Decay Resistance of Various Timber Species against Soft Rot Fungus, *Chaetomium globosum* KUNZE, in Accelerated Laboratory Tests*

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Abstract——Decay resistance of various temperate zone timber species (138 spp. of hardwoods and 44 spp. of softwoods) against a soft rot fungus, *Chaetomium globosum* KUNZE was estimated with reference to methanol extractives in wood in laboratory sand block tests. *Morus alba, Morus bombycis, Robinia pseudoacacia, Picrasma quessioides, Ternstroemia japonica, Pieris japonica, Vacinum bracteatum, Ehretia ovalifolia* and *Paulownia tomentosa* were designated as very durable hardwoods. Heartwoods of 14 species were classified in perishable class. Variances of decay resistance among species and families were considered not to be much different from those in the case of Basidiomycetes. Softwood species were slightly attacked and the greater part of species retained high resistance after treatment with hot methanol. In the case of *Coriolus versicolor* QUÉL., a white rot fungus, extractive-rich species of softwoods were more resistant to decay, and the greater part of such species became less resistant after the treatment. It may be possible to conclude that the role of extractives on the higher resistance of softwoods against soft rot fungi is generally poor.

Introduction

In the three major types of wood decay caused by fungi, an apparent host-wood preference has been found to exist. Brown rot fungi are associated most frequently with the decay of softwoods, and white rot and soft rot fungi with the decay of hardwoods, although there seems to be no complete specificity involved.[1] The fact that a preference to hardwoods is strong in the decay by soft rot fungi has been pointed out over the past years as an important feature in soft rot.[2,3,4,5] However, data on the decay resistance of hardwoods against soft rot fungi have been restricted to comparatively narrow range in botanical taxis. Consequently, an insufficient number of experimental results cannot draw a conclusion that there is a tendency for the decay resistance of various hardwoods against soft rot fungi to be generally similar to the reputed durability of these woods mainly established from the results with Basidiomycetes and termites.

The higher resistance of softwoods against soft rot fungi, as a reflection of the strong preference to hardwoods, has been discussed in relation to the different natures and content of lignins in softwoods and hardwoods.[6,7,8] In addition, different natures of hemicelluloses in these woods have been suggested with reference to the different susceptibility to soft rot fungi.[7,9,10] BAILEY *et al.*[7], from the results obtained with three species of softwoods after water and organic solvent extraction using three species of soft rot fungi, concluded that an inhibition effect of toxic compounds in the woods on the susceptibility to soft rot fungi was not present. However, it seems to be uncertain, due to an insufficient numner of experimental materials, that absence

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of such an effect is generalized in various softwoods.

In the present investigation, in course of studying the different susceptibility of softwoods and hardwoods against soft rot fungi, decay resistance of various timber species against a soft rot fungus, *Chaetomium globosum*, was estimated with reference to heartwood extractives, occasionally comparing with the results using a white rot fungus, *Coriolus versicolor*.

Materials and Methods

Timber species and preparation of test blocks

The names of timber species used in the experiment and their sources are listed in Table 1 and Table 2. Almost of important species in Japan are involved in 138 species of hardwoods, which covered 41 families, including 89 genera, and 44 species of softwoods, which covered 8 families, including 24 genera. Considering the well established trend of increasing decay resistance from the innermost to the outermost heartwood,[11,12] heartwood samples were taken as near as possible from the intermediate portion. Sampling of sapwood samples, if possible, was made also from the middle part.

The size of test block was : 2.0 (tangential) $\times$ 2.0 (radial) $\times$ 0.5 (longitudinal) (cm).

Test fungi

Usually, *Chaetomium globosum* KUNZE (Strain No. 8059) was used as a test fungus. For the purpose of comparison, *Coriolus versicolor* QUÉL. (No. 1030) was used in decay tests of softwood specics.

Extraction of test blocks with hot methanol

It is frequently pointed out that the durability of a specific heartwood is due to toxic extractives in the wood. Extractives are those substances which are removed from wood by extraction with neutral solvents. Although no single sequence of extractions is equally applicable to all woods owing to the variable composition of the extractives, methanol is preferentially used as the first solvent for successive extractions. In order to clarify the effect of the removal of extractives on decay resistance, test blocks from those species which were designated resistant against *Ch. globosum* from the results with decay tests of non-treated blocks, were extracted with hot methanol for eight hours and exposed to the test fungi. The content of methanol extractives was calculated by reweighing the extracted test block.

Decay tests

The decay tests were carried out by the sand block method. Cylindrical glass bottles (9 cm in diameter and 16 cm in height), containing 350 g of quartz sand (ca. 30 mesh) and 120 ml of nutrient solution, were screwed with metal caps. The bottles were autoclaved and inoculated with the test fungi which were allowed to cover the surface of the medium before the test blocks were inserted. Three blocks were inserted into a bottle and 6 blocks in two bottles were used in each species.

The composition of the nutrient solutions was as follows :

for the decay test using *Ch. globosum*,

NH_4NO_3 3.0 g, KH_2PO_4 2.5 g, K_2HPO_4 2.0 g, $MgSO_4 \cdot 7H_2O$ 2.0 g, glucose 25.0 g and distilled water 1000 ml.

for the decay test using *Co. versicolor*,

KH_2PO_4 3.0 g, $MgSO_4 \cdot 7H_2O$ 2.0 g, peptone 5.0 g, malt extract 10.0 g, glucose 25.0 g and dis-

Table 1. Hardwood timber species used in the experiment.

No.*	Family	Botanical name**	Common name***		Remark****
			Japanese	English	
H- 1	Salicaceae	*Populus maximowiczii* HENRY	Doro-no-ki	Japan poplar	W
H- 2	,,	*Populus nigra* L. var. *italica* KOEHNE	Seiyo-hako-yanagi	Lombardy poplar	K
H- 3 H- 3	,,	*Salix sachalinensis* Fr. SCHM.	Onoe-yanagi	(Willow)	A
H- 4	,,	*Salix alopechroa* KIMURA	Sai-goku-kitsune-yanagi	(Willow)	K
H- 5 H- 5	,,	*Toisusu urbaniana* KIMURA var. *schneideri* KIMURA	Tokachi-yanagi	(Willow)	W
H- 6	Juglandaceae	*Juglans mandschurica* MAXIM. subsp. *sieboldiana* KITAM.	Oni-gurumi	Japanese walnut	W
H- 7 H- 7	,,	*Pterocarya rhoifolia* SIEB. et ZUCC.	Sawa-gurumi	Japanese wingnut	W
H- 8	Betulaceae	*Ostrya japonica* SARG.	Asada	Japanese hophornbeam	W
H- 9 H- 9	,,	*Carpinus japonica* BLUME	Kuma-shide	(Hornbeam)	W
H- 10	,,	*Carpinus tschnoskii* MAXIM.	Inu-shide	(Hornbeam)	W
H- 11	,,	*Corylus sieboldiana* BLUME	Tsuno-hashibami	(Hazel)	A
H- 12 H- 12	,,	*Betula ermani* CHAM.	Dake-kanba	Dakekaba	W
H- 13 H- 13	,,	*Betula grossa* SIEB. et ZUCC.	Mizume	(Birch)	W
H- 14 H- 14	,,	*Betula platyphylla* SUKAT. var. *japonica* HARA	Shira-kanba	Shirakaba	W
H- 15	,,	*Alnus firma* SIEB. et ZUCC. var. *hirtella Franch.* et SAV.	Miyama-yasha-bushi	(Alder)	K
H- 16	,,	*Alnus hirsuta* TURCZ.	Ke-yama-han-no-ki	(Alder)	W
H- 17	,,	*Alnus hirsuta* TURCZ. var. *sibirica* C. K. SCHNEID.	Yama-han-no-ki	(Alder)	K
H- 18	,,	*Alnus japonica* STEUD.	Han-no-ki	Japanese alder	K
H- 19 H- 19	Fagaceae	*Fagus crenata* BLUME	Buna	Japanese beech	W
H- 20	,,	*Querqus acutissima* CARR.	Kunugi	Kunugi oak	W
H- 21	,,	*Querqus mongolica* FISCH.	Mizu-nara	Karafuto oak	W
H- 22 H- 22	,,	*Querqus serrata* THUNB.	Ko-nara	Konara oak	A
H- 23	,,	*Querqus variabilis* BLUME	Abe-maki	(Oak)	K
H- 24	,,	*Querqus acuta* THUMB.	Aka-gashi	(Oak)	W
H- 25 H- 25	,,	*Querqus gilva* BLUME	Ichii-gashi	(Oak)	W
H- 26	,,	*Querqus glauca* THUNB.	Ara-kashi	Ring-cupped oak	K
H- 27 H- 27	,,	*Querqus hondai* MAKINO	Hanaga-gashi	(Oak)	W
H- 28	,,	*Lithocarpus amygdafolia* SIEB. et ZUCC.	Ami-gashi	(Lithocarpus)	W
H- 29	,,	*Castanea crenata* SIEB. et ZUCC.	Kuri	Japanese chestnut	W
H- 30	,,	*Castanopsis cuspidata* SCHOTTKY	Tsubura-jii	(Western chinquapin)	W
H- 31 H- 31	,,	*Castanopsis* sp.	(Shii)	(Castanopsis)	W
H- 32	,,	*Passania edulis* MAKINO	Mateba-shii	(Passania)	K

H- 33 H- 33	Ulmaceae	*Ulmus davidiana* PLANCH. var. *japonica* NAKAI	Haru-nire	Nire-elm	W
H- 34	,,	*Ulmus lacinata* MAYR	O-hyo	Ohyo-nire	W
H- 35 H- 35	,,	*Zelkova serrata* MAKINO	Keyaki	Keyaki	W
H- 36	,,	*Celtis sinensis* PERS. var. *japonica* NAKAI	Enoki	Japanese hackberry	W
H- 37	,,	*Aphananthe aspera* PLANCH.	Muku-no-ki	(Aphananthe)	W
H- 38 H- 38	Moraceae	*Morus alba* L.	Kuwa	Silkworm mulberry	W
H- 39 H- 39	,,	*Morus bombycis* KOIDZ.	Yama-guwa	(Mulberry)	A
H- 40	,,	*Broussonetia kazinoki* SIEB.	Kouzo	Paper mulberry	A
H- 41	,,	*Cudrania tricuspidata* BUREAU	Hari-guwa	(Cudrania)	K
H- 42 H- 42	Trochodendraceae	*Trochodendron aralioides* SIEB. et ZUCC.	Yama-guruma	(Trochodendron)	W
H- 43 H- 43	Cercidiphyllaceae	*Cercidiphyllum japonicum* SIEB. et ZUCC.	Katsura	Katsura	W
H- 44	Magnoliaceae	*Magnolia liliflora* DESR.	Moku-ren	(Cucumber tree)	K
H- 45	,,	*Magnolia kobus* DC.	Kobushi	Thunber's Magnolia	K
H- 46	,,	*Magnolia praecocissima* KOIDZ.	Ezo-kobushi	(Cucumber tree)	W
H- 47	,,	*Magnolia obovata* THUNB.	Ho-no-ki	Japanese cucumber tree	W
H- 48	,,	*Magnolia salicifolia* MAX.	Tamushi-ba	(Cucumber tree)	A
H- 49 H- 49	Lauraceae	*Cinnamomum camphora* SIEB.	Kusu-no-ki	Camphorwood	W
H- 50 H- 50	,,	*Cinnamomum japonicum* SIEB.	Yabu-nikkei	(Camphorwood)	W
H- 51	,,	*Machilus thunbergii* SIEB. et ZUCC.	Tabu-no-ki	(Machilus)	W
H- 52 H- 52	,,	*Lindera erythrocarpa* MAKINO	Kana-kugi-no-ki	(Lindera)	W
H- 53 H- 53	,,	*Neolitsea aciculata* KOIDZ.	Inu-gashi	(Neolitsea)	W
H- 54 H- 54	,,	*Actinodaphne lancifolia* MEISSN.	Kago-no-ki	(Actinodaphne)	W
H- 55 H- 55	,,	*Actinodaphne longifolia* NAKAI	Bari-bari-no-ki	(Actinodaphne)	W
H- 56 H- 56	Saxifragaceae	*Hydrangea paniculata* SIEB.	Nori-utsugi	Panicle hydrangea	A
H- 57	Hamamelidaceae	*Distylium racemosum* SIEB. et ZUCC.	Isu-no-ki	(Distylium)	W
H- 58 H- 58	,,	*Hamamelis japonica* SIEB. et ZUCC.	Man-saku	Japanese witch hazel	A
H- 59	,,	*Hamamelis japonica* SIEB. et ZUCC. var. *obtusata* MATSUM.	Maru-ba-mansaku	(Witch hazel)	K
H- 60 H- 60	Rosaceae	*Prunus sargenti* REHD.	O-yama-zakura	(Plum, Cherry)	W
H- 61 H- 61	,,	*Prunus sargenti* REHD. subsp. *jamasakura* OHWI	Yama-zakura	(Plum, Cherry)	W
H- 62	,,	*Prunus ssiori* FR. SCHM.	Shiuri-zakura	(Plum, Cherry)	W
H- 63	,,	*Prunus subhirtella* MIQ.	Higan-zakura	(Plum, Cherry)	W
H- 64 H- 64	,,	*Prunus spinulosa* SIEB. et ZUCC.	Rin-boku	(Plum, Cherry)	W
H- 65	,,	*Eriobotrya japonica* LINDL.	Biwa	Loquat	K
H- 66	,,	*Chaenomeles sinensis* KOEHNE	Karin	(Flowering quince)	K

H- 67	Rosaseae	*Sorbus commixta* HEDL.	Nana-kamado	Mountain ash	A
H- 68	,,	*Crataegus chlorosarca* MAXIM.	Kuro-mi-sanzashi	(Hawthorn)	W
H- 69	Leguminosae	*Albizzia julibrissin* DURAZZ.	Nemu-no-ki	Silk flower	W
H- 70	,,	*Maackia amurensis* RUPE. et MAXIM. var. *buergeri* C. K. SCHNEID.	Inu-enjyu	(Maackia)	W
H- 71 H- 71	,,	*Cladrastis platycarpa* MAKINO	Fuji-ki	(Yellow wood)	W
H- 72 H- 72	,,	*Wisteria prachybotrys* SIEB. et ZUCC.	Yama-fuji	(Wisteria)	A
H- 73	,,	*Robinia pseudoacacia* L.	Hari-enjyu	Black locust	K
H- 74	Rutaceae	*Zanthoxyllum ailanthoides* SIEB. et ZUCC.	Karasu-zansho	(Toothache tree)	K
H- 75	,,	*Phellodendron amurense* RUPR.	Ki-hada	Amur cork tree	W
H- 76	Simaroubaceae	*Ailanthus altissima* SWINGLE	Niwa-urushi	Tree of heaven	K
H- 77	,,	*Picrasma quessioides* BENN.	Niga-ki	(Bitter wood)	W
H- 78	Euphorbiaceae	*Mallotus japonicus* MUEL. ARG.	Aka-me-gashiwa	(Mallotus)	A
H- 79 H- 79	,,	*Daphiniphyllum macropodium* MIQ.	Yuzuri-ha	(Daphiniphyllum)	W
H- 80	Anacardiaceae	*Rhus succedanea* L.	Haze-no-ki	Japanese wax tree	W
H- 81	,,	*Rhus sylvestris* SIEB. et ZUCC.	Yama-haze	(Sumac)	
H- 82 H- 82	,,	*Rhus verniciflua* STOKES	Urushi	Varnish tree	A
H- 83	Aquifoliaceae	*Ilex crenata* THUNB.	Inu-tsuge	Japanese holly	W
H- 84 H- 84	,,	*Ilex macropoda* MIQ.	Ao-hada	(Holly)	A
H- 85	,,	*Ilex rotunda* THUNB.	Kuro-gane-mochi	(Holly)	W
H- 86	Aceraceae	*Acer crataegifolium* SIEB. et ZUCC.	Uri-kae-de	Hawthorn maple	A
H- 87	,,	*Acer japonicum* THUNB.	Ha-uchiwa-kae-de	Fullmoon maple	A
H- 88	,,	*Acer mono* MAXIM.	Itaya-kae-de	Painted maple	A
H- 89 H- 89	,,	*Acer mono* MAXIM. var. *mayrii* KOIDZ.	Beni-itaya	(Maple)	A
H- 90	,,	*Acer rufinerve* SIEB. et ZUCC.	Uri-hada-kae-de	(Maple)	W
H- 91	,,	*Acer palmatum* THUNB.	Iroha-momiji	(Maple)	W
H- 92 H- 92	Hippocastanaceae	*Aesculus turbinata* BLUME	Tochi-no-ki	Japanese horse-chestnut	A
H- 93	Sapindaceae	*Sapindus mukurosii* GAERTN.	Mukuro-ji	Soap nut tree	W
H- 94 H- 94	Sabiaceae	*Meliosma myriantha* SIEB. et ZUCC.	Awa-buki	(Meliosma)	A
H- 95	,,	*Meliosma oldhami* MIQ.	Yan-baru-awa-buki	(Meliosma)	K
H- 96	,,	*Meliosma rigida* SIEB. et ZUCC.	Yama-biwa	(Meliosma)	W
H- 97 H- 97	Rhamnaceae	*Hovenia dulcis* THUNB.	Kenpo-nashi	Japanese raisin tree	A
H- 98 H- 98	Elaeocarpaceae	*Elaeocarpus japonicus* SIEB. et ZUCC.	Koban-mochi	(Elaeo-carpus)	W
H- 99	Tiliaceae	*Tilia japonica* SIMK.	Shina-no-ki	Shina-lime	W
H- 100	,,	*Tilia kiusiana* MAKINO et SHIRASAWA	Hera-no-ki	Kiushu-linden	W
H- 101	Actinidiaceae	*Actinidia polygama* MAXIM.	Mata-tabi	(Actinidia)	A
H- 102	Theaceae	*Camellia japonica* L.	Tsubaki	Camellia	W
H- 103	,,	*Camellia sasanqua* THUNB.	Sazan-ka	(Camellia)	W
H- 104 H- 104	,,	*Stewartia monadelpha* SIEB. et ZUCC.	Hime-shara	(Stewartia)	W
H- 105	,,	*Ternstroemia japonica* THUNB.	Mokkoku	(Ternstroemia)	W

H-106	,,	*Eurya japonica* THUNB.	Hi-sakaki	Japanese Eurya	W
H-107	Flacourtiaceae	*Idesia polycarpa* MAXIM.	Ii-giri	(Idesia)	W
H-108	Araliaceae	*Aralia elata* SEEM.	Tara-no-ki	Japanese angelica tree	A
H-109 H-109	,,	*Acanthopanax sciadophylloides* FR. et SAV.	Koshi-abura	(Acanthopanax)	A
H-110 H-110	,,	*Evodiopanax innovans* NAKAI	Taka-no-tsume	(Evodiopanax)	A
H-111	,,	*Kalopanax septemlobus* KOIDZ.	Sen	Castor Aralia	W
H-112 H-112	,,	*Kalopanax septemlobus* KOIDZ. var. *lutchuense* NEMOTO	Miyako-dara	(Castor Aralia)	W
H-113 H-113	Cornaceae	*Cornus controversa* HEMSL.	Mizu-ki	Cornel	W
H-114	,,	*Cornus macrophylla* WALL.	Kuma-no-mizu-ki	(Cornel)	W
H-115	Clethraceae	*Clethra barbinervis* SIEB. et ZUCC.	Ryu-bu	Clethra	A
H-116	Ericaceae	*Rhododendron tashiroi* MAXIM.	Sakura-tsutsuji	(Rose bay)	W
H-117 H-117	,,	*Pieris japonica* D. DON	Asebi	Japanese Andromeda	A
H-118 H-118	,,	*Lyonia elliptica* OKUYAMA	Neji-ki	(Lyonia)	A
H-119	,,	*Vacinum bracteatum* THUNB.	Sha-shan-po	(Billberry)	W
H-120 H-120	Ebenaceae	*Diospyros kaki* THUMB. var. *sylvestris* MAKINO	Yama-gaki	(Persimmon)	W
H-121 H-121	,,	*Diospyros morrisiana* HANCE	Tokiwa-gaki	(Persimmon)	W
H-122	Symplocaceae	*Symplocos chinensis* DRUCE var. *leucocarpa* OHWI f. *pilosa* OHWI	Sawa-futagi	Japanese turquoise tree	A
H-123	,,	*Symplocos lucida* SIEB. et ZUCC.	Kuro-ki	(Sweetleaf)	W
H-124	,,	*Symplocos prunifolia* SIEB. et ZUCC.	Kuro-bai	(Sweetleaf)	W
H-125	Styracaceae	*Styrax japonica* SIEB. et ZUCC.	Ego-no-ki	Japanese snowbell	W
H-126 H-126	,,	*Pterostyrax hipsida* SIEB. et ZUCC.	O-ba-asa-gara	Fragrant eponlette	A
H-127	Oleaceae	*Syringa reticulata* HARA	Hashi-doi	(Lilac)	W
H-128	,,	*Ligustrum lucidum* AIT.	To-nezumi-mochi	Glossy Privet	K
H-129 H-129	,,	*Fraxinus languinosa* KOIDZ. var. *serrata* NAKAI	Koba-no-toneriko	(Ash)	W
H-130	,,	*Fraxinus mandschurica* RUPR. var. *japonica* MAX.	Yachi-damo	Japanese Manchurian ash	W
H-131 H-131	,,	*Fraxinus longicuspis* SIEB. et ZUCC.	Yamato-ao-damo	(Ash)	A
H-132 H-132	,,	*Fraxinus spaethiana* Lingelsh	Shio-ji	(Ash)	W
H-133	,,	*Fraxinus insularis* HEMSL.	Shima-toneriko	(Ash)	K
H-134 H-134	Boraginaceae	*Ehretia ovalifolia* HASSK.	Chisha-no-ki	(Ehretia)	W
H-135	Verbenaceae	*Callicarpa japonica* THUNB.	Murasaki-shiki-bu	(Beauty berry)	A
H-136	,,	*Clerodendron trichotomum* THUMB.	Kusa-gi	(Clerodendron)	A
H-137	Scrophulariaceae	*Paulownia tomentosa* STEUD.	Kiri	Kiri	W
H-138	Caprifoliaceae	*Sambucus racemosa* L. subsp. *sieboldiana* HARA	Niwa-toko	Red-berried elder	A

* Underlined figure represents a sapwood sample.

** According to KITAMURA, S. and S. OKAMOTOS' "Coloured Illustrations of Trees and Shurubs of Japan" (Genshoku Nippon Jyumoku Zukan), Hoikusha, Osaka (1960).

*** Mainly according to KISHIMA, T., S. OKAMOTO and S. HAYASHIS' "Atlas of Wood in Colour" (Genshoku Mokuzai Dai Zukan), Hoikusha, Osaka (1962), and occasionally to J. BARNER's "Die Nutzhölzer der Welt" (Neudruck), Banden 1-4, Verlag von J. Cramer, Weinheim (1961-1962). The bracketed name is the general name of the genus.

**** The material was taken from the following sources:

A : Kyoto University Forests in Ashiu, Kyoto Pref.

K : Kyoto University Forests in Kamigamo Experimental Station, Kyoto Pref.

W : Collection of Wood Research Institute, Kyoto University.

Table 2. Softwood timber species used in the experiment.

No.*	Family	Botanical name**	Common name***		Remark****
			Japanese	English	
1	Ginkgoaceae	*Ginkgo biloba* L.	Icho	Maidenhair tree	W
2	Taxaceae	*Taxus cuspidata* SIEB. et ZUCC.	Ichi-i	Japanese yew	W
3	,,	*Torreya nucifera* SIEB. et ZUCC.	Kaya	Japanese Torreya	W
4	Podocarpaceae	*Podocarpus macrophylla* D. DON	Inu-maki	Longleaf Podocarp	W
5	,,	*Podocarpus nagi* ZOLL. et MORITZ.	Nagi	Nagi Podocarp	W
6	Cephalotaxaceae	*Cephalotaxus harringtonia* K. KOCH	Inu-gaya	Japanese plum yew	W
7	Pinaceae (Abietoideae)	*Abies firma* SIEB. et ZUCC.	Momi	Japanese fir	W
8	,,	*Abies mariessi* MAST.	Aomori-todo-matsu	Maries' fir	W
9	,,	*Abies sachalinensis* Fr. SCHM.	Todo-matsu	Sachalin fir	W
10 10	,,	*Abies sachalinensis* Fr. SCHM. var. *mayriana* MIYABE et KUDO	Ao-todo-matsu	(Fir, Spruce)	W
11	,,	*Pseudotsuga japonica* BEISSN.	Toga-sawara	Japanese Douglas fir	K
12 12	,,	*Tsuga sieboldii* CARR.	Tsuga	Japanese hemlock	W
13 13	,,	*Picea glehnii* MAST.	Aka-ezo-matsu	Glehn's spruce	W
14	,,	*Picea jezoensis* CARR.	Ezo-matsu	Yezo spruce	W
15 15	,,	*Picea abies* KARST.	Doitsu-to-hi	Spruce	A
16 16	,,	*Larix leptolepsis* GORD.	Kara-matsu	Japanese larch	A
17	,,	*Larix gmelini* LEDEB.	Gui-matsu	Kurile larch	W
18	,,	*Keteleeria davidiana* BEISSN.	Yu-san	Abura-sugi	K
19 19	(Pinoideae)	*Pinus densiflora* SIEB. et ZUCC.	Aka-matsu	Japanese red pine	W
20 20	,,	*Pinus pentaphylla* MAYR.	Hime-ko-matsu	Japanese white pine	A
21 21	,,	*Pinus thunbergii* PARL.	Kuro-matsu	Japanese black pine	W
22	,,	*Pinus tabulaeformis* CARR.	Manshu-kuro-matsu	Manchurian pine	K
23	,,	*Pinus radiata* D. DON	Radiata-matsu	Montrey pine	K
24	,,	*Pinus rigida* MILL.	Rigida-matsu	Black pine	K
25	,,	*Pinus taeda* L.	Te-da-matsu	Torchpine	K
26	,,	*Pinus sylvestris* L.	O-shu-aka-matsu	Scots pine	K
27	,,	*Pinus nigra* ARN.	O-shu-kuro-matsu	Corcican black pine	K
28	,,	*Pinus strobus* L.	Suto-ro-bu-matsu	White pine	K
29	,,	*Pinus virginiana* MILL.	Ba-jinia-matsu	Virginia pine	K
30	,,	*Pinus elliottii* ENGELM.	Eriotti-matsu	American pitch pine	K

31	Sciadopity-aceae	*Sciadopitys verticillata* Sieb. et Zucc.	Koya-maki	Umbrella pine	W
32 32	Taxodiaceae	*Sequoia sempervirens* Endl.	Sekoia	Redwood	K
33 33	,,	*Metasequoia glyptostroboides* Hu et Cheng	Meta-sekoia	Dawn redwood	A
34	,,	*Glyptostrobus pensilis* K. Koch	Sui-sho	Swamp cypress	K
35	,,	*Taxodium distichum* Rich.	Numa-sugi	Bald cypress	K
36 36	,,	*Cryptomeria japonica* D. Don	Sugi	Japanese Cryptomeria	W
37 37	,,	*Cunninghamia konisii* Hayata	Randai-sugi	Formosa fir	W
38	,,	*Taiwania cryptomerioides* Hayata	Taiwan-sugi	Taiwania	W
39 39	Cupressaceae	*Chamaecyparis obtusa* Endl.	Hi-no-ki	Japanese cypress	W
40 40	,,	*Chamaecyparis pisifera* Endl.	Sawara	Sawara cypress	W
41 41	,,	*Chamaecyparis formosensis* Matsum.	Beni-hi	Formosan cypress	W
42	,,	*Thuja standishii* Carr.	Nezu-ko	Japanese arbor-vitae	W
43 43	,,	*Thujopsis dolabrata* Sieb. et Zucc.	Asu-naro	Hiba arbor-vitae	W
44	,,	*Juniperus virginiana* L.	Enpitsu-byaku-shin	Eastern red cedar	

Notes in this table are same as those in Table 1.

tilled water 1000 ml.

The weighed test blocks were sterilized by fumigation with propylene oxide, and exposed to test fungi. Test blocks for the decay test using *Ch. globosum* were soaked in sterilized distilled water after the fumigation, since soft rot fungi have a preference for wet conditions. The temperature was maintained at 28±2°C during a 56-day incubation period.

The decayed blocks, cleaned of mycelium, were dried to constant weight in a preconditioned room and oven. The percentage weight loss, calculated from initial and final weights, was used as a measure of the decay resistance.

Results and Discussion

On the classification of timbers on the basis of durability, a few schemes have been established over the past years. In England,[13] five classes were distinguished:

Durability	Loss in dry weight in laboratory test (%)
1 Very durable	nil or negligible
2 Durable	0 to 5
3 Moderately durable	5 to 10
4 Non-durable	10 to 30
5 Perishable	over 30

German classification[14] was:

Durability	Loss in dry weight in laboratory test (%)
1 Extremely durable	0 to 2

2	Very durable	2 to 12.5
3	Durable	12.5 to 25
4	Moderately durable	25 to 37.5
5	Non-durable	37.5 to 50
6	Perishable	over 50

In United States,[15] four classes were distinguished:

	Durability	Loss in dry weight in laboratory test (%)
1	Very resistant	0 to 10
2	Resistant	11 to 24
3	Moderately resistant	25 to 44
4	Non-resistant	over 45

These classification schemes have been essentially decided by comparing with the durability of test stakes in the field. English classification listed above corresponds with the life of test stake as follows:

1	Very durable	over 25 years
2	Durable	15 to 25 〃
3	Moderately durable	10 to 15 〃
4	Non-durable	5 to 10 〃
5	Perishable	less than 5 〃

On the other hand, United States classification corresponds with the weight loss of test stake as follows:

1	Very resistant	0 to 22 (%)
2	Resistant	23 to 40 〃
3	Moderately resistant	41 to 67 〃
4	Non-resistant	over 68 〃

In Japan, Matsuoka *et al.*[16] classified the durability of timbers into five groups on the basis of results with life of stake in the field:

1	Very durable	over 8 years
2	Durable	6 to 7 〃
3	Moderately durable	4 to 5 〃
4	Non-durable	2 to 3 〃
5	Perishable	less than 2 〃

Furthermore, Matsuoka *et al.*,[17] on the correlation between the loss of weight in laboratory test and the life of test stake in the field, presented the linear regression equation:

$$Y = 5.97 - 0.09X \quad (r = 0.6163, \ s = \pm 1.29)$$

in which Y represents life of test stake (years) and X loss in dry weight in laboratory test (%).

However, due to an insufficient number of test species, classification scheme has not yet been established in Japan.

In this experiment, on the basis of the weight loss in Japanese beech and frequency distribution in the weight loss of each species, the decay resistance of hardwood timber species

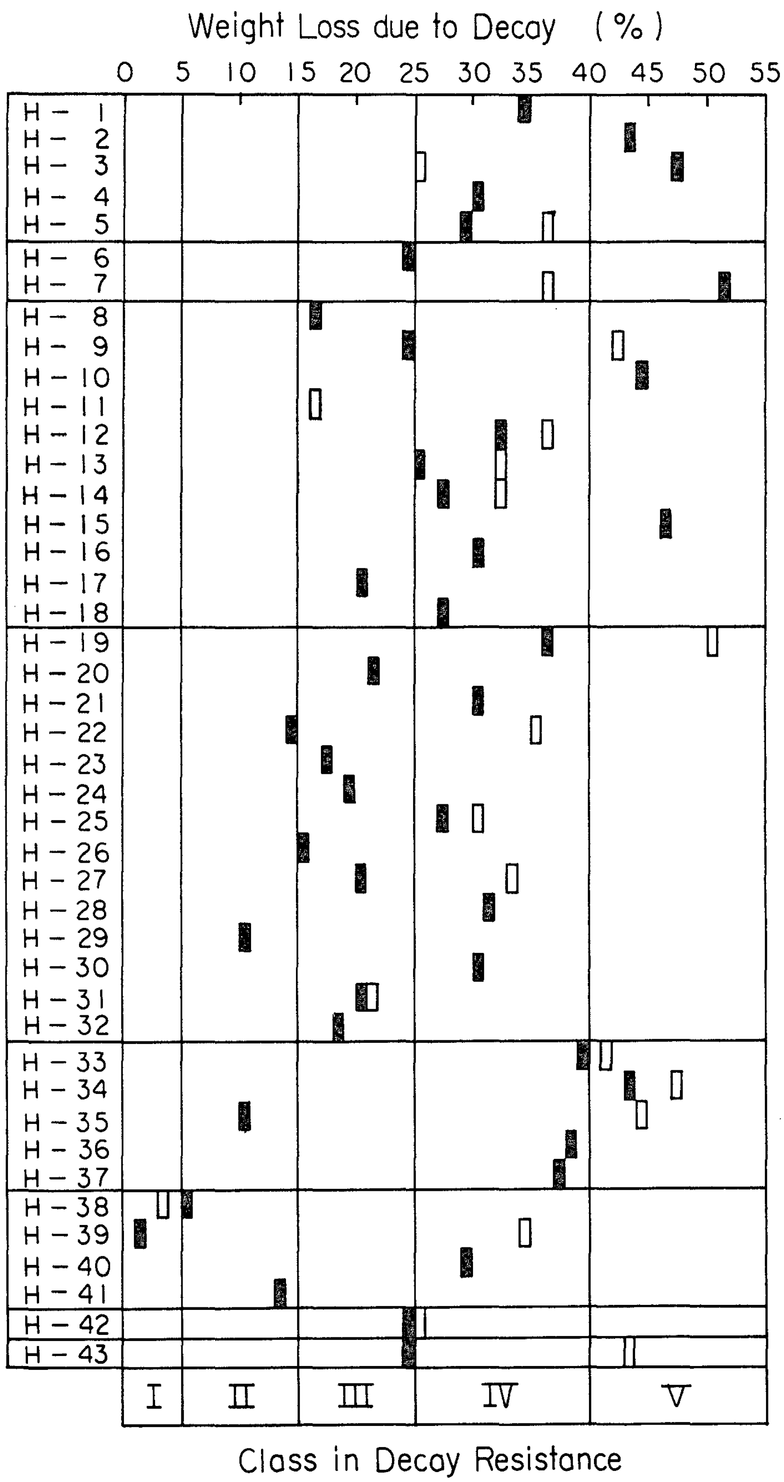

Fig. 1-1. Decay resistance of each hardwood timber species against *Ch. globosum*.
Number at leftmost corresponds with the number of timber species shown in Table 1. Black and white rectangles are illustrated as the weight loss value in heartwood and sapwood samples, respectively.

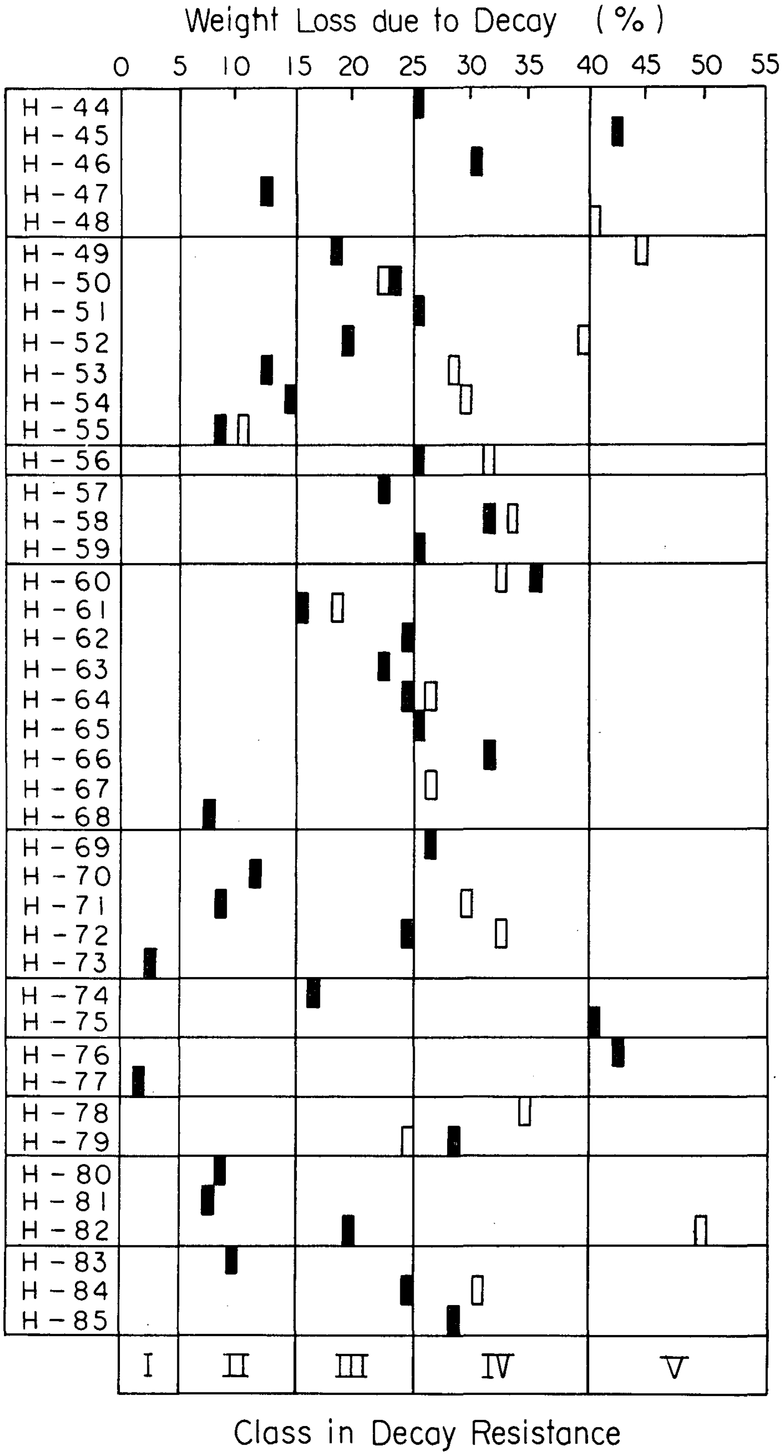

Fig. 1-2. Decay resistance of each hardwood timber species against *Ch. globosum*.
Number at leftmost corresponds with the number of timber species shown in Table 1. Black and white rectangles are illustrated as the weight loss value in heartwood and sapwood samples, respectively.

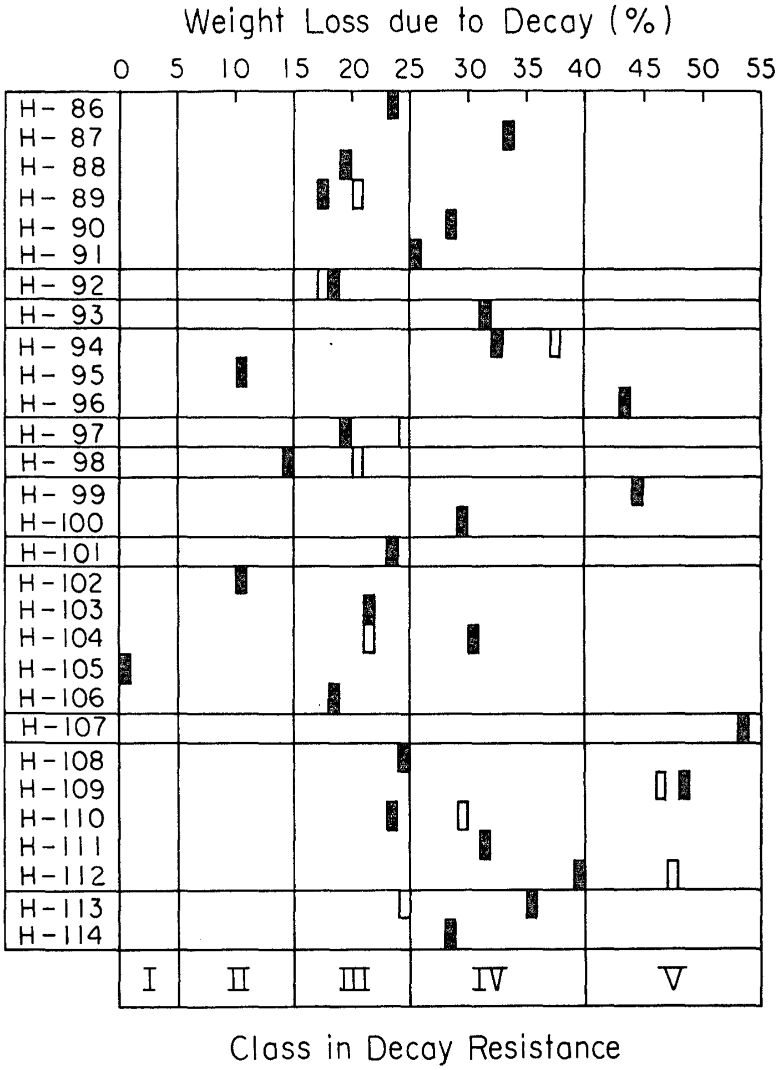

Fig. 1-3. Decay resistance of each hardwood timber species against *Ch. globosum*.
Number at leftmost corresponds with the number of timber species shown in Table 1. Black and white rectangles are illustrated as the weight loss value in heartwood and sapwood samples, respectively.

against *Ch. globosum* was distinguished in five classes as follows:

	Durability	Loss in dry weight in laboratory test (%)
I	Very durable	0 to 5
II	Durable	5 to 15
III	Moderately durale	15 to 25
IV	Non-durable	25 to 40
V	Perishable	over 40

According to this scheme, decay resistance of each hardwood timber species was shown in Figs. 1-1, 2, 3 and 4.

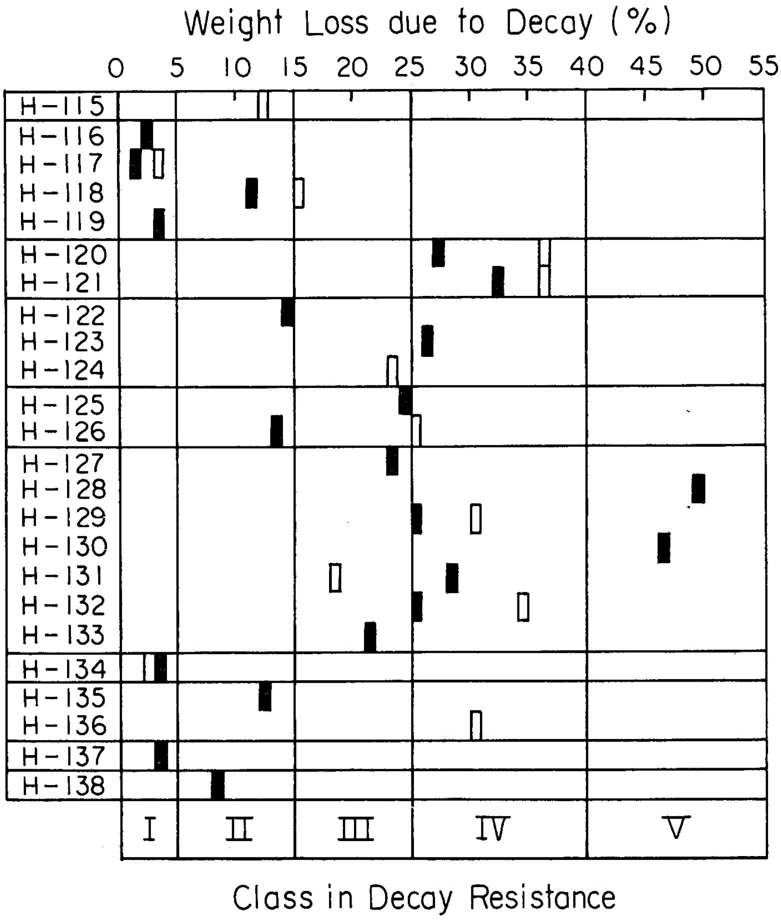

Fig. 1-4. Decay resistance of each hardwood timber species against *Ch. globosum*.
Number at leftmost corresponds with the number of timber species shown in Table 1. Black and white rectangles are illustrated as the weight loss value in heartwood and sapwood samples, respectively.

Thirty two species were classified into class I and class II. In these species, *Castanea crenata* (H-29),[16,18] *Zelkova serrata* (H-35)[16,18] and *Morus bombycis* (H-39)[16,18,20] are well known for their higher resistance against wood decay. It may be all right to consider that presences of tannins and related compounds in *C. crenata*,[24] keyakinin and keyakinol in *Z. serrata*,[25] and oxyresveratol and resveratol in *M. bombycis*[26] are mainly responsible for the higher resistance of these species.

Ternstroemia japonica (H-105)[19] is known as a very resistant species against termite attack. It was found that the cause of the resistance was associated with the presence of saponins in the wood extractives,[19,20,21] though the mechanism of the antitermitic action has not yet been clarified completely. Within the limit of the literature which we searched, we could not get the information on the antifungal action of saponins. However, it was reported that some surface active agents which have surface and hemolytic activities like saponins exhibited antifungal[27] or antitermitic action.[20] It will be of interest to see if saponins are associated with the higher resistance of *T. japonica* against *Ch. globosum*.

Magnolia obovata (H-47),[16] *Maackia amurensis* var. *buergeri* (H-70),[18] *Robinia pseudoacacia* (H-73),[16,18] *Rhus succedanea* (H-80)[21] and *Camellia japonica* (H-102)[19] have been also designated as durable species. In these species, correlation between durability and extractives has not yet been established, though various extractives, including alkaloids of *Magnolia*,[28,29] fisetin and fustin of *Rhus*[30] and saponins of *Camellia*[31], have been identified.

Informations on the durability of other species classified in class I and class II could not be obtained. However, oxyresveratol and resveratol have been isolated from *Cudrania tricuspidata* (H-41) and *Morus alba* (H-39).[31,32] Furansequiterpene[33] and paulownin[34] may be partly responsible for the higher resistance in *Neolitsea aciculata* (H-53) and *Paulownia tomentosa* (H-137), respectively. *Rhododendron tashiroi* (H-116), *Pieris japonica* (H-117, 117), *Lyonia elliptica* (H-118) and *Vacinum bracteatum* (H-119), all of them classified as Ericaceae, were very resistant against *Ch. globosum.* Grayanotoxin,[35] normally occurring in this family, may be partly associated with the higher resistance of these species. In addition, occurrences of pieristoxin[36] in *P. japonica*, and of lyoniatoxin and lyoniol[37] in *L. elliptica* have been reported.

Cercidiphyllum japonicum (H-43),[16] *Cinnamomum camphora* (H-49),[18] *Distylium racemosum* (H-57)[18,38] and *Prunus sargenti* subsp. *jamasakura* (H-61)[18] were not so resistant in this experiment as expected from their reputed durability. