Wood Preference of Selected Malaysian Subterranean Termites (Isoptera: Rhinotermitidae, Termitidae)

by

Peng-Soon Ngee[1,2], Ai Tashiro[3], Tsuyoshi Yoshimura[3], Zairi Jaal[1] & Chow-Yang Lee[1,4]

ABSTRACT

Laboratory preference of 15 Malaysian wood species: nyatoh (*Ganua* sp.), jelutong (*Dyera costulata*), teak (*Tectona grandis*), angsana (*Pterocarpus indicus*), pine (*Pinus caribaea*), balau (*Shorea* sp.), red meranti (*Shorea* sp.), white meranti (*Shorea* sp.), rubber (*Hevea brasieliensis*), merbau (*Intsia palembanica*), membatu (*Parinari* sp.), terentang (*Campnosperma auriculata*), medang (a species of Lauraceae), melunak (*Pentace* sp.) and perah (*Elateriospermum tapos*) and 14 Japanese wood species: hiba (*Thujopsis dolabrata*) , natural hinoki (*Chamaecyparis obtusa*), planted hinoki (*Chamaecyparis obtusa*), ezomatsu (*Picea jezoensis*), todomatsu (*Abies sachaliensis*), katsura (*Cercidiphyllum japonicum*), kuri (*Castanea crenata*), sugi (*Cryptomeria japonica*), keyaki (*Zelkova serrata*), kusunoki (*Cinnamomun camphora*), mizunara (*Quercus mongolica*), karamatsu (*Larix leptolepis*), akamatsu (*Pinus densiflora*), buna (*Fagus crenata*) and akagashi (*Quercus acuta*) were evaluated against selected Malaysian termite pest species using choice-feeding tests. Results indicated that rubber, jelutong and terentang were the most preferred species among the 29 wood species tested in the laboratory on four Malaysian termite species (*Coptotermes gestroi* [Wasmann], *Coptotermes curvignathus* Holmgren, *Globitermes sulphureus* (Haviland) and *Microcerotermes crassus* Snyder). Field studies of 15 Malaysian wood species on mixed termite species, and on *Macrotermes gilvus* (Hagen) confirmed the findings from the laboratory evaluation.

Keywords: Wood preference, Malaysia, *Coptotermes gestroi*, *Coptotermes curvignathus*, *Microcerotermes crassus*, *Globitermes sulphureus*, *Macrotermes gilvus*

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[1]Urban Entomology Laboratory, Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, MALAYSIA

[2]Present address: Kiwi Manufacturing Sdn Bhd., Homesafe Products (M) Sdn Bhd, 8, Jalan Hasil, Kawasan Tampoi, 81200 Johor Bahru, Johor, MALAYSIA

[3]Laboratory of Deteroriation Control, Wood Research Institute, Kyoto University, Uji, Kyoto 611-0011, JAPAN

[4]Reprint requests should be addressed to: Email: chowyang@usm.my

INTRODUCTION

The natural environment contains many wood species that can be utilized by termites as food. However, certain wood species are more preferred than the others. Generally, termite feeding activity is influenced by its density (Becker 1969, Sornnuwat *et al.* 1995), wood hardness (Behr *et al.* 1972), moisture in wood (Delaplane & La Fage 1989a), damage done by conspecifics (Delaplane & La Fage 1989b), wood extractives (Carter 1979, Carter & Beal 1982, Carter *et al.* 1983, Su & Tamashiro 1986, Waller 1989, Sornnuwat *et al.* 1995), wood decayed by fungus (Smythe *et al.* 1971), soldier proportions (Su & La Fage 1987), caste composition (Watson *et al.* 1978), temperature (Harverty & Nutting 1974, Smith & Rust 1993a) and colony variation (Creffield *et al.* 1985).

Smythe & Carter (1970a) and Morales-Ramos & Rojas (2001) reported the importance of wood combination offered to termites when doing laboratory choice feeding tests. It was shown that the preference of termites to a particular wood species could be altered by the wood combination offered to them. Smythe & Carter (1970b) tested the feeding preference of *R. virginicus* on 11 North American wood species and found that under the choice feeding tests, termite preference of four wood species increased, when compared to that in force feeding tests. This indicated that the choice feeding test was the more appropriate method to be used in determining termite wood preference than the non-choice test (force-feeding) because under the latter test method, termites were forced to feed on whatever resource available for survivorship.

Earlier, it was reported that several peridomestic species such as *Globitermes sulphureus*, *Microcerotermes* spp. and *Macroctermes gilvus* did not respond well to paper-based bait matrix (Lee 2002a, 2002b). We speculated that this could be due to the nature of matrix which is not preferred by these termite species. Thus, we hope that by determining the wood preference of Malaysian subterranean termite species, it would be possible to find a suitable wood species that can be used as part of a bait matrix against a wide spectrum of termite pest species. In this study, we tested the laboratory preference of various commercially available Malaysian wood species against four species of Malaysian subterranean termites (*Coptotermes gestroi* [3 colonies], *Coptotermes curvignathus* , *Microcerotermes crassus* and *Globitermes sulphureus*. Laboratory preference of these termite species for Japanese wood species was also evaluated for comparison purposes. Field preference studies were conducted using Malaysian wood species against mixed termite species in a natural environment, as well as against *Macrotermes gilvus*.

MATERIALS AND METHODS

Laboratory preference test

Test insects

Coptotermes gestroi (three colonies), *C. curvignathus* and *G. sulphureus* were collected from infested rubber (*Hevea brasiliensis*) wood stakes in underground monitoring stations (40 x 25 x 15 cm) on Penang Island, Malaysia. As for *M. crassus*, direct excavation of their aboreal nests was done. The collected termites were brought back to the laboratory and separated from debris using a slightly modified method as described by Tamashiro *et al.* (1973).

