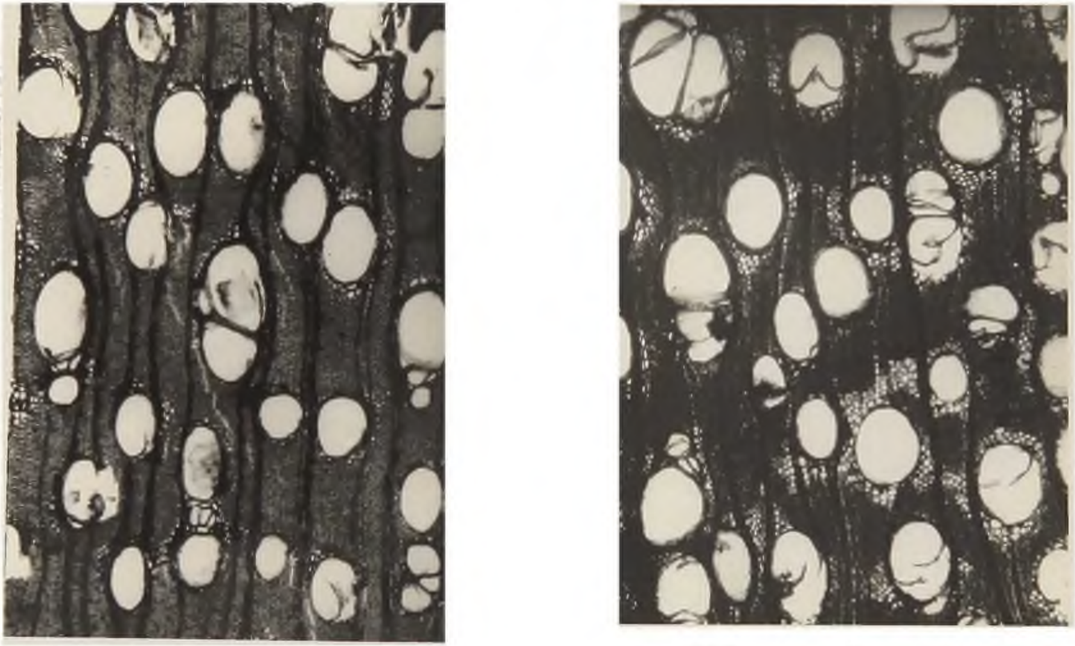
Tables 7.1 and 7.2 give the number of vessels per square millimetre and their maximum tangential diameters. Fig. 7.1 shows transverse sections of sap, outer and inner heartwoods of one of the discs.

The vessels were oval in cross section. The void volume available for accumulation of extractives would therefore be approximately proportional to the square of the tangential diameter of a vessel. This means the amount of extractives in the wood in a given cross-section would be proportional to the square of the tangential diameter of the vessels. Hence if the amount of extractives present in the section was related to the termite damage, then the damage would be related to the square of the tangential diameter. The square of the tangential diameter could also relate to the termite damage in another way. If the vessels are empty, then the greater the square of the tangential diameter, the smaller would be the density of the wood and hence the greater the termite activity. The correlation between termite damage and the square of the tangential diameter was therefore computed for each disc.

On the whole, termite damage was positively correlated with the total cross-sectional area of the vessels except in Discs 1, 2 and 5 of Tree 1 in which damage decreased with size of the vessels. The correlation between termite resistance of the wood and the vessel size, however, was not high in all the discs. Table 7.3 gives the values of the correlation coefficients.

The positive correlation between termite damage and vessel size as observed in most of the discs suggests that the pores probably were not filled with extractives poisonous or toxic to the termites. They might have contained air and moisture which would encourage the growth of fungi in the wood and hence rendered it suitable food for the insects. The negative correlation between termite susceptibility and vessel size in Discs 1, 2 and 5 of Tree 1 could be expected since the larger the vessels, the greater the accumulation of materials toxic, repellent or poisonous to termites.

The relationships (see Table 7.3) between termite damage and the cross-sectional area of the vessels in the wood indicated another fundamental difference between Trees 1 and 2.



SAPWOOD

OUTER-HEARTWOOD

FIG. 7.1 TRANSVERSE SECTIONS X 50
FROM TREE 1 DISC 1

FIG. 7.1 INNER-HEARTWOOD

TRANSVERSE SECTION X 50

FROM TREE 1 DISC 1

TABLE 7.1

Number of vessels per unit area and tangential diameters of the vessels in sapwood, outer and inner heartwoods of Tree 1.

Disc	SAPWOOD		OUTER-HEARTWOOD		INNER-HEARTWOOD	
	Mean No. of vessels per sq.mm.	Mean tangential diameter in microns	Mean No. of vessels per sq.mm.	Mean tangential diameter in microns	Mean No. of vessels per sq.mm.	Mean tangential diameter in microns
1	5.27	189.8	4.10	228.5	5.33	198.0
2	4.76	197.9	3.76	240.8	5.12	193.9
3	5.00	232.6	3.50	249.0	3.66	230.6
4	4.24	249.0	3.80	235.1	4.81	210.2
5	4.76	224.5	2.42	185.7	5.12	212.2

TABLE 7.2

Number of vessels per unit area and tangential diameters of the vessels in sapwood, outer and inner heartwoods of Tree 2.

Disc	SAPWOOD		OUTER-HEARTWOOD		INNER-HEARTWOOD	
	Mean No. of vessels per sq.mm.	Mean tangential diameter in microns	Mean No. of vessels per sq.mm.	Mean tangential diameter in microns	Mean No. of vessels per sq.mm.	Mean tangential diameter in microns
1	4.80	209.2	4.45	218.1	4.38	166.3
2	4.00	224.5	4.35	240.8	4.00	187.7
3	5.22	209.2	4.12	212.4	4.12	212.2
4	4.23	229.3	4.18	208.1	5.36	187.7
5	3.10	183.7	4.06	208.1	4.26	183.7

TABLE 7.3

Correlation between termite damage and cross-sectional area of vessels. Following symbols are used in the table for significance:

***, $p \leqslant 0.001$
*, $0.01 < p \leqslant 0.05$
n.s, $p > 0.05$

DISC	CORRELATION COEFFICIENTS	
	TREE 1	TREE 2
1	-0.759 *	+0.613 n.s
2	-0.512 n.s	+0.671 n.s
3	+0.976 ***	+0.123 n.s
4	+0.985 ***	+0.345 n.s
5	-0.100 n.s	+0.586 n.s

4. MULTIPLE REGRESSION ANALYSES OF RESULTS

The final aim of this investigation was to assess the correlation between termite resistance and factors of the wood such as specific gravity, strength and number and size of vessels per unit area. The effects of each of these factors have been considered already and Appendix 5 gives the correlation matrices of the factors in each disc of the two trees. All the factors were correlated amongst themselves hence a simple linear regression analysis of termite damage with these factors could be misleading. To obtain a better indication of termite resistance and of the real importance of each factor, it was necessary to allow for these correlations. The effects of these factors have therefore been examined by multiple regression analyses of the data.

In the absence of any other hypothesis, the simple additive model was used. The regression equation with this model has the form

$$W \text{ (per cent weight loss)} = C_o + C_1S + C_2E + C_3ND^2$$

where W = percentage weight loss,

S = specific gravity

E = modulus of elasticity,

ND^2 = cross-sectional area of vessel and

C_o, C_1, C_2 and C_3 are constants.

Analyses of variance for the regression showed that though all three factors influence the resistance of the wood, they were not all significant in determining the susceptibility or resistance of the wood at all heights in the trees. This means that no single property studied can be used alone in predicting the termite resistance of *Terminalia ivorensis*.

Tables 8.1 and 8.2 give details of the regression equations involving the specific gravity (S), the tensile strength (E) and the cross-sectional area of the vessels assumed to be proportional to ND^2. In Tables 8.3 and 8.4 the factors which did not contribute significantly to the resistance or susceptibility of the wood were excluded from the regression analysis.

TABLE 8.1

REGRESSION ANALYSIS OF DATA FOR TREE 1

Regression equation -

$$W(\%\ \text{weight loss}) = C_o + C_1S + C_2E + C_3ND^2$$

DISC	REGRESSION COEFFICIENTS				CORRELATION COEFFICIENT R	VARIANCE RATIO F
	C_o	C_1	C_2	C_3		
1	91.742 ±2.830	- 30.560n.s ± 32.068	8.270×10^{-6} n.s $\pm 76.907 \times 10^{-6}$	- 340.812n.s ± 149.314	0.816 *	2.651 n.s
2	30.879 ±3.013	- 20.680n.s ± 35.829	2.0×10^{-5} n.s $\pm 16 \times 10^{-5}$	- 65.722n.s ± 100.471	0.572 n.s	0.649 n.s
3	23.242 ±1.620	- 44.689** ± 11.029	-4.0×10^{-5} n.s $\pm 5.0 \times 10^{-5}$	9.0×10^{-5}** $\pm 10^{-5}$	0.995 ***	141.747 ***
4	313.029 ±0.538	- 27.251* + 7.553	-9.792×10^{-9} *** $\pm 1.611 \times 10^{-9}$	-1393.729*** ± 303.811	0.999 ***	553.091 ***
5	160.167 ±10.160	-180.121n.s ± 89.479	49.0×10^{-5} n.s $\pm 25.0 \times 10^{-5}$	4.0×10^{-5} n.s $\pm 3.0 \times 10^{-5}$	0.739 *	1.608 n.s

TABLE 8.2

REGRESSION ANALYSIS OF DATA FOR TREE 2

Regression equation -

$$W(\%\ \text{weight loss}) = C_o + C_1S + C_2E + C_3ND^2$$

DISC	REGRESSION COEFFICIENTS				CORRELATION COEFFICIENT R	VARIANCE RATIO F
	C_o	C_1	C_2	C_3		
1	8.578 ±11.302	3.000n.s ±96.206	-0.144 x 10^{-9}n.s ±0.122 x 10^{-9}	1.0 x 10^{-5}n.s 2.0 x 10^{-5}	0.740*	1.615n.s
2	0.507 + 7.641	8.674n.s +100.322	-0.333 x 10^{-9}n.s ±0.153 x 10^{-9}	3.24 x 10^{-6}n.s ±9.21 x 10^{-6}	0.914**	6.803*
3	135.713 + 8.259	-223.530* + 89.845	-0.159 x 10^{-9}n.s ±0.308 x 10^{-9}	-8.0 x 10^{-8}n.s ±1552.0 x 10^{-8}	0.872**	4.245n.s
4	53.210 + 7.603	- 79.126n.s +108.408	-0.194 x 10^{-9} ±0.067 x 10^{-9}	-6.3 x 10^{-6}n.s ±2.6 x 10^{-6}	0.892**	5.199n.s
5	36.832 + 3.319	- 56.560n.s + 27.896	-0.091 x 10^{-9}n.s ±0.055 x 10^{-9}	2.0 x 10^{-6}n.s ±4.9 x 10^{-6}	0.903**	5.907n.s

TABLE 8.3

REGRESSION ANALYSIS OF DATA FOR TREE 1 ELIMINATING FACTORS NOT SIGNIFICANT

Regression equation -

$$W(\% \text{ weight loss}) = C_o + C_1S + C_2E + C_3ND^2$$

DISC	REGRESSION COEFFICIENT				CORRELATION COEFFICIENT R	VARIANCE RATIO F
	C_o	C_1	C_2	C_3		
1	76.356 $\pm$2.602			-352.077*	0.759*	8.134*
3	27.006 $\pm$1.577	-41.485*** $\pm$10.102		87.684×10^{-6}*** $\pm4.228\times10^{-6}$	0.994***	224.027***
4	313.029 $\pm$0.538	-27.251** $\pm$ 7.553	-9.792×10^{-9}*** $\pm1.611\times10^{-9}$	-1393.729*** $\pm$ 303.811	0.999***	553.091***

TABLE 8.4

REGRESSION ANALYSIS OF DATA FOR TREE 2 ELIMINATING FACTORS NOT SIGNIFICANT

Regression equation -

$$W(\%\ \text{weight loss}) = C_o + C_1S + C_2E + C_3ND^2$$

DISC	REGRESSION COEFFICIENT				CORRELATION COEFFICIENT R	VARIANCE RATIO F
	C_o	C_1	C_2	C_3		
2	5.921 ±6.372		-0.352×10^{-9}*** $\pm0.065\times10^{-9}$		0.911**	29.095**
3	152.363 ±7.190	-251.097*** ± 62.614			0.853**	16.082**
5	2.732 ±3.877		-0.140×10^{-9}** $\pm0.044\times10^{-9}$		0.789*	9.919*

5. GENERAL CONCLUSIONS

Following the discussions in the previous sections, the following conclusions were drawn:

i. The wood of Terminalia ivorensis varied significantly in its resistance against attack by termites in the radial direction. The outer-heartwood was the most resistant part of the tree.

   These results are similar to those obtained by Da Costa et al.(1958, 1961); Rudman and Da Costa(1969); and Rudman et al.(1967) for teak (Tectona grandis).

ii. The susceptibility of the inner-heartwood to subterranean termite attack decreased towards the top of the tree, thus the inner-heartwood near the top of the tree was more resistant than the inner-heartwood near the butt. There was no significant difference between the outer and inner heartwoods near the top of the tree.

iii. Termite damage to the wood was inversely correlated to the specific gravity. The strength of the wood also influenced its susceptibility to damage. The damage often increased with strength.

iv. The natural resistance of the wood against termite attack generally decreased with increase in total cross-sectional area of the vessels in the wood.

v. The two trees tested showed significant differences in their resistance to termite. These trees came from the same environment and there should not be any significant differences due to environmental growth conditions. The differences exhibited by the trees could be due to genetic factors. This means that naturally growing trees of _T. ivorensis_ obtained from different Forest Reserves in Ghana could be expected to vary widely in their resistance against attack by subterranean termites due to genetic and environmental growth factors.

One may, however, ask if the variations observed in the radial direction are of any practical importance. The answer to this will be relevant to only the heartwoods (the outer and inner heartwoods) since the sapwood is not normally used for buildings or in constructing permanent structures. The variations in the heartwoods are of practical importance since they help to explain some of the differences observed in the performance of wood in service. One may use timber of one species obtained from a single source and find that some of the woods fail more easily than others. The failure could be due to differences in strength, density and resistance against termite attack as exhibited by _T. ivorensis_. To ensure resistance against termite damage and high strength when using _T. ivorensis_, the use of outer-heartwood is recommended. Since the person using the wood may not know which part of the tree a piece of Idigbo he is buying comes from, it will be good if timber merchants will market wood mainly from the outer-heartwood or wood from the inner-heartwood near the top of the tree. This will ensure good faith in the performance of the wood, encourage its use and promote the sale of it.

More work needs to be done on the extractives of _T. ivorensis_ to find out the chemical constituents which impart natural resistance to the outer-heartwood. The water soluble extractives appeared not to increase much the termite resistance of the wood and as already said, it could be that the leachates used were too dilute. Rudman (1959, 1962) found that decay resistance in Eucalyptus is due to both the amount and toxicity of the polyphenolic heartwood extractives, particularly those removed by methanol and, to a lesser extent, those removed in a subsequent extraction by alkali. In the present work, it is also possible that the water soluble toxic materials behave differently "in vivo" and "in vitro".

It is not easy in this study to classify Idigbo according to its termite resistance, that is, if the wood is "Moderately resistant, Resistant or Very resistant." Even if it were possible to do this, such a classification must take into account the significant differences in the termite resistance of the two heartwood zones. In this investigation where the wood had been exposed for 18 months to intensive termite attack, one may rate the outer-heartwood as resistant (overall mean percentage weight loss less than 4%, see Tables 3.16 and 3.19) and the inner-heartwood as not resistant (overall mean percentage weight loss greater than 10%, see Tables 3.16 and 3.19).

Terminalia ivorensis is a wood of the future in Ghana. As the country advances technologically, she will find diverse and sophisticated uses for wood. As a resistant (or at least moderately resistant) wood, the use of T. ivorensis for furniture, cabinet, fittings, panelling and as sleepers in mines will increase. It is also a good wood to use in constructing low cost houses.

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APPENDIX 1

ANALYSES OF VARIANCE OF TERMITE DAMAGE

This appendix contains tables of the results of the analyses of variance of the damage due to termites alone in 18 months. The percentage weight losses were first transformed into angles by the arcsin transformation before being analysed. In the first fifteen Tables all the 8 radial zones in a disc were considered. Tables A1.16 to A1.21 give the analyses of variance of the damage to the sapwood, the outer-heartwood and the inner-heartwood of the two trees. The following symbols were used for significance:

***, $p \leq 0.001$

**, $0.001 < p \leq 0.01$

*, $0.01 < p \leq 0.05$

n.s, $p > 0.05$

TABLE A1.1

The analysis of variance of termite damage to test samples from Tree 1 Disc 1

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Zones	7	1712.8116	244.6874	5.564	***
Plots	7	1195.4637	170.7805	3.883	**
Error	49	2155.0667	43.9810		
Total	63	5063.3420			

TABLE A1.2

The analysis of variance of termite damage to test samples from Tree 2 Disc 1

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Zones	7	7727.5947	1103.9421	7.432	***
Plots	7	2777.9298	396.8471	2.672	*
Error	49	7278.5652	148.5421		
Total	63	17784.0897			

TABLE A1.3

The analysis of variance of termite damage to test samples from Tree 1 Disc 1 and Tree 2 Disc 1

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Tree	1	2895.7952	2895.7952	24.110	***
Zones	7	6264.8492	894.9785	7.452	***
Plots	7	3130.6166	447.2309	3.724	***
Error	112	13451.9659	120.1068		
Total	127	25743.2269			

TABLE A1.4

The analysis of variance of termite damage to test samples from Tree 1 Disc 2

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Zones	7	924.2942	132.0420	2.459	*
Plots	7	1673.5365	239.0766	4.451	***
Error	49	2631.6981	53.7081		
Total	63	5229.5281			

TABLE A1.5

The analysis of variance of termite damage to test samples from Tree 2 Disc 2.

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Zones	7	8096.4980	1156.6426	4.324	***
Plots	7	3730.1488	532.8784	1.992	n.s
Error	49	13108.2999	267.5163		
Total	63	24934.9467			

TABLE A1.6

The analysis of variance of termite damage to test samples from Tree 1 Disc 2 and Tree 2 Disc 2

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Tree	1	1700.3925	1700.3925	9.719	**
Zones	7	6195.0282	885.0040	5.058	***
Plots	7	4374.3556	624.9079	3.572	**
Error	112	19595.0917	174.9562		
Total	127	31864.8680			

TABLE A1.7

The analysis of variance of termite damage to test samples from Tree 1 Disc 3

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Signi-ficance
Zones	7	8028.5626	1146.9375	6.543	***
Plots	7	1036.8228	148.1175	0.845	n.s
Error	49	8589.4050	175.2940		
Total	63	17654.7904			

TABLE A1.8

The analysis of variance of termite damage to test samples from Tree 2 Disc 3

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Signi-ficance
Zones	7	7508.1343	1072.5906	5.978	***
Plots	7	2495.5207	356.5030	1.987	n.s
Error	49	8791.1022	179.4102		
Total	63	18794.7572			

TABLE A1.9

The analysis of variance of termite damage to test samples from Tree 1 Disc 3 and Tree 2 Disc 3

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Signi-ficance
Tree	1	1471.4634	1471.4634	7.040	**
Zones	7	10406.6290	1486.6613	7.113	***
Plots	7	2635.6953	376.5279	1.802	n.s
Error	112	23408.1989	209.0018		
Total	127	37921.9866			

TABLE A1.10

The analysis of variance of termite damage to test samples from Tree 1 Disc 4

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Signi-ficance
Zones	7	2822.1138	403.1591	3.856	**
Plots	7	1854.0022	264.8595	2.533	*
Error	49	5122.9442	104.5499		
Total	63	9799.0602			

TABLE A1.11

The analysis of variance of termite damage to test samples from Tree 2 Disc 4

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Zones	7	6927.2712	989.6102	4.880	***
Plots	7	1964.9058	280.7008	1.384	n.s
Error	49	9936.5319	202.7864		
Total	63	18828.7089			

TABLE A1.12

The analysis of variance of termite damage to test samples from Tree 1 Disc 4 and Tree 2 Disc 4

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Tree	1	2653.4702	2653.4702	16.500	***
Zones	7	7860.5578	1122.9368	6.983	***
Plots	7	2755.7519	393.6788	2.448	*
Error	112	18011.4594	160.8166		
Total	127	31281.2393			

TABLE A1.13

The analysis of variance of termite damage to test samples from Tree 1 Disc 5

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Signi-ficance
Zones	7	6788.8855	969.8408	16.012	***
Plots	7	579.5260	82.7894	1.367	n.s
Error	49	2967.8674	60.5687		
Total	63	10336.2789			

TABLE A1.14

The analysis of variance of termite damage to test samples from Tree 2 Disc 5

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Signi-ficance
Zones	7	1900.7314	271.5331	2.309	*
Plots	7	3450.9782	492.9969	4.192	**
Error	49	5763.2384	117.6171		
Total	63	11114.9480			

TABLE A1.15

The analysis of variance of termite damage to test samples from Tree 1 Disc 5 and Tree 2 Disc 5

Source of variation	Degree of freedom	Sum of squares	Mean square	Variance ratio	Significance
Tree	1	10.8228	10.8228	0.094	n.s
Zones	7	5630.3266	804.3324	6.955	***
Plots	7	2868.6453	409.8065	3.544	**
Error	112	12952.2550	115.6451		
Total	127	21462.0497			

TABLES A1.16-21 give the analyses of variance of the damage to the sapwood, the outer and inner heartwoods in the axial direction of the two trees. The means are back transformed (figure in brackets) after calculation had been based on data subjected to arcsin transformation. Difference between the means of any two discs is compared with the 'Least Significant Difference' (LSD) at the 5% level. If the difference is greater than the LSD, then the means differ significantly (Snedecor and Cochran, 1967).

TABLE A1.16

VARIATION IN TERMITE RESISTANCE OF SAPWOOD ALONG TREE 1

Analysis of variance of termite damage

Source	d.f	S.S	M.S	F	
Discs	4	4536.3257	1134.0814	4.011	*
Plots	7	5844.0608	834.8658	2.953	*
Error	28	7917.0560	282.7520		
Total	39	18297.4425			

DISCS	3	5	4	2	1	LSD
MEAN % WEIGHT LOSS	37.97 (37.90)	33.77 (30.90)	24.56 (17.30)	14.10 (5.90)	10.65 (3.40)	20.13

The analysis of variance shows significant difference between means at 5 per cent level. The sapwood of Disc 1 is significantly more resistant to termite damage than those of Discs 3 and 5 (see Table above).

TABLE A1.17

VARIATION IN TERMITE RESISTANCE OF OUTER-HEARTWOOD ALONG TREE 1

Analysis of variance of termite damage

Source	d.f	S.S	M.S	F	
Discs	4	168.4824	42.121	2.652	n.s
Plots	7	393.8946	56.271	3.544	*
Error	28	444.6447	15.880		
Total	39	1007.0217			

DISCS	2	4	5	3	1	LSD
MEAN % WEIGHT LOSS	7.87 (1.89)	7.59 (1.75)	5.18 (0.82)	4.43 (0.59)	2.37 (0.18)	4.97

Comparison of the differences of pairs of means with the LSD shows the outer-heartwood of Disc 1 to be significantly more resistant to termite damage than the outer-heartwoods of Discs 2 and 4.

TABLE A1.18

VARIATION IN TERMITE RESISTANCE OF INNER-HEARTWOOD ALONG TREE 1

Analysis of variance of termite damage

Source	d.f	S.S	M.S	F	
Discs	4	216.8188	54.2047	1.506	n.s
Plots	7	461.5599	65.9371	1.833	n.s
Error	28	1007.4973	35.9820		
Total	39	1685.8760			

DISCS	3	2	1	4	5	LSD
MEAN %	9.72	9.21	7.42	5.54	3.46	6.58
WEIGHT	(2.84)	(2.56)	(1.66)	(0.92)	(0.37)	
LOSS						

Table A1.18 indicates no significant differences in the termite resistance of the inner-heartwood along the tree.

TABLE A1.19

VARIATION IN TERMITE RESISTANCE OF SAPWOOD ALONG TREE 2

Analysis of variance of termite damage

Source	d.f	S.S	M.S	F	
Discs	4	2835.3505	708.8376	2.158	n.s
Plots	7	6336.6294	905.2328	2.756	*
Error	28	9196.1282	328.4332		
Total	39	18368.1081			

DISCS	4	1	3	2	5	LSD
MEAN % WEIGHT LOSS	35.86 (34.39)	27.73 (21.60)	19.00 (10.60)	16.54 (8.07)	12.46 (4.67)	21.38

Table A1.19 shows the sapwood of Disc 5 to be significantly more resistant to subterranean termite attack than the sapwood of Disc 4.

TABLE A1.20

VARIATION IN TERMITE RESISTANCE OF OUTER-HEARTWOOD ALONG TREE 2

Analysis of variance of termite damage

Source	d.f	S.S	M.S	F	
Discs	4	235.0949	58.7737	2.256	n.s
Plots	7	598.2405	85.4629	3.281	*
Error	28	729.3551	26.0484		
Total	39	1562.6905			

DISCS	2	4	3	1	5	LSD
MEAN % WEIGHT LOSS	9.32 (2.61)	9.06 (2.50)	8.00 (1.94)	6.10 (1.13)	2.76 (0.24)	6.25

Comparison of the differences of pairs of means with the LSD shows the outer heartwood of Disc 5 to be significantly more resistant to termite damage than the outer heartwoods of Discs 2 and 4.

TABLE A1.21

VARIATION IN TERMITE RESISTANCE OF INNER-HEARTWOOD ALONG TREE 2

Analysis of variance of termite damage

Source	d.f	S.S	M.S	F	
Discs	4	879.3745	219.8436	5.000	**
Plots	7	2009.8560	287.1223	6.530	***
Error	28	1231.0961	43.9677		
Total	39	4120.3266			

DISCS	3	2	4	1	5	LSD
MEAN % WEIGHT LOSS	25.40 (18.40)	23.09 (15.39)	22.08 (14.16)	21.05 (12.96)	11.75 (4.18)	9.77

By comparing the differences between pairs of means with the LSD (see TABLE A1.21), it is found that the inner-heartwood of Disc 5 is significantly less susceptible to termite damage than the inner heartwoods of Discs 2,3 and 4.

APPENDIX 2

A brief theory for the determination of Young's modulus of elasticity (E) by cantilever method is presented here. References were made from Tyler (1958) and Worsnop and Flint (1950).

THEORY

Consider a light beam fixed horizontally at one end and loaded with a mass m at the other. If the mass of the beam is small compared with the load m, the whole depression may be taken as due to the load.

Elements above the middle line (or neutral axis) AC are in extension, and those below it are in compression.

In Fig. 6.1A, let AC^1 be the unloaded position for the neutral surface, and AC the position taken when the load is applied at C. Let R be the radius of curvature at B.

To obtain an expression for the depression at a point distant x from A in terms of the dimensions of the bar, m and E, it is convenient to refer to a system of axes with the end A as origin, AC^1 as the x-axis, and a line at right angles to AC^1 from A in the plane of the paper as the y-axis. The curvature of the loaded beam is assumed to be small, that is, the total depression at C is small.

Consider a section at B (Fig. 6.1A), x cm from A A system of forces exists across the face of this section causing extensions above the neutral axis and compression below it in the segment BC. These forces constitute a counter-clockwise couple

$M = \frac{IE}{R}$ on BC, where I is the moment of innertia of cross section of beam about the neutral axis. The force mg at C has a clock-wise moment equal to mg(L-x) on BC.

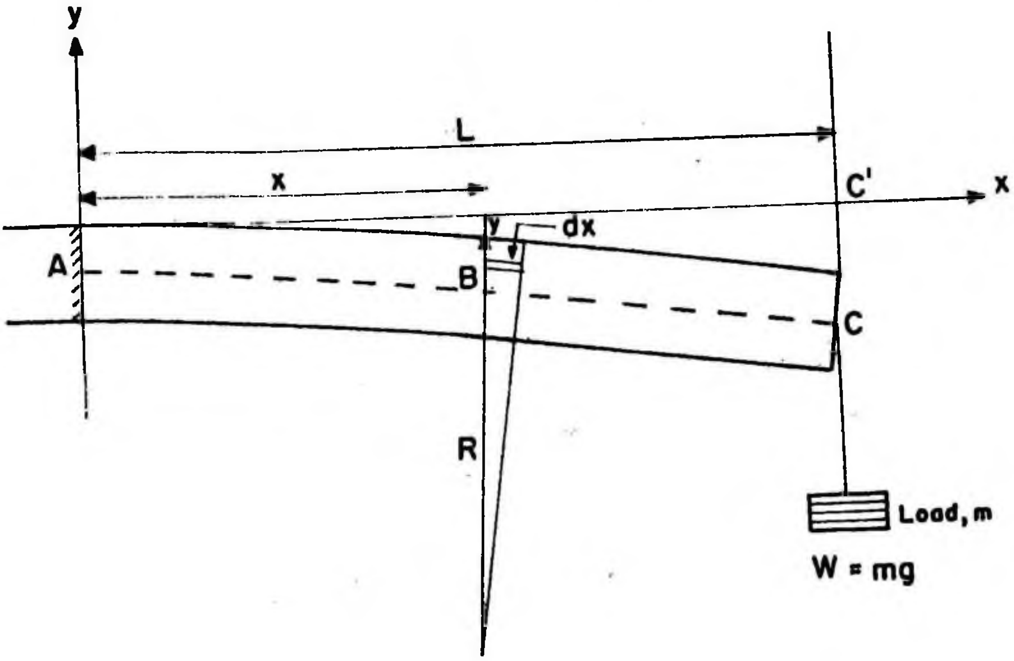

FIG. 6.1 A SCHEMATIC REPRESENTATION OF A TEST SAMPLE WHEN LOADED.

For equilibrium, these two opposite couples are equal in magnitude. That is,

$$\frac{IE}{R} = mg\ (L - x) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad I$$

But

$$R = \frac{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}{\frac{d^2y}{dx^2}}$$

Since the total depression is assumed to be small, dy/dx is small so that $(dy/dx)^2$ is negligible compared with unity.

$$\therefore \quad R = 1/d^2y/dx^2$$

substituting for R in equation I,

$$\frac{d^2y}{dx^2} = \frac{mg}{IE}(L - x) = \frac{W}{IE}(L - x), \text{ where } W = mg$$

Integrating, we have

$$\int \frac{d^2y}{dx^2} \cdot dx = \frac{W}{EI} \int (L - x)\ dx + C$$

where C is a constant of integration.

$$\text{when } x = 0, \ \frac{dy}{dx} = 0$$

$$\therefore C = 0$$

$$\text{Hence } \frac{dy}{dx} = \frac{W}{IE}\left[Lx = \tfrac{1}{2}x^2\right]$$

Integrating again to obtain the depression at a point Xo from A, we have

$$\int_0^y \frac{dy}{dx} \cdot dx = \frac{W}{EI} \int_0^{Xo} (Lx - \tfrac{1}{2}x^2)\ dx$$

$$\therefore\ y = \frac{W}{EI}\left[\frac{LXo^2}{2} - \frac{Xo^3}{6}\right] \quad \ldots\ldots\ldots\ldots\ldots\ \text{II}$$

In these tests, L and Xo were fixed. Only W was varied and the corresponding y measured. Equation II therefore shows that for small deflections, y is directly proportional to W.

Hence a graph of y against W should yield a straight line of slope equal to $1/EI\left(\frac{LXo^2}{2} - \frac{Xo^3}{6}\right)$

The slope of the line is obtained from the linear regression equation of y on W, i.e. $y = ao + bW$.

The regression coefficient $b = \frac{1}{EI}\left[\frac{LXo^2}{2} - \frac{Xo^3}{6}\right]$

ao is the end correction to the deflection y. The parameters ao and b are determined by solving simultaneously the normal equations

$$\begin{aligned} \sum y &= Nao + b\sum W \\ \sum Wy &= ao\sum W + b\sum W^2 \end{aligned} \qquad (N = \text{number of } (y,W) \text{ pairs})$$

The correlation between y and W is given by the correlation coefficient,

$$r = \frac{N\sum Wy - \sum W \sum y}{\left\{\left[N\sum W^2 - (\sum W)^2\right]\left[N\sum y^2 - (\sum y)^2\right]\right\}^{\frac{1}{2}}}$$

For a rectangular beam, the moment of inertia, I, about the neutral axis is

$I = \frac{wt^3}{12}$, where w is the width and t the thickness of the beam.

From the equation

$$b = \frac{1}{EI}\left[\frac{LXo^2}{2} - \frac{Xo^3}{6}\right]$$

$$E = \frac{12}{wt^3}\left[\frac{LXo^2}{2} - \frac{Xo^3}{6}\right]$$

Putting L = 8.0cm, Xo = 6.0cm, $g = 9.80\text{ms}^{-2}$ and W = mg,

$$E = \frac{5000.315328 \times 10^8}{b \times w \times t^3} \quad \text{Nm}^{-2}$$

w and t are in mm.

A computer programme for computing ao, b, r and E is given in Appendix 3. In the programme the parameters ao, b, r and E are denoted as follows:

ao = A
b = B
r = R
E = E

APPENDIX 3

COMPUTER PROGRAMME TO COMPUTE THE VALUES REQUIRED IN ESTIMATING YOUNG'S MODULUS OF ELASTICITY (SEE APPENDIX 2)

```
      DIMENSION  NAME(16,4),X(16,5),Y(16,5),THICK(16),WIDTH(16)
  999 WRITE(5,14)
      READ(2,73)N
      WRITE(5,15)
      DO 8  J=1,N
      READ (2,10) (NAME(J,I),I=1,4)
   10 FORMAT(4A1)
      READ (2,11) (X(J,I),I=1,5)
11    FORMAT(F8.0,4F9.0)
      READ (2,12) (Y(J,I),I=1,5)
12    FORMAT(F8.0,4F9.0)
      READ(2,13) THICK(J),WIDTH(J)
13    FORMAT(2F9.0)
    8 CONTINUE
      DO 9  J=1,N
      WRITE(5,16) (NAME(J,I),I=1,4),THICK(J),WIDTH(J),(X(J,I),I=1,5),(Y(
     1J,I),I=1,5)
    9 CONTINUE
      WRITE(5,27)
      A1=5.
      DO 3  I=1,N
      SUMX=0
      SUMY=0
      SUMXY=0
      SUMX2=0
      SUMY2=0
      DO 4  J=1,5
      SUMX=SUMX+X(I,J)
      SUMY=SUMY+Y(I,J)
      SUMXY=SUMXY+X(I,J)*Y(I,J)
      SUMX2=SUMX2+X(I,J)**2
      SUMY2=SUMY2+Y(I,J)**2
    4 CONTINUE
      R=(A1*SUMXY-SUMX*SUMY)/SQRT((A1*SUMX2-SUMX**2)*(A1*SUMY2-SUMY**2))
      B=(A1*SUMXY-SUMX*SUMY)/(A1*SUMX2-SUMX**2)
      A=SUMY/A1-B*SUMX/A1
      E=500.0135*10.0**9/(B*WIDTH(I)*THICK(I)**3)
      WRITE(5,30) (NAME(I,L),L=1,4),A,B,R,E
    3 CONTINUE
   16 FORMAT(1X4A1,2F8.3,5F5.0,4X,5F6.1/)
   14 FORMAT('1',34X,'I N P U T    D A T A'/)
   15 FORMAT(60H NAME    THICK    WIDTH X(1) X(2) X(3) X(4) X(5)       Y(1)
     1  Y(2)  Y(3)  Y(4)  Y(5)/)
   30 FORMAT(1X4A1,1X3F15.5,F20.5)
   27 FORMAT(66H NAME              A-VALUE          B-VALUE          R-VALUE
     1   E-VALUE/)
   73 FORMAT(I2)
      GO TO 999
      END
```

APPENDIX 4

The relationship between specific gravity of a sample and its position in the wood at a given height was examined. It was found that parabolic equations approximated the relation between specific gravity (S) and the radial position (Z) of the sample. The parabolic relations were of the form

$$S = ao + a_1 Z + a_2 Z^2$$

where ao, a_1 and a_2 were constants determined by solving simultaneously the normal equations

$$\sum S = Nao + a_1 \sum Z + a_2 \sum Z^2$$

$$\sum ZS = ao \sum Z + a_1 \sum Z^2 + a_2 \sum Z^3$$

$$\sum Z^2 S = ao \sum Z^2 + a_1 \sum Z^3 + a_2 \sum Z^4$$

N = number of (S, Z) pairs

Examination of polynomials in higher powers of Z showed that the coefficients of powers of Z greater than 2 were significant only at $p > 0.1$. The values of ao, a_1 and a_2 are given in TABLES 4.1 to 4.5 and were significant at $0.001 < p < 0.01$.

APPENDIX 5

This Appendix gives Tables of Matrices of correlation coefficients between the termite damage (W) and the specific gravity (S), the modulus of elasticity (E) and the total cross-sectional area of the vessels assumed to be proportional to ND^2 where N was the number of vessels per unit area and D was the mean maximum tangential diameter.

TABLE A5.1

Matrix of correlation coefficients of Tree 1 Disc 1

	W	S	E	ND^2
W	1.000	-0.321	-0.431	-0.759
S	-0.321	1.000	0.282	0.029
E	-0.431	0.282	1.000	0.428
ND^2	-0.759	0.029	0.428	1.000

TABLE A5.2

Matrix of correlation coefficients of Tree 1 Disc 2

	W	S	E	ND^2
W	1.000	-0.478	-0.344	-0.512
S	-0.478	1.000	-0.406	0.514
E	-0.344	-0.406	1.000	0.507
ND^2	-0.512	0.514	0.507	1.000

TABLE A5.3

Matrix of correlation coefficients of Tree 1 Disc 3

	W	S	E	ND^2
W	1.000	-0.199	-0.594	0.976
S	-0.199	1.000	0.278	0.274
E	-0.594	0.278	1.000	-0.554
ND^2	0.976	0.274	-0.554	1.000

TABLE A5.4

Matrix of correlation coefficients of Tree 1 Disc 4

	W	S	E	ND^2
W	1.000	-0.052	0.992	0.985
S	-0.052	1.000	-0.242	-0.071
E	0.992	-0.242	1.000	-0.756
ND^2	0.985	-0.071	-0.756	1.000

TABLE A5.5

Matrix of correlation coefficient of Tree 1 Disc 5

	W	S	E	ND^2
W	1.000	-0.248	-0.231	-0.100
S	-0.248	1.000	-0.686	-0.526
E	-0.231	-0.686	1.000	0.407
ND^2	-0.100	-0.526	0.407	1.000

TABLE A5.6

Matrix of correlation coefficients of Tree 2 Disc 1

	W	S	E	ND^2
W	1.000	-0.585	0.689	0.613
S	-0.585	1.000	0.573	0.858
E	0.689	0.573	1.000	0.722
ND^2	0.613	0.858	0.722	1.000

TABLE A5.7

Matrix of correlation coefficients of Tree 2 Disc 2

	W	S	E	ND^2
W	1.000	-0.621	0.911	0.671
S	-0.621	1.000	0.416	0.765
E	0.911	0.416	1.000	0.795
ND^2	0.671	0.765	0.795	1.000

TABLE A5.8

Matrix of correlation coefficients of Tree 2 Disc 3

	W	S	E	ND^2
W	1.000	-0.853	0.551	0.123
S	-0.853	1.000	0.377	0.023
E	0.551	0.377	1.000	-0.369
ND^2	0.123	0.023	-0.369	1.000

TABLE A5.9

Matrix of correlation coefficients of Tree 2 Disc 4

	W	S	E	ND^2
W	1.000	-0.614	0.689	0.345
S	-0.614	1.000	-0.529	-0.072
E	0.689	-0.529	1.000	0.136
ND^2	0.345	-0.072	0.136	1.000

TABLE A5.10

Matrix of correlation coefficients of Tree 2 Disc 5

	W	S	E	ND^2
W	1.000	-0.711	0.789	0.586
S	-0.711	1.000	0.742	0.506
E	0.789	0.742	1.000	0.331
ND^2	0.586	0.506	0.331	1.000

APPENDIX 6

This appendix gives the list of termites found damaging or in association with baits of *Triplochiton scleroxylon* during the study of the termite fauna and their distribution on the Fumesua Test Site. The termites found damaging the test blocks of *Terminalia ivorensis* in the present work are indicated with asterik (*) against each. The nomenclature follows Snyder(1949) for most groups though the subfamily Nasutitermitinae follows Sands(1965). *Macrotermes* follows Ruelle(1970) and *Ancistrotermes* follows Harris(1966). The termites are arranged in alphabetical order within sub-families.

Family, subfamily and species

Rhinotermitidae
    Coptotermitinae
    Coptotermes intermedius Silvestri*
    C. sjöstedti Holmgren
Rhinotermitinae
    Schedorhinotermes putorius Sjöstedt

Termitidae
    Amitermitinae
    Amitermes evuncifer Silvestri*
    Amenteotermes polyscolus Sands
    Astalotermes quietus (Silvestri)
    Cephalotermes rectangularis (Sjöstedt)
    Microcerotermes brachygnathus Silvestri
    M. fuscotibialis Sjöstedt
    Sp. A (near *Labidotermes*)

Termitinae
    Allognathotermes hypogeus Silvestri
    Basidentitermes mactus (Sjöstedt)

Cubitermes subcrenulatus Silvestri
Euchilotermes tensus Silvestri
Ophiotermes grandilabius (Emerson)
Pericapritermes urgens Silvestri
Procubitermes aburiensis (Sjöstedt)
Thoracotermes macrothorax (Sjöstedt)

Macrotermitinae
Ancistrotermes cavithorax (Sjöstedt)
A. crucifer (Sjöstedt)*
A. guineensis (Silvestri)*
Ancistrotermes sp.
Macrotermes bellicosus (Smeathman)*
M. subhyalinus (Rambur)*
Macrotermes sp.
Microtermes subhyalinus Silvestri
Odontotermes fidens (Sjöstedt)
O. pauperans (Silvestri)*
Pseudacanthotermes militaris (Hagen)*

Nasutitermitinae
Leptomyxotermes doriae (Silvestri)
Nasutitermes arborum (Smeathman)
N. elegantulus (Sjöstedt)
N. latifrons (Sjöstedt)
N. lujae (Wasmann)

APPENDIX 7

The initial weights of the samples and the weights after 6, 12 and 18 months exposure to subterranean termites are presented in this Appendix.

The data on the fungal decay are also given here.

PLOT 1

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	62.37	61.25	59.97	58.61
112	46.06	44.47	43.53	42.82
113	63.47	63.14	62.79	61.98
114	52.95	52.69	51.88	50.03
115	54.66	54.49	54.13	53.18
116	62.80	62.41	61.73	60.73
117	53.61	52.96	52.67	51.64
118	57.26	56.88	54.58	49.59
121	58.70	51.25	48.16	36.71
122	55.97	55.45	55.11	52.95
123	69.86	69.75	69.44	66.93
124	68.97	68.65	68.27	66.94
125	66.68	66.39	66.04	65.08
126	62.31	62.09	58.42	57.10
127	54.48	54.13	53.69	52.73
128	59.77	59.55	57.53	53.02
131	63.33	54.11	52.61	0.00
132	68.67	68.49	67.95	65.93
133	70.53	69.79	69.50	66.61
134	71.58	71.25	70.94	70.00
135	65.70	65.38	64.95	63.54
136	66.47	66.17	65.70	65.16

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
137	58.79	58.50	57.09	55.76
138	68.09	67.62	66.85	62.85
141	67.26	52.36	50.81	17.82
142	67.02	66.56	64.94	60.85
143	57.55	57.25	56.83	55.89
144	72.61	71.98	71.61	70.26
145	50.76	50.33	49.23	48.20
146	65.55	65.27	64.83	62.78
147	60.80	60.42	59.01	57.75
148	57.09	56.51	56.31	55.73
151	72.14	70.16	66.46	53.33
152	64.60	63.94	62.68	58.78
153	66.84	66.64	66.42	65.46
154	66.99	66.45	65.83	64.51
155	69.42	68.88	68.43	67.28
156	78.80	77.92	77.33	76.28
157	86.66	85.54	84.77	83.60
158	55.44	55.22	54.80	52.99
211	66.00	65.09	64.75	61.45
212	61.65	61.42	60.23	56.82
213	63.29	63.06	62.32	60.03
214	56.81	56.56	55.30	52.97
215	52.87	52.33	51.13	48.92
216	61.77	61.32	60.42	58.69
217	49.55	49.03	46.65	40.68
218	47.76	47.31	44.94	40.38
221	59.41	58.44	56.05	52.49
222	60.91	60.67	59.89	58.69
223	58.06	57.90	57.43	55.16

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
224	60.30	60.16	59.31	57.73
225	51.73	51.62	50.74	49.94
226	57.31	57.14	56.16	54.53
227	62.91	62.59	61.30	59.85
228	51.18	50.94	17.68	Eliminated
231	61.13	60.88	59.97	58.43
232	61.50	61.38	60.92	59.35
233	59.83	59.60	58.65	55.45
234	60.93	60.70	59.95	58.72
235	55.88	55.41	53.70	50.99
236	56.37	56.17	52.87	47.52
237	50.75	50.45	47.49	41.43
238	51.54	51.14	42.24	36.14
241	66.12	62.50	60.15	51.90
242	71.27	70.69	69.77	68.91
243	79.31	78.89	78.40	77.26
244	66.15	66.01	62.31	60.88
245	64.09	63.51	62.98	61.86
246	58.83	58.46	54.70	46.35
247	56.78	56.08	54.42	40.58
248	52.26	51.87	50.77	48.91
251	76.19	75.14	74.16	72.28
252	69.19	69.19	68.95	67.68
253	67.10	66.96	66.15	64.99
254	64.95	64.47	63.22	61.94
255	62.86	62.55	62.11	61.13
256	64.62	64.21	63.77	62.23
257	63.14	62.79	62.08	59.52
258	67.76	67.53	66.34	64.46

PLOT 2

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	66.82	65.50	62.56	56.82
112	64.64	64.38	62.42	57.64
113	69.02	68.90	68.69	64.74
114	45.23	45.12	44.27	42.14
115	62.43	62.32	61.97	58.42
116	63.82	63.53	62.01	58.91
117	43.16	42.96	41.26	37.35
118	58.14	57.39	54.00	50.39
121	50.23	48.53	44.63	35.58
122	69.51	69.32	68.09	66.56
123	66.71	66.71	65.87	62.20
124	68.97	68.97	67.80	64.97
125	66.67	66.64	65.84	63.82
126	62.60	62.28	61.80	58.37
127	51.99	51.99	51.25	41.40
128	49.23	49.00	48.07	40.64
131	66.53	62.67	57.82	47.57
132	68.22	67.77	67.53	62.78
133	71.75	71.55	71.26	64.09
134	71.58	71.36	70.50	68.38
135	65.65	65.48	60.57	57.39
136	64.65	64.64	62.85	55.82
137	57.70	57.53	55.40	49.63
138	54.55	54.28	53.21	39.64
141	64.88	63.45	58.42	33.50
142	76.15	74.73	72.88	67.26
143	59.35	59.11	58.64	54.49
144	64.59	62.05	55.92	46.10

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
145	65.72	65.67	65.55	59.03
146	50.60	50.42	46.87	41.75
147	60.60	60.31	59.47	54.78
148	61.04	60.89	59.29	55.63
151	77.30	69.93	66.24	53.14
152	67.61	67.27	66.13	63.96
153	63.15	62.93	62.57	59.94
154	68.19	68.02	67.62	62.88
155	50.18	50.00	49.37	46.09
156	54.35	54.09	53.71	51.53
157	59.52	59.32	57.60	48.23
158	67.90	67.61	66.78	63.03
211	92.28	89.43	88.18	83.03
212	73.70	73.21	72.08	68.93
213	65.17	65.17	64.09	59.29
214	63.62	63.42	62.13	58.16
215	54.10	53.82	52.96	33.63
216	57.13	56.92	55.18	47.41
217	44.97	44.97	16.73	Eliminated
218	54.08	53.69	50.86	37.86
221	65.06	64.52	62.70	58.92
222	69.59	69.47	68.21	61.07
223	64.16	64.14	63.41	60.38
224	61.12	61.12	60.10	53.24
225	51.91	51.91	51.77	45.51
226	53.42	53.21	51.52	46.75
227	62.47	62.44	60.65	55.78
228	54.09	53.87	43.27	2.63

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
231	61.50	60.71	52.00	37.83
232	63.83	63.36	61.51	55.92
233	57.27	57.22	55.76	53.31
234	55.62	55.44	54.44	50.09
235	62.03	61.61	61.08	53.64
236	57.69	57.59	3.52	0.71
237	51.83	51.67	47.50	39.40
238	50.64	50.27	48.83	30.67
241	69.30	66.99	63.34	56.72
242	69.54	69.16	69.13	64.53
243	63.95	63.22	62.77	57.21
244	68.37	67.69	67.09	62.26
245	64.41	64.41	63.98	59.61
246	60.91	60.01	52.90	21.09
247	66.04	65.90	64.28	62.22
248	59.22	58.48	51.29	30.77
251	66.26	64.95	60.82	47.99
252	85.03	84.78	84.61	82.22
253	92.63	92.12	90.41	86.57
254	72.44	72.44	70.84	67.35
255	71.05	70.86	70.39	67.61
256	70.25	69.89	69.05	64.59
257	68.92	68.72	68.60	65.99
258	70.95	68.92	60.95	19.63

PLOT 3

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	79.47	76.58	75.52	63.16
112	58.77	58.12	57.38	54.35
113	62.77	62.20	62.01	60.47
114	65.38	64.81	64.43	62.99
115	60.19	59.35	47.90	44.44
116	54.83	54.01	53.49	52.08
117	57.44	56.73	54.54	52.54
118	61.93	59.67	58.85	34.74
121	68.75	65.82	58.56	53.04
122	62.81	61.72	60.55	47.88
123	68.82	67.68	67.26	63.65
124	68.76	67.53	67.11	63.55
125	66.48	65.34	64.30	53.67
126	63.44	61.00	60.58	45.72
127	50.22	49.08	47.23	41.13
128	55.93	54.76	53.76	38.04
131	70.70	67.79	66.10	0.00
132	74.57	73.07	73.00	69.99
133	71.11	70.10	68.20	67.87
134	66.76	65.84	65.45	63.43
135	70.16	69.17	67.39	65.70
136	71.21	69.43	66.58	64.61
137	83.77	82.09	80.96	78.40
138	54.27	53.36	50.23	47.66
141	68.79	66.31	63.02	61.60
142	74.34	72.28	70.41	67.68
143	76.07	74.74	72.67	67.80
144	76.46	75.27	73.67	73.48

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
145	78.28	77.29	75.60	74.66
146	52.92	52.09	51.90	49.39
147	64.29	62.90	62.07	59.85
148	54.63	53.53	53.18	49.93
151	67.00	63.24	59.92	24.91
152	71.23	69.53	66.74	49.32
153	64.43	63.00	62.72	59.93
154	74.89	73.52	71.30	71.23
155	71.61	70.23	69.78	67.41
156	69.76	68.34	66.67	65.74
157	54.30	52.10	50.37	47.09
158	69.33	67.96	66.62	66.25
211	59.16	58.14	56.60	43.81
212	82.63	81.44	78.86	78.49
213	60.98	59.74	57.86	56.89
214	61.29	60.16	58.53	56.96
215	63.02	61.94	61.52	58.03
216	48.60	46.96	44.04	37.75
217	57.28	56.52	54.57	48.46
218	50.09	49.12	44.16	33.34
221	61.19	59.15	52.45	12.66
222	59.18	58.28	57.33	56.21
223	63.48	62.82	61.65	16.88
224	64.56	63.94	60.33	57.97
225	63.59	62.62	48.54	41.87
226	54.10	53.27	52.04	49.92
227	58.19	57.26	55.46	48.36
228	56.34	55.15	53.95	46.92

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
231	63.97	61.43	58.77	54.62
232	65.46	64.50	63.31	60.93
233	57.37	56.48	48.44	40.70
234	55.27	54.45	53.52	50.65
235	60.76	59.69	56.56	51.68
236	61.97	60.99	60.48	58.52
237	50.33	49.34	48.57	38.58
238	56.21	54.90	51.12	33.00
241	67.09	38.69	34.82	12.75
242	69.12	67.95	66.01	63.80
243	72.02	70.30	68.38	68.35
244	74.82	72.77	71.00	70.70
245	66.72	65.55	65.09	57.51
246	63.10	61.21	54.42	48.50
247	54.20	53.05	50.80	38.42
248	58.72	57.13	56.47	49.23
251	78.44	76.64	74.90	74.23
252	69.77	68.62	67.25	66.04
253	63.99	62.76	61.57	61.50
254	64.93	63.36	62.31	60.18
255	69.65	68.25	66.65	50.97
256	67.20	65.64	64.81	58.85
257	72.63	71.25	66.10	64.67
258	72.00	70.71	68.37	65.47

PLOT 4

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	66.45	65.00	63.29	61.15
112	69.04	68.06	67.65	66.33
113	62.36	62.16	60.94	59.73
114	48.28	48.04	47.31	46.78
115	67.78	67.55	65.77	60.73
116	60.16	59.61	58.30	55.92
117	61.98	61.24	58.70	56.51
118	50.37	49.80	48.71	46.09
121	67.12	66.24	64.97	58.37
122	68.23	67.93	67.14	65.94
123	63.14	62.69	62.22	59.27
124	65.54	65.14	64.34	63.29
125	65.07	64.94	63.82	62.37
126	62.54	62.38	61.39	58.06
127	61.46	60.99	60.25	58.78
128	56.29	56.08	54.84	53.54
131	67.44	65.68	62.99	52.79
132	66.95	66.42	66.37	64.88
133	75.45	75.19	74.20	72.24
134	68.75	68.63	68.00	66.69
135	66.93	66.86	65.80	64.42
136	38.73	38.49	37.81	36.18
137	65.22	64.63	62.36	60.45
138	54.16	53.58	53.02	45.44
141	51.43	49.72	46.38	39.91
142	53.39	52.71	52.16	50.70
143	74.94	74.28	73.87	72.42
144	67.38	66.95	66.66	65.29
145	72.52	71.91	71.12	64.98

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
146	50.27	49.50	48.89	47.91
147	62.66	62.14	60.69	59.03
148	60.42	59.62	59.22	57.98
151	71.82	69.45	64.10	31.30
152	69.85	69.40	68.54	67.13
153	61.01	60.29	59.24	57.97
154	63.25	63.09	62.61	61.52
155	72.01	71.26	70.86	69.12
156	73.38	72.71	72.24	70.91
157	66.00	65.85	64.15	63.35
158	63.35	63.20	62.59	61.32
211	63.57	61.76	59.61	26.35
212	66.37	65.66	63.93	62.07
213	63.44	63.02	62.10	61.50
214	59.33	59.21	58.25	56.22
215	60.18	59.90	59.06	58.08
216	47.74	46.94	42.91	36.51
217	49.34	49.17	43.91	25.83
218	56.32	55.74	54.17	52.45
221	62.97	61.94	60.62	54.95
222	61.32	60.99	60.50	58.33
223	61.93	61.80	60.34	59.44
224	60.38	60.06	58.06	56.43
225	62.07	61.81	59.40	57.75
226	64.83	64.44	62.64	60.84
227	54.18	54.13	53.12	48.78
228	54.46	52.80	50.58	18.62
231	61.30	60.46	59.75	56.64
232	61.33	61.13	60.55	57.67

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
233	59.45	59.26	58.43	56.97
234	59.46	59.14	58.61	56.84
235	57.13	56.62	55.71	54.46
236	57.13	56.87	54.40	49.56
237	52.15	51.85	49.03	45.16
238	52.53	51.47	25.19	4.74
241	47.99	33.56	0.00	0.00
242	68.70	68.14	67.44	65.49
243	69.01	68.73	67.78	64.74
244	70.06	68.82	68.40	61.14
245	67.87	67.35	65.34	62.08
246	61.22	60.71	57.95	38.40
247	63.66	62.83	60.25	49.28
248	62.83	62.32	60.43	56.41
251	60.27	59.08	57.74	53.31
252	66.89	66.27	65.99	64.64
253	57.54	57.00	56.35	55.08
254	66.59	65.91	64.76	63.31
255	68.34	68.05	67.04	65.43
256	69.00	68.45	67.96	66.40
257	62.87	62.44	61.50	59.72
258	72.41	71.96	70.32	67.53

PLOT 5

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	66.93	65.09	62.91	59.80
112	46.62	46.04	45.30	44.38
113	64.24	63.75	62.01	60.83
114	64.00	63.29	60.80	58.38
115	63.64	63.73	61.97	59.45
116	62.70	62.42	61.04	59.13
117	43.01	41.84	40.24	39.51
118	60.90	60.54	59.64	56.48
121	64.32	63.02	61.02	57.39
122	69.45	69.20	68.87	63.68
123	68.89	68.67	68.11	66.45
124	66.38	65.65	65,47	63.61
125	66.15	66.20	64.97	58.97
126	56.02	56.21	54.87	45.57
127	58.58	58.78	57.32	56.22
128	59.07	58.65	54.30	52.59
131	66.72	64.68	60.69	58.08
132	48.32	47.76	47.20	44.45
133	70.73	70.60	70.34	68.84
134	68.65	68.69	67.37	66.89
135	69.66	69.52	68.45	67.37
136	80.92	80.55	79.43	77.85
137	80.31	79.90	79.46	77.38
138	76.91	76.42	75.33	73.81
141	66.60	65.05	63.04	58.43
142	54.36	54.11	53.54	51.68
143	69.05	69.13	67.60	66.90
144	65.72	65.20	64.34	62.69

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
145	71.99	71.73	70.32	69.58
146	52.71	52.61	50.54	49.69
147	49.68	49.28	48.51	47.53
148	28.87	28.73	27.10	24.91
151	58.03	56.59	54.63	36.43
152	76.21	75.67	75.16	73.16
153	64.45	63.97	63.21	62.57
154	73.89	73.87	71.77	69.95
155	71.66	71.08	70.57	68.68
156	70.49	70.16	68.16	66.24
157	56.53	56.12	54.91	53.02
158	71.50	71.12	68.00	66.56
211	65.83	64.31	57.77	56.13
212	64.04	63.71	63.13	61.91
213	63.98	63.81	63.05	61.32
214	58.12	57.68	53.42	52.02
215	59.60	59.30	58.25	56.94
216	52.59	52.37	50.65	48.78
217	44.50	44.40	41.87	35.43
218	40.99	40.40	35.30	33.36
221	63.75	62.63	59.61	57.64
222	59.92	59.57	58.97	57.85
223	62.17	62.03	56.75	55.95
224	56.78	56.48	52.47	51.63
225	55.53	55.57	54.50	52.44
226	59.96	59.97	59.23	57.57
227	51.79	51.29	48.33	47.66
228	62.28	61.84	60.80	59.67

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
231	62.18	61.09	56.59	54.33
232	63.25	63.15	61.75	59.06
233	54.95	54.87	54.11	52.17
234	59.66	59.27	57.35	56.56
235	61.50	61.14	59.93	57.28
236	56.10	55.72	50.10	49.37
237	50.13	49.82	41.67	39.50
238	52.83	52.40	46.60	42.46
241	73.28	71.68	70.61	59.69
242	70.22	69.86	68.04	65.27
243	69.70	69.29	67.18	65.83
244	65.44	65.16	63.67	62.13
245	64.25	63.91	62.06	60.00
246	62.88	62.30	61.60	56.14
247	56.50	55.64	31.80	30.60
248	51.91	51.42	49.08	46.81
251	64.96	63.34	56.47	53.13
252	47.74	47.41	47.38	45.86
253	67.75	67.19	66.12	64.28
254	69.55	68.77	67.96	66.28
255	67.05	66.91	66.87	66.30
256	71.18	70.70	70.11	67.43
257	66.99	66.26	63.72	63.23
258	68.26	67.75	66.62	64.05

PLOT 6

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	79.49	77.94	76.30	35.17
112	63.97	63.63	62.62	56.00
113	71.02	71.07	70.02	67.79
114	54.95	54.61	53.65	49.48
115	65.65	65.23	62.83	60.88
116	56.26	55.96	50.80	46.94
117	50.56	50.24	45.58	43.84
118	61.55	61.44	58.74	52.73
121	63.59	62.91	60.38	52.98
122	57.29	57.25	56.50	54.20
123	69.71	69.54	67.90	63.77
124	68.55	68.40	66.74	62.76
125	66.40	66.40	66.04	62.14
126	61.41	61.51	60.93	58.59
127	58.17	58.21	57.44	55.18
128	60.17	60.22	57.29	45.14
131	64.09	62.58	60.91	33.51
132	73.23	73.09	72.38	68.11
133	68.92	68.60	67.45	63.92
134	68.87	68.82	67.21	63.34
135	68.26	68.00	65.80	62.62
136	84.62	84.38	83.91	79.23
137	58.86	58.19	55.69	38.88
138	57.35	57.04	42.55	34.30
141	57.14	57.10	53.64	9.47
142	52.59	52.28	51.97	47.05
143	53.28	53.21	52.43	45.36
144	55.69	55.69	54.37	51.67

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
145	64.99	65.14	63.64	59.87
146	66.17	66.10	63.53	56.35
147	50.86	50.73	48.74	44.94
148	59.95	59.13	52.66	48.13
151	72.95	70.98	59.79	22.18
152	67.93	67.35	66.17	63.93
153	60.25	59.69	58.66	55.98
154	58.81	58.42	57.13	53.35
155	85.83	85.17	84.36	81.64
156	76.39	75.16	74.59	72.18
157	60.47	60.65	59.40	56.99
158	66.67	66.76	66.26	62.26
211	64.27	62.76	57.87	22.61
212	63.10	63.22	62.50	58.02
213	62.92	63.22	62.66	60.33
214	61.28	61.43	59.58	51.80
215	62.21	62.12	52.11	47.32
216	59.66	59.66	45.97	36.04
217	44.33	43.98	39.49	20.23
218	59.76	59.53	48.36	40.14
221	61.11	60.23	58.13	49.54
222	59.62	59.67	58.73	53.86
223	61.54	61.47	60.28	57.05
224	57.51	57.47	54.75	49.27
225	62.89	62.80	53.73	43.36
226	60.12	60.26	54.67	51.40
227	55.41	55.46	38.37	3.07
228	48.47	48.36	45.54	16.54

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
231	61.56	60.98	58.87	30.77
232	60.81	60.75	59.62	53.52
233	60.58	60.59	59.13	46.95
234	59.55	59.60	57.26	49.50
235	59.95	59.67	58.20	51.54
236	60.52	60.33	56.43	49.84
237	55.68	55.05	51.63	27.18
238	60.14	59.85	58.71	53.02
241	70.38	69.06	63.40	14.23
242	66.39	66.22	65.14	58.07
243	63.86	63.62	62.06	52.47
244	68.83	68.55	64.68	59.80
245	66.57	66.18	63.75	61.26
246	60.67	60.34	53.10	44.89
247	61.96	61.66	33.32	27.70
248	59.86	59.39	55.50	47.64
251	62.33	60.34	46.81	13.67
252	69.15	68.97	67.90	62.83
253	67.26	67.11	65.60	62.99
254	65.03	64.86	62.70	60.06
255	66.92	66.78	49.25	47.78
256	59.73	59.41	59.03	57.18
257	57.71	56.81	46.40	22.01
258	70.49	70.33	47.80	44.63

PLOT 7

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	66.96	66.00	64.54	58.25
112	51.01	50.65	49.76	48.96
113	71.77	70.91	70.56	68.70
114	63.44	62.98	62.00	58.66
115	53.68	53.40	51.87	46.91
116	63.47	63.13	62.56	58.06
117	39.82	39.50	37.20	35.59
118	50.61	50.06	47.99	36.93
121	65.30	64.80	62.93	54.92
122	70.17	69.99	69.41	66.83
123	68.78	68.37	67.10	64.76
124	64.62	64.62	61.92	54.95
125	55.30	55.16	52.24	50.45
126	60.67	60.13	58.85	54.91
127	64.07	63.70	62.91	58.88
128	56.74	56.23	54.72	45.55
131	60.12	58.98	54.95	49.40
132	68.89	68.28	67.81	66.21
133	71.30	70.92	69.87	67.56
134	69.41	69.02	66.88	65.18
135	65.41	64.87	63.55	61.15
136	59.49	58.93	49.12	44.99
137	59.71	59.29	58.50	54.26
138	71.44	70.93	69.04	63.14
141	71.88	70.24	68.82	63.81
142	70,20	69.81	69.02	66.30
143	78.25	77.37	76.74	74.50
144	71.16	70.64	70.01	64.78

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
145	70.04	69.37	68.90	66.31
146	64.65	63.78	61.89	59.38
147	34.11	33.68	29.95	27.05
148	47.33	46.81	46.40	41.77
151	70.36	68.33	64.23	58.63
152	55.44	54.43	52.19	43.42
153	40.61	39.78	37.63	35.04
154	55.42	54.86	54.66	52.71
155	76.87	76.12	75.67	73.87
156	53.38	52.61	51.72	50.44
157	45.00	44.51	43.35	41.05
158	68.21	67.32	66.44	62.99
211	65.74	63.75	47.93	25.32
212	65.78	65.51	64.03	62.37
213	54.53	54.37	53.78	51.90
214	64.46	64.26	63.32	61.58
215	59.77	59.61	58.47	55.88
216	58.90	58.61	56.73	53.79
217	45.11	44.88	29.75	13.99
218	41.89	41.33	32.07	12.49
221	58.36	57.35	54.95	47.45
222	63.26	62.92	62.52	57.20
223	63.68	63.24	62.70	60.38
224	60.74	60.04	58.10	55.15
225	59.95	59.87	54.14	52.65
226	55.93	55.54	51.87	47.23
227	55.75	55.24	51.76	48.07
228	52.16	51.41	48.42	41.93

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
231	65.08	64.34	59.49	51.57
232	62.69	62.14	61.85	58.90
233	65.06	64.55	60.64	57.17
234	54.57	53.92	52.71	48.15
235	56.64	55.93	53.95	51.04
236	62.06	61.52	59.50	53.71
237	46.87	46.36	42.41	20.39
238	55.27	54.54	46.58	19.85
241	70.66	69.23	57.14	32.99
242	68.52	68.24	67.47	59.40
243	71.89	71.59	71.41	69.25
244	74.34	74.00	73.03	66.04
245	60.28	59.82	58.46	51.20
246	63.47	62.92	61.14	52.37
247	56.51	56.13	54.26	39.36
248	64.61	64.30	59.70	57.19
251	63.69	62.75	60.41	50.73
252	52.95	52.40	52.20	50.63
253	66.34	65.88	64.47	59.18
254	76.41	75.59	75.00	72.96
255	69.64	69.28	68.76	65.50
256	65.24	65.12	63.77	60.05
257	57.49	57.21	56.68	52.74
258	67.38	66.82	66.13	52.62

PLOT 8

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	61.74	59.53	58.00	53.94
112	60.82	59.99	59.15	57.49
113	66.45	65.78	64.98	61.60
114	57.83	57.26	56.62	53.76
115	62.10	61.03	59.77	56.74
116	40.24	39.29	37.66	34.24
117	43.08	42.09	39.21	37.49
118	53.67	52.31	51.24	47.35
121	56.46	53.93	50.64	45.00
122	53.00	51.35	50.53	47.39
123	69.54	68.46	67.52	65.81
124	65.98	65.98	65.45	64.72
125	69.24	68.39	66.60	65.58
126	64.50	63.55	62.08	57.22
127	62.04	61.21	60.02	57.95
128	55.16	54.25	52.12	49.37
131	68.56	65.66	63.70	56.47
132	73.38	72.28	71.54	70.16
133	67.80	66.73	66.61	64.17
134	70.14	69.01	68.36	64.67
135	68.09	66.86	65.73	64.03
136	61.50	60.09	58.71	54.80
137	65.42	64.14	61.05	52.46
138	59.54	58.50	57.81	53.07
141	56.84	54.41	52.60	49.32
142	69.05	67.67	66.23	64.57
143	76.22	74.95	74.36	70.30
144	76.08	75.01	74.47	70.10

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
145	53.07	52.17	51.30	48.86
146	49.54	48.76	48.06	46.52
147	66.37	65.16	63.01	61.14
148	58.38	57.14	54.21	50.03
151	56.68	54.41	52.42	44.87
152	72.24	70.67	69.86	68.35
153	71.89	70.45	69.71	67.92
154	69.77	68.41	67.10	65.83
155	60.03	58.68	57.98	56.63
156	70.95	69.66	67.43	65.68
157	69.35	68.06	66.71	65.08
158	58.75	57.66	57.24	55.48
211	64.88	62.69	57.93	50.91
212	63.18	61.95	61.73	59.68
213	75.86	74.84	73.20	73.12
214	59.53	57.21	55.18	51.60
215	55.20	54.32	50.58	47.80
216	56.16	55.30	52.73	45.24
217	54.43	53.69	19.69	16.50
218	46.85	45.87	28.90	25.35
221	48.64	47.34	44.33	40.02
222	59.80	58.81	58.10	55.64
223	64.00	63.11	62.32	57.92
224	61.94	61.00	60.30	56.81
225	60.88	59.07	58.91	56.23
226	56.80	57.98	55.51	51.63
227	65.01	63.91	61.23	52.66
228	53.99	52.90	45.02	31.40

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
231	62.82	60.42	47.02	44.25
232	63.38	62.49	61.31	57.74
233	57.72	56.74	55.91	54.48
234	59.61	58.71	57.47	55.07
235	60.83	60.01	57.20	53.07
236	58.21	57.58	54.42	47.47
237	54.54	53.96	52.37	46.77
238	49.41	47.88	45.57	16.56
241	65.49	63.30	60.84	57.26
242	87.58	85.76	84.54	81.98
243	72.53	70.93	70.62	68.37
244	69.33	68.48	67.66	62.09
245	64.40	63.62	59.62	57.47
246	65.14	64.67	64.05	61.10
247	60.75	59.48	34.34	26.35
248	74.74	73.65	73.60	69.43
251	63.47	62.01	60.44	57.08
252	69.77	68.60	67.76	65.14
253	67.53	66.41	65.65	63.90
254	68.61	67.88	67.58	64.51
255	66.40	65.20	64.46	62.70
256	64.75	64.21	62.40	60.37
257	69.34	68.22	67.62	64.95
258	71.57	69.97	66.60	59.04

FUNGAL DECAY TESTS

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
111	35.42	34.32	31.12	29.93
111A	36.52	35.90	33.60	33.51
113	72.12	71.42	65.66	64.50
113A	68.89	68.42	65.77	65.51
117	61.02	60.65	56.50	55.37
117A	47.79	45.34	42.46	41.87
121	50.87	49.33	45.55	44.34
121H	50.67	48.48	44.84	43.54
123	56.91	56.62	54.00	53.75
123A	68.85	68.54	66.02	65.88
127A	63.90	61.92	58.56	58.38
127	63.70	63.23	58.14	56.68
131	71.74	69.89	68.10	65.31
131A	70.84	69.21	65.42	65.32
133	74.73	74.33	71.16	71.09
133A	70.84	69.21	65.42	65.32
137	63.84	62.94	55.67	53.29
137A	62.66	61.91	59.50	59.12
141	67.95	65.48	60.75	59.72
141D	67.16	65.06	61.32	60.33
143	68.19	67.39	63.73	63.50
143D	76.87	76.18	73.63	72.95
147	34.87	34.18	31.91	31.29
147A	47.89	47.08	44.44	43.71
151	71.82	70.46	66.67	64.95
151A	72.75	68.92	64.64	64.13
153	74.66	74.15	70.76	70.09
153A	74.25	73.65	70.50	69.79

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
157	61.92	61.33	58.35	57.95
157A	56.65	56.01	53.44	53.09
211C	91.30	89.92	85.90	85.84
211G	55.53	54.47	51.06	50.18
213A	63.49	63.00	60.28	59.86
213G	63.75	63.57	60.42	59.96
217A	41.12	40.61	35.73	33.36
217D	56.47	56.13	52.83	51.42
221A	62.92	61.42	56.99	55.76
221H	63.99	62.66	58.75	57.64
223A	67.53	66.57	63.06	62.49
223	61.13	60.72	57.33	57.14
227	54.51	54.18	50.96	50.40
227A	54.99	54.39	51.69	50.81
231	66.36	65.13	60.80	58.71
231A	53.16	52.74	50.37	49.77
233E	61.62	61.17	58.22	57.26
233B	61.02	60.55	57.24	56.78
237	53.73	53.35	49.77	49.07
237A	56.65	56.04	52.63	51.37
241A	48.39	46.61	44.00	43.12
241B	62.63	60.00	54.80	53.34
243B	69.16	69.16	66.43	65.72
243E	68.51	68.14	64.83	64.53
247A	57.94	57.14	54.07	53.36
247E	62.58	61.99	57.85	57.40
251A	11.97	11.61	10.51	10.11
251B	12.51	12.03	10.82	10.35

SAMPLE	WEIGHTS IN GRAMS			
	INITIAL	AFTER 6 MONTHS	AFTER 12 MONTHS	AFTER 18 MONTHS
253	59.00	58.46	55.06	54.83
253A	65.25	65.03	61.88	61.54
257	64.97	63.02	59.33	58.69
257B	74.53	73.57	70.37	70.35