Wood species

A total of 29 wood species (untreated) from Malaysia and Japan were tested namely: Malaysia - nyatoh (*Ganua* sp.), jelutong (*Dyera costulata*), teak (*Tectona grandis*), angsana (*Pterocarpus indicus*), pine (*Pinus caribaea*), balau (*Shorea* sp.), red meranti (*Shorea* sp.), white meranti (*Shorea* sp.), rubber (*Hevea brasieliensis*), merbau (*Intsia palembanica*), membatu (*Parinari* sp.), terentang (*Campnosperma auriculata*), medang (a species of Lauraceae), melunak (*Pentace* sp.) and perah (*Elateriospermum tapos*); Japan - hiba (*Thujopsis dolabrata*), natural hinoki (*Chamaecyparis obtusa*), planted hinoki (*Chamaecyparis obtusa*), ezomatsu (*Picea jezoensis*), todomatsu (*Abies sachaliensis*), katsura (*Cercidiphyllum japonicum*), kuri (*Castanea crenata*), sugi (*Cryptomeria japonica*), keyaki (*Zelkova serrata*), kusunoki (*Cinnamomun camphora*), mizunara (*Quercus mongolica*), karamatsu (*Larix leptolepis*), akamatsu (*Pinus densiflora*), buna (*Fagus crenata*) and akagashi (*Quercus acuta*). All Japanese wood used in this study were from the heartwood.

Experimental procedures

A choice test was executed to study wood preference. A rectangular-shaped polyethylene container (40 cm x 25 cm x 15 cm) was used as test arena for this study. Three hundred g of moistened water-washed sand (mesh size 40) was placed evenly within the container. All wood species described above in pre-weighed wood blocks (2 x 2 x 1 cm) were oven-dried, and placed randomly in the container in the order of 6 x 5. Approximately 5000 workers and 250 soldiers were introduced equally (non-localized) into the container and the experiment was replicated 10 times for each of the termite species tested. The containers were left in total darkness for 30 days under environmental conditions of 26.0 ± 2.0 °C and 60 ± 5 % relative humidity.

After this period, all the wood blocks were recovered, washed, oven-dried at 80 °C and weighed to determine weight loss. Wood consumption in grams and the percentage of each wood species was calculated.

Field wood preference test against mixed termite species

Test site

The location of the field test was Lurah Burung, a small secondary forest reserve in Universiti Sains Malaysia Minden campus. Our earlier observation found that there were various termite species from several genera including *Coptotermes*, *Globitermes*, *Microtermes*, *Odontotermes*, *Macrotermes*, *Subuliolitermes*, *Pericapritermes* and *Microcerotermes* in the test location.

Experimental procedures

Cylindrical-shaped containers (25 cm diameter x 15 cm height) were used in this study. Fifteen Malaysian wood species measuring 10 cm x 1.5 cm x 1.5 cm (4 stakes in one group) were oven-dried, pre-weighed and placed inside the container in a random design. A total of 20 replicates were prepared and inserted completely into the soil. Each replicate was set at least 2 m apart from each other. The experiment was terminated after 3 months. All wood samples were brought back to the laboratory, washed, oven-dried and weighed. One important parameter was recorded, i.e. total termite-contact, which was based on either one of the three criteria: termite feeding, deposited faecal material or mud and gallery built on the wood. This was expressed in percentage of contact (%). All wood blocks were also visually rated based on a modified rating system of the original American Standards for Testing and Materials (ASTM 1984) method: 0 = no attack; 1 = slight superficial attack; 2 = superficial to medium attack (not deep inside); 3 = heavy attack (to penetration); 4 = very heavy attack (almost collapsed) to completely consumed.

Field wood preference test against *M. gilvus*

Test site

The test was conducted near the Sports Complex of Universiti Sains Malaysia Minden campus where many active *M. gilvus* mounds were located.

Experimental procedures

Cylindrical-shaped containers (25 cm diameter x 15 cm height) were used in this study. Fifteen Malaysian wood species were prepared in blocks of 10 x 1.5 x 1.5 cm (2 stakes in one group), oven-dried, pre-weighed and placed inside the container in randomized manner. A total of nine replicates were prepared and three each were inserted into a *M. gilvus* mound for a period of two months. Upon termination of the experiment, mean wood consumption of termites for each wood species was presented in gram mass loss.

Data analyses

Data in mass loss (g) were subjected to analysis of variance, and their means were separated using Tukey's HSD. Data in percentage were transformed to arc-sine values before analysis of variance.

RESULTS AND DISCUSSION

Laboratory preference test

Choice feeding test indicated that rubber wood was the most

Table 1: Mean mass loss of various Malaysian and Japanese wood species after 30 days choice-feeding test against *C. gestroi* (colony A).

Wood species	Common name	Mean wood mass loss ± SEM[1] (g)	Mean wood mass loss ± SEM[1] (%)
Shorea sp.	Balau	0.0141 ± 0.0024 a	0.4338 ± 0.0849 a
Pterocarpus indicus	Angsana	0.0199 ± 0.0020 a	0.7388 ± 0.0587 ab
Chamaecyparis obtuse	Hinoki (planted)	0.0220 ± 0.0025 a	1.4091 ± 0.1144 abc
Chamaecyparis obtuse	Hinoki (natural)	0.0261 ± 0.0019 a	1.2297 ± 0.1405 abc
Cryptomeria japonica	Sugi	0.0304 ± 0.0046 a	2.1071 ± 0.3136 a-d
Quercus acuta	Akagashi	0.0329 ± 0.0037 a	1.1834 ± 0.1373 abc
Abies sachaliensis	Todomatsu	0.0436 ± 0.0053 a	2.9254 ± 0.3980 a-d
Species of Lauraceae	Medang	0.0441 ± 0.0055 a	1.3705 ± 0.1844 abc
Castanea crenata	Kuri	0.0511 ± 0.0076 a	2.8292 ± 0.4395 a-d
Tectona grandis	Teak	0.0605 ± 0.0118 ab	2.6663 ± 0.1745 a-d
Pinus densiflora	Akamatsu	0.0740 ± 0.0099 ab	3.5999 ± 0.4562 a-e
Zelkova serrata	Keyaki	0.0869 ± 0.0111 abc	2.9442 ± 0.3461 a-d
Intsia palembanica	Merbau	0.1317 ± 0.0168 a-d	3.3788 ± 0.4390 a-d
Shorea sp.	White meranti	0.1487 ± 0.0201 a-e	3.8255 ± 0.5959 a-e
Quercus mongolica	Mizunara	0.1612 ± 0.0282 a-e	6.1088 ± 0.7944 a-e
Parinari sp.	Membatu	0.1650 ± 0.0203 a-e	4.4210 ± 0.5567 a-e
Cercidiphyllum japonicum	Katsura	0.1677 ± 0.0019 a-f	9.5195 ± 1.0499 def
Picea jezoensis	Ezomatsu	0.1684 ± 0.0221 a-f	10.7377 ± 1.4133 ef
Thujopsis dolabrata	Hiba	0.1690 ± 0.0177 a-f	9.9456 ± 0.9457 def
Pentace sp.	Melunak	0.2430 ± 0.0348 b-f	7.9148 ± 1.1943 b-e
Elanteriospermum tapos	Perah	0.2560 ± 0.0275 c-f	8.1987 ± 0.9871 cde
Dyera costulata	Jelutong	0.2945 ± 0.0295 def	21.2314 ± 2.1659 gh
Larix leptolepis	Karamatsu	0.3026 ± 0.0263 efg	18.1306 ± 1.5339 g
Cinnamomun camphora	Kusunoki	0.3364 ± 0.0361 fg	16.3739 ± 2.0815 fg
Fagus crenata	Buna	0.4697 ± 0.0443 gh	20.4458 ± 1.9755 gh
Shorea sp.	Red meranti	0.5098 ± 0.0466 h	25.7219 ± 2.5729 h
Campnosperma auriculata	Terentang	0.5875 ± 0.0460 hi	46.0207 ± 4.0566 i
Ganua sp.	Nyatoh	0.6197 ± 0.0786 hi	15.7470 ± 1.9212 fg
Pinus caribaea	Pine	0.7543 ± 0.0486 i	44.0792 ± 2.3390 i
Hevea brasieliensis	Rubber	1.2099 ± 0.0917 j	45.0819 ± 2.3742 i

[1]Means within the same column followed by different letters are significantly different (Tukey HSD, $p < 0.05$).

preferred wood among the 30 wood species when tested against *C. gestroi* colony A (Table 1). Mean wood mass losses showed that five Malaysian woods namely rubber, pine, nyatoh, terentang and red meranti (decreasing in preference) were the most preferred wood species by this colony. Differences among the latter four woods were not significant, except between pine and red meranti. Our force-feeding experiment revealed that jelutong was found to be more highly attractive than other wood species such as rubber, nyatoh, terentang and red meranti by this colony (P.S. Ngee *et al.*, unpublished data), but when the termites were given choices, the findings became different. This reconfirmed earlier reports of interactions among the wood species

Table 2: Mean mass loss of various Malaysian and Japanese wood species after 30 days choice-feeding test against *C. gestroi* (colony B).

Wood species	Common name	Mean wood mass loss ± SE[1] (g)	Mean wood mass loss ± SE[1] (%)
Castanea crenata	Kuri	0.0069 ± 0.0064 a	0.3049 ± 0.2835 a
Quercus acuta	Akagashi	0.0165 ± 0.0058 a	0.5454 ± 0.1889 a
Shorea sp.	White meranti	0.0219 ± 0.0029 a	0.8565 ± 0.1303 a
Pentace sp.	Melunak	0.0289 ± 0.0070 ab	0.9242 ± 0.2285 a
Shorea sp.	Balau	0.0301 ± 0.0063 ab	0.8867 ± 0.1758 a
Abies sachaliensis	Todomatsu	0.0310 ± 0.0229 ab	2.4802 ± 1.8277 a
Pterocarpus indicus	Angsana	0.0325 ± 0.0017 ab	1.4342 ± 0.0811 a
Chamaecyparis obtusa	Hinoki (planted)	0.0384 ± 0.0017 ab	2.1404 ± 0.0966 a
Thujopsis dolabrata	Hiba	0.0396 ± 0.0059 ab	2.1189 ± 0.3141 a
Thujopsis dolabrata	Hinoki (natural)	0.0411 ± 0.0034 ab	2.3945 ± 0.2145 a
Zelkova serrata	Keyaki	0.0537 ± 0.0139 ab	1.7317 ± 0.4501 a
Cryptomeria japonica	Sugi	0.0597 ± 0.0218 ab	4.9393 ± 1.9464 a
Tectona grandis	Teak	0.0659 ± 0.0176 ab	2.7961 ± 0.7486 a
Parinari sp.	Membatu	0.0675 ± 0.0091 ab	1.7537 ± 0.2644 a
Species of Lauraceae	Medang	0.0698 ± 0.0142 ab	2.8709 ± 0.7079 a
Picea jezoensis	Ezomatsu	0.0761 ± 0.0192 ab	4.7684 ± 1.1596 a
Pinus densiflora	Akamatsu	0.0973 ± 0.0296 abc	6.2309 ± 1.8803 a
Intsia palembanica	Merbau	0.1019 ± 0.0275 abc	2.7026 ± 0.8520 a
Cercidiphyllum japonicum	Katsura	0.2063 ± 0.1058 a-d	11.4374 ± 5.8080 ab
Shorea sp.	Red meranti	0.2542 ± 0.0621 a-e	13.8053 ± 3.6068 abc
Elanteriospermum tapos	Perah	0.4614 ± 0.0569 a-e'	10.6339 ± 1.9621 ab
Larix leptolepis	Karamatsu	0.5540 ± 0.0546 b-f	31.9014 ± 3.1186 cd
Dyera costulata	Jelutong	0.6213 ± 0.0751 c-g	46.0002 ± 5.6914 def
Quercus mongolica	Mizunara	0.6418 ± 0.0894 d-g	28.3549 ± 3.8964 bcd
Campnosperma auriculata	Terentang	0.7642 ± 0.0889 efg	74.0464 ± 7.0408 g
Pinus caribaea	Pine	0.9583 ± 0.1053 fgh	55.8489 ± 6.2998 efg
Fagus crenata	Buna	1.0486 ± 0.2714 fgh	38.9162 ± 9.8911 de
Ganua sp.	Nyatoh	1.0967 ± 0.2644 gh	28.4789 ± 6.4276 bcd
Hevea brasieliensis	Rubber	1.4210 ± 0.1689 h	64.0881 ± 7.4014 fg

[1]Means within the same column followed by different letters are significantly different (Tukey HSD, $p < 0.05$)

tested as reported by Morales-Ramos & Rojas (2001). Buna, kusunoki, karamatsu, jelutong, perah and melunak were found to have a mean wood mass loss greater than 0.2 g, but no significant differences were detected among these wood species. The rest of the wood species showed little consumption (less than 0.2 g) by the colony and no significant differences among them were observed.

Table 2 showed the relative mean wood mass losses of 30 Malaysian and Japanese timbers during a month exposure to *C. gestroi* colony B. Rubber, nyatoh, buna, pine, terentang, mizunara, jelutong, karamatsu, perah, red meranti and katsura were found to be the most preferred

Table 3: Mean mass loss of various Malaysian and Japanese wood species after 30 days choice-feeding test against *C. gestroi* (colony C).

Wood species	Common name	Mean wood mass loss ± SE[1] (%)	Mean wood mass loss ±SE[1] (%)
Chamaecyparis obtusa	Hinoki (planted)	0.0206 ± 0.0016 a	1.1613 ± 0.0880 a
Cryptomeria japonica	Sugi	0.0243 ± 0.0012 a	1.8518 ± 0.0767 ab
Thujopsis dolabrata	Hiba	0.0269 ± 0.0047 a	1.5418 ± 0.2829 ab
Abies sachaliensis	Todomatsu	0.0303 ± 0.0116 a	2.0769 ± 0.7282 ab
Quercus acuta	Akagashi	0.0311 ± 0.0074 a	1.0850 ± 0.2650 a
Shorea sp.	Balau	0.0322 ± 0.0034 a	0.9348 ± 0.0920 a
Castanea crenata	Kuri	0.0323 ± 0.0015 a	1.6159 ± 0.1088 ab
Chamaecyparis obtusa	Hinoki (natural)	0.0346 ± 0.0011 a	1.9881 ± 0.0553 ab
Species of Lauraceae	Medang	0.0346 ± 0.0070 a	0.9738 ± 0.1939 a
Pterocarpus indicus	Angsana	0.0403 ± 0.0035 a	1.6910 ± 0.1057 ab
Pinus densiflora	Akamatsu	0.0404 ± 0.0043 a	2.3422 ± 0.2706 ab
Picea jezoensis	Ezomatsu	0.0408 ± 0.0064 a	2.5791 ± 0.3931 ab
Pentace sp.	Melunak	0.0458 ± 0.0096 a	1.4573 ± 0.3041 ab
Zelkova serrata	Keyaki	0.0614 ± 0.0161 a	2.0339 ± 0.5224 ab
Parinari sp.	Membatu	0.0662 ± 0.0089 a	1.7048 ± 0.2293 ab
Tectona grandis	Teak	0.0669 ± 0.0182 a	2.8311 ± 0.7675 ab
Shorea sp.	White meranti	0.0745 ± 0.0227 a	2.2833 ± 0.6811 ab
Intsia palembanica	Merbau	0.0818 ± 0.0125 a	2.2298 ± 0.3579 ab
Cercidiphyllum japonicum	Katsura	0.0843 ± 0.0226 a	4.7951 ± 1.2577 abc
Cinnamomun camphora	Kusunoki	0.1078 ± 0.0156 a	4.6379 ± 0.5425 abc
Larix leptolepis	Karamatsu	0.2180 ± 0.0300 ab	12.6508 ± 1.7523 a-d
Shorea sp.	Red meranti	0.2480 ± 0.0905 ab	11.6219 ± 4.2114 a-d
Ganua sp.	Nyatoh	0.2567 ± 0.0391 ab	6.8324 ± 0.9690 abc
Dyera costulata	Jelutong	0.2679 ± 0.0134 ab	20.1707 ± 1.1433 cd
Hevea brasieliensis	Rubber	0.5377 ± 0.0673 bc	16.9615 ± 2.0239 bcd
Fagus crenata	Buna	0.5819 ± 0.0853 bc	23.8701 ± 3.5656 de
Campnosperma auriculata	Terentang	0.5984 ± 0.0496 bc	55.7917 ± 6.9437 f
Elanteriospermum tapos	Perah	0.7091 ± 0.3139 cd	16.7610 ± 7.4055 bcd
Quercus mongolica	Mizunara	0.8819 ± 0.1806 cd	37.9501 ± 8.3505 e
Pinus caribaea	Pine	1.0212 ± 0.1086 d	58.6015 ± 6.7721 f

[1]Means within the same column followed by different letters are significantly different (Tukey HSD, $p < 0.05$)

wood species. Kuri, akagashi, white meranti, melunak, balau, todomatsu, angsana, hinoki (both natural growth and planted), hiba, keyaki, sugi, teak, membatu, medang, ezomatsu, akamatsu and merbau were the least attacked wood species with an average wood mass losses of < 0.2 g and no significant differences were found among these wood species. The results obtained were comparable to those with *C. gestroi* colony A, where the similar group of wood species was also identified as non-preferred ones.

Similar results for non-preferred species were also recorded for colony C of *C. gestroi* (Table 3). However, there appeared to be some variations for the most preferred species. Pine was the most preferred

Table 4: Mean mass loss of various Malaysian and Japanese wood species after 30 days choice-feeding test against *C. curvignathus*..

Wood species	Common name	Mean wood mass loss ± SE[1] (g)	Mean wood mass loss ± SE[1] (%)
Zelkova serrata	Keyaki	0.0216 ± 0.0056 a	0.6863 ± 0.1741 a
Shorea sp.	Balau	0.0389 ± 0.0106 a	1.1816 ± 0.3584 a
Pentace sp.	Melunak	0.0479 ± 0.0096 a	1.5243 ± 0.3019 a
Abies sachaliensis	Todomatsu	0.0604 ± 0.0194 a	4.7643 ± 1.5522 abc
Shorea sp.	White meranti	0.0607 ± 0.0211 a	1.6909 ± 0.6079 a
Chamaecyparis obtusa	Hinoki (natural)	0.0666 ± 0.0447 a	3.8503 ± 2.3649 abc
Quercus acuta	Akagashi	0.0815 ± 0.0235 a	2.7188 ± 0.8126 ab
Thujopsis dolabrata	Hiba	0.0868 ± 0.0339 a	4.6148 ± 1.8186 abc
Pterocarpus indicus	Angsana	0.1041 ± 0.0359 a	3.7945 ± 1.2489 abc
Castanea crenata	Kuri	0.1204 ± 0.0362 a	5.7320 ± 1.7699 abc
Parinari sp.	Membatu	0.1225 ± 0.0375 a	3.1467 ± 0.9522 ab
Tectona grandis	Teak	0.1234 ± 0.0519 a	5.2617 ± 2.2629 abc
Chamaecyparis obtusa	Hinoki (planted)	0.1275 ± 0.0708 a	7.1499 ± 3.9795 abc
Species of Lauraceae	Medang	0.1363 ± 0.0442 a	5.8150 ± 2.3881 abc
Pinus densiflora	Akamatsu	0.1410 ± 0.0282 a	9.3933 ± 1.9250 abc
Intsia palembanica	Merbau	0.1868 ± 0.0477 a	5.6346 ± 1.6509 abc
Cercidiphyllum japonicum	Katsura	0.2792 ± 0.0619 ab	15.3060 ± 3.3475 a-d
Picea jezoensis	Ezomatsu	0.3021 ± 0.0496 ab	19.3758 ± 3.1945 bcd
Cryptomeria japonica	Sugi	0.3269 ± 0.0381 ab	27.5647 ± 3.4372 def
Elanteriospermum tapos	Perah	0.5836 ± 0.1378 bc	14.6272 ± 3.9613 a-d
Shorea sp.	Red meranti	0.5999 ± 0.0914 bc	36.8936 ± 5.4654 ef
Larix leptolepis	Karamatsu	0.6852 ± 0.0717 cd	39.7592 ± 4.4698 f
Hevea brasieliensis	Rubber	0.7298 ± 0.0932 cd	30.1955 ± 4.1064 def
Ganua sp.	Nyatoh	0.7563 ± 0.1307 cd	20.6879 ± 3.7463 cde
Fagus crenata	Buna	0.7964 ± 0.1225 cd	29.5325 ± 4.4560 def
Campnosperma auriculata	Terentang	0.8896 ± 0.0376 cd	80.4927 ± 1.5332 h
Dyera costulata	Jelutong	0.9709 ± 0.0906 de	72.9861 ± 7.6281 gh
Pinus caribaea	Pine	1.3058 ± 0.0507 ef	74.3674 ± 4.3261 gh
Quercus mongolica	Mizunara	1.3596 ± 0.1499 f	60.3724 ± 6.6409 g

[1]Means within the same column followed by different letters are significantly different (Tukey HSD; $p < 0.05$)

wood, not rubber as observed for colony A & B. No significant difference was noticed among mizunara, perah, terentang, buna, rubber, jelutong, nyatoh, red meranti and karamatsu, except between mizunara and jelutong, nyatoh, red meranti, karamatsu.

C. curvignathus, the most aggressive termite species, showed a great preference for mizunara and pine, but no significant difference was found between the two species (Table 4). This was followed by jelutong, terentang, buna, nyatoh, rubber, karamatsu, red meranti and perah with no significant difference observed among them (with exception to between jelutong, red meranti and perah). Generally, mean mass losses

Table 5: Mean mass loss of various Malaysian and Japanese wood species after 30 days choice-feeding test against *G. sulphureus*..

Wood species	Common name	Mean wood mass loss ± SE[1] (g)	Mean wood mass Loss ± SE[1] (%)
Thujopsis dolabrata	Hiba	0.0149 ± 0.0005 a	0.0891 ± 0.0289 a
Picea jezoensis	Ezomatsu	0.0183 ± 0.0050 a	1.1711 ± 0.3686 a
Abies sachaliensis	Todomatsu	0.0218 ± 0.0023 a	1.5079 ± 0.1609 a
Chamaecyparis obtusa	Hinoki (planted)	0.0312 ± 0.0107 ab	1.6883 ± 0.6091 a
Tectona grandis	Teak	0.0315 ± 0.0055 ab	1.4457 ± 0.2237 a
Chamaecyparis obtusa	Hinoki (natural)	0.0337 ± 0.0009 ab	1.8274 ± 0.0211 ab
Pterocarpus indicus	Angsana	0.0338 ± 0.0050 ab	1.3876 ± 0.1932 a
Shorea sp.	Balau	0.0366 ± 0.0046 ab	1.0341 ± 0.1316 a
Pinus densiflora	Akamatsu	0.0418 ± 0.0009 ab	2.0110 ± 0.0251 abc
Pinus caribaea	Pine	0.0432 ± 0.0094 ab	3.1246 ± 0.5615 abc
Quercus acuta	Akagashi	0.0441 ± 0.0038 ab	1.6056 ± 0.1311 a
Cryptomeria japonica	Sugi	0.0574 ± 0.0189 abc	3.9463 ± 1.3050 a-d
Larix leptolepis	Karamatsu	0.0577 ± 0.0153 abc	3.4202 ± 0.7783 abc
Zelkova serrata	Keyaki	0.0623 ± 0.0010 abc	2.3165 ± 0.0329 abc
Parinari sp.	Membatu	0.0631 ± 0.0040 abc	1.6927 ± 0.1195 a
Species of Lauraceae	Medang	0.0669 ± 0.0108 abc	2.0415 ± 0.3248 abc
Cinnamomun camphora	Kusunoki	0.0800 ± 0.0112 abc	4.0898 ± 0.5927 a-d
Intsia palembanica	Merbau	0.1102 ± 0.0250 a-d	2.9376 ± 0.6394 abc
Ganua sp.	Nyatoh	0.1166 ± 0.0056 a-d	3.0241 ± 0.1883 abc
Pentace sp.	Melunak	0.1172 ± 0.0280 a-d	3.7322 ± 0.8806 abc
Shorea sp.	White meranti	0.1365 ± 0.0235 a-d	3.6949 ± 0.6611 abc
Shorea sp.	Red meranti	0.1393 ± 0.0297 a-d	8.1669 ± 1.8881 b-f
Dyera costulata	Jelutong	0.1524 ± 0.0250 a-d	11.1392 ± 2.0071 ef
Campnosperma auriculata	Terentang	0.1670 ± 0.0240 bcd	11.6288 ± 2.1028 ef
Quercus mongolica	Mizunara	0.1887 ± 0.0234 cd	7.2786 ± 0.9216 a-f
Cercidiphyllum japonicum	Katsura	0.1899 ± 0.0659 cd	10.6590 ± 3.6323 ef
Elanteriospermum tapos	Perah	0.1906 ± 0.0701 cd	5.2317 ± 1.6997 a-e
Hevea brasieliensis	Rubber	0.2290 ± 0.0822 d	8.3476 ± 2.9846 c-f
Fagus crenata	Buna	0.2356 ± 0.0214 d	10.2909 ± 0.9493 def
Castanea crenata	Kuri	0.2386 ± 0.0570 d	13.4460 ± 3.2379 f

[1]Means within the same column followed by different letters are significantly different (Tukey HSD, $p < 0.05$)

of wood due to attack by *C. curvignathus* were more clearly differentiated than those fed by *C. gestroi*. However, its preference for the respective wood species were generally similar to those recorded for *C. gestroi*.

It is interesting to note that hiba and teak, two highly resistant wood species and least preferred by Japanese *Coptotermes formosanus* (Imamura 2001), was found to be moderately preferred by the Malaysian *Coptotermes* spp. used in this study. On the other hand, buna which was classified to be moderately resistant to *C. formosanus* (Imamura 2001) was highly preferred by Malaysian *Coptotermes* species with mean wood mass loss between 20 – 39% after 30 days choice-

Table 6: Mean mass loss of various Malaysian and Japanese wood species after 30 days choice-feeding test against *M. crassus*..

Wood species	Common name	Mean wood mass loss ± SE[1] (g)	Mean wood mass loss ± SE[1] (%)
Thujopsis dolabrata	Hiba	0.0144 ± 0.0004 a	0.8496 ± 0.0243 a
Cryptomeria japonica	Sugi	0.0236 ± 0.0017 ab	1.6171 ± 0.1109 a
Shorea sp.	Balau	0.0255 ± 0.0022 ab	0.7433 ± 0.0573 a
Pentace sp.	Melunak	0.0266 ± 0.0017 ab	0.8535 ± 0.0539 a
Abies sachaliensis	Todomatsu	0.0271 ± 0.0013 ab	1.8569 ± 0.0879 a
Pinus densiflora	Akamatsu	0.0318 ± 0.0017 ab	1.5171 ± 0.0782 a
Chamaecyparis obtuse	Hinoki (natural)	0.0342 ± 0.0036 ab	1.8586 ± 0.1926 a
Parinari sp.	Membatu	0.0369 ± 0.0016 ab	0.9478 ± 0.0451 a
Larix leptolepis	Karamatsu	0.0369 ± 0.0099 ab	2.1823 ± 0.5881 a
Pterocarpus indicus	Angsana	0.0395 ± 0.0024 ab	1.4030 ± 0.0811 a
Chamaecyparis obtusa	Hinoki (planted)	0.0481 ± 0.0082 abc	2.5475 ± 0.3484 a
Tectona grandis	Teak	0.0487 ± 0.0067 abc	2.1130 ± 0.2986 a
Cercidiphyllum japonicum	Katsura	0.0656 ± 0.0128 a-d	3.7020 ± 0.6961 a
Quercus acuta	Akagashi	0.0716 ± 0.0183 a-d	2.5608 ± 0.6604 a
Castanea crenata	Kuri	0.0882 ± 0.0148 a-d	4.9051 ± 0.8277 a
Species of Lauraceae	Medang	0.0923 ± 0.0362 a-d	2.6006 ± 0.9372 a
Shorea sp.	Red meranti	0.1076 ± 0.0244 a-e	5.0240 ± 1.0211 a
Pinus caribaea	Pine	0.1132 ± 0.0366 a-e	6.7711 ± 2.1896 a
Zelkova serrata	Keyaki	0.1211 ± 0.0166 a-e	4.1461 ± 0.5472 a
Intsia palembanica	Merbau	0.1362 ± 0.0199 a-e	3.4940 ± 0.5523 a
Shorea sp.	White meranti	0.1522 ± 0.0262 a-e	3.8389 ± 0.7264 a
Elanteriospermum tapos	Perah	0.1560 ± 0.0281 b-e	4.9159 ± 1.1101 a
Dyera costulata	Jelutong	0.1577 ± 0.0130 b-e	11.4436 ± 0.9751 a
Fagus crenata	Buna	0.1587 ± 0.0313 b-f	6.8613 ± 2.8284 a
Picea jezoensis	Ezomatsu	0.1880 ± 0.0330 c-f	11.7724 ± 2.0375 a
Ganua sp.	Nyatoh	0.1949 ± 0.0532 def	5.0862 ± 1.4251 a
Quercus mongolica	Mizunara	0.2397 ± 0.0288 ef	8.9087 ± 1.0729 a
Hevea brasieliensis	Rubber	0.2987 ± 0.0519 f	9.9480 ± 1.7035 a
Campnosperma auriculata	Terentang	0.7126 ± 0.0873 g	66.0917 ± 11.0652 b

[1]Means within the same column followed by different letters are significantly different (Tukey HSD, $p < 0.05$)

feeding test. This suggested a differential feeding preference among different species of *Coptotermes* toward wood species that were uncommon to the foraging colonies.

G. sulphureus, a higher termite species, is a slow feeder (Ngee & Lee 2002, Lee *et al.* 2003). It was found to share the same feeding preference as *Coptotermes* spp., but its consumption rate on preferred wood species was much lower (Table 5). Of the 30 wood species offered to this species, kuri, buna and rubber were among the three most preferred. However, it is not possible to separate the wood species into preferred and non-preferred groups due to lack of significant difference among them.

On the other hand, *M. crassus* demonstrated a clear difference in their feeding patterns against the tested wood species. This species was found to only prefer only terentang, and showed a relatively poor response on other wood species (Table 6). Approximately 66.09% of the terentang wood block was consumed at the end of the experiment. It was anticipated that if the experimental period was extended, different feeding patterns may be detected upon terentang wood supply in the arena diminished. This species may have a slower exploratory behavior, thus more time was needed to explore the other potential wood species. This factor, however cannot be proven in this study, unless a longer evaluation period was done.

Field wood preference test against mixed termite species

Field evaluation of 15 Malaysian wood species to subterranean termite attacks showed that significantly higher mean wood mass loss for rubber when compared to other wood species (Table 7). This pointed the suitability of using rubber as a termite bait matrix. Pine was ranked as the second most preferred wood after rubber. Visual rating demonstrated relatively comparable results to the mean wood mass losses where both species suffered "heavy" to "very heavy" attack by various termite species in the field. On the other hand, balau, white meranti, medang, melunak, merbau, membatu and teak registered "no attack" to "slight superficial attack", whereas red meranti, angsana, nyatoh and perah were rated to have "slight superficial" to "medium attack".

Field wood preference test against mixed termite species

M. gilvus has been reported to be a peridomestic termite pest species in Malaysia that may cause infestation to buildings and structures upon elimination of the more dominant *Coptotermes* spp. (Lee 2002a, 2002b). Table 8 shows the mean wood mass losses, percentage of wood contacted and visual damage assessments of 15 Malaysian wood species after two-month exposure to three field colonies of *M. gilvus*.

Table 7: Mean wood consumption and wood contact of 15 Malaysian wood species by various termite species after 3 months exposure in the field.

Timber species	Common name	Mean wood mass loss[1] (g)	Mean wood mass loss[1] (%)	Termite contact [1,2] (%)	Mean ± SE [1,3] Visual rating
Shorea sp.	Balau	0.3299 ± 0.1466 a	0.1835 ± 0.0815	100.00	0.06 ± 0.00 a
Shorea sp.	White meranti	0.6078 ± 0.5119 a	0.3784 ± 0.3237	81.25	0.06 ± 0.03 a
Species of Lauraceae	Medang	0.6259 ± 0.2122 a	0.4848 ± 0.1591	87.50	0.05 ± 0.02 a
Tectona grandis	Teak	0.7155 ± 0.9073 a	0.5187 ± 0.1716	87.50	0.08 ± 0.04 a
Shorea sp.	Red meranti	0.8365 ± 0.1426 a	0.6870 ± 0.1249	93.75	0.17 ± 0.06 a
Pentace sp.	Melunak	1.0472 ± 0.8055 a	0.5467 ± 0.1062	81.25	0.09 ± 0.04 a
Intsia palembanica	Merbau	1.0675 ± 0.1951 a	0.6188 ± 0.1108	87.50	0.05 ± 0.03 a
Pterocarpus indicus	Angsana	1.4011 ± 0.2090 a	0.9972 ± 0.9973	87.50	0.16 ± 0.05 a
Ganua sp.	Nyatoh	1.5089 ± 0.7815 a	1.1314 ± 0.6108	100.00	0.13 ± 0.05 a
Parinari sp.	Membatu	3.4524 ± 0.0095 a	2.1395 ± 0.3493	93.75	0.06 ± 0.04 a
Elanteriospermum tapos	Perah	11.9155 ± 1.8049 ab	7.8347 ± 1.2615	100.00	1.14 ± 0.11 b
Campnosperma auriculata	Terentang	26.3131 ± 5.5201 bc	31.2553 ± 6.2165	100.00	2.89 ± 0.14 c
Dyera costulata	Jelutong	32.7176 ± 7.2589 c	36.9478 ± 7.839	100.00	2.88 ± 0.14 c
Pinus caribaea	Pine	62.9121 ± 7.2887 d	61.9379 ± 7.0272	100.00	3.78 ± 0.07 c
Hevea brasieliensis	Rubber	109.7103 ± 8.3387 e	54.9608 ± 4.1771	100.00	3.59 ± 0.07 c

[1]Data were based on 64 stakes (16 replicates x 4 stakes per wood species) and, means within the same column followed by different letters were significantly different (Tukey's HSD; $P < 0.05$).
[2]Termite feeding, depositing fecal materials or building mud or gallery on wood.
[3]Visual assessment: 0 = No attack; 1 = Slight superficial attack; 2 = Superficial-medium attack (not deep inside); 3 = Heavy attack (penetrated); 4 = Very heavy attack (almost collapsed).

Results indicated that rubber was the most preferred wood with a significantly higher mean wood mass loss when compared with other wood species, followed by terentang and jelutong. No significant difference, however was detected for the latter two wood species. The remaining wood species were less preferred and were found to have no significant difference in wood mass losses. These results were also comparable with the mean visual rating for damage assessments where

Table 8: Mean wood consumption and wood contact of 15 Malaysian wood species by *M. gilvus* after 2 months exposure in the field.

Wood species	Common name	Mean wood mass loss[1] (g)	Means wood mass loss[1] (%)	Termite Contact[1,2] (%)	Mean ± SE [1,3] Visual rating
Shorea sp.	White meranti	- 0.0387± 0.1939 a	- 0.5064 ± 0.2521	100.00	0.06 ± 0.06 a
Shorea sp.	Balau	0.0839 ± 0.0739 a	0.0959 ± 0.0803	100.00	0.11 ± 0.08 a
Pentace sp.	Melunak	0.0946 ± 0.1016 a	0.1036 ± 0.1104	100.00	0.06 ± 0.06 a
Intsia palembanica	Merbau	0.1149 ± 0.1246 a	0.1328 ± 0.1444	100.00	0.22 ± 0.13 a
Ganua sp.	Nyatoh	0.2067 ± 0.2347 a	0.3176 ± 0.3629	100.00	0.11 ± 0.11 a
Species of Lauraceae	Medang	0.4418 ± 0.1133 a	0.6893 ± 0.1748	100.00	0.17 ± 0.09 a
Pterocarpus indicus	Angsana	0.7875 ± 0.2014 a	1.1773 ± 0.3046	100.00	0.00 ± 0.00 a
Parinari sp.	Membatu	1.3293 ± 0.4027 a	1.6280 ± 0.5057	100.00	0.11 ± 0.08 a
Shorea sp.	Red meranti	1.5774 ± 0.8466 a	2.6790 ± 1.4125	100.00	0.78 ± 0.23 ab
Tectona grandis	Teak	2.2798 ± 2.3195 a	3.1111 ± 3.3393	100.00	0.56 ± 0.24 ab
Elanteriospermum tapos	Perah	3.3443 ± 0.9564 a	4.8416 ± 1.3994	100.00	0.83 ± 0.22 ab
Pinus caribaea	Pine	6.5923 ± 2.8233 a	13.0608 ± 5.6061	100.00	2.33 ± 0.30 bc
Dyera costulata	Jelutong	25.9405 ± 4.8591 b	60.4262 ± 4.8591	100.00	3.56 ± 0.17 c
Campnosperma auriculata	Terentang	32.6265 ± 3.1876 b	79.3174 ± 7.1274	100.00	3.44 ± 0.24 c
Hevea brasieliensis	Rubber	47.2344 ± 8.0337 c	46.2676 ± 7.9872	100.00	3.44 ± 0.21 c

[1]Data were based on 18 stakes (9 replicates x 2 stakes per wood species) and, means within the same column followed by different letters were significantly different.
[2]Termite feeding, depositing fecal materials or building mud or gallery on wood.
[3]Visual assessment: 0 = No attack; 1 = Slight superficial attack; 2 = Superficial-medium attack (not deep inside); 3 = Heavy attack (penetrated); 4 = Very heavy attack (almost collapsed)

"heavy" to "very heavy attack" were found on rubber, terentang and jelutong. Therefore, rubber, terentang and jelutong could be the most suitable wood to be used in termite baiting system against *M. gilvus*.

CONCLUSION

Three Malaysian woods namely, rubber, jelutong and terentang were shown to have great potential to be used in termite bait matrix. This selection was based on the results obtained from various evaluations on relative preferences of these wood species to the various termite species tested. These wood species are also easily procured from most sawmills in Malaysia. Several Japanese wood species (such as hiba and buna) which were tested in this study were relatively more preferred by the Malaysian *Coptotermes* when compared to the earlier studies of Japanese *C. formosanus*. This possibly suggested differential feeding response among *Coptotermes* species, as well as towards wood species from different geographical localities.

In most commercially available baiting systems, southern yellow pine (*Pinus radiate*) is widely used. The choice of this species was likely based on studies which had been conducted in the United States. Our experience has revealed that rubber wood is a better choice for detection of multiple termite species in monitoring stations in Malaysia (C.Y. Lee *et al.*, unpublished). Thus the use of a more attractive wood species may increase the percentage of monitoring devices being attacked and aggregated by termites during the monitoring process. In addition, the cost of baiting can probably be reduced if the period between installation of monitoring devices to termite attacks can be reduced. This may also decrease the cost of baiting since fewer visits to the baited site will be required of the pest control operator if the period between installation of monitoring stations and termite attack is reduced.

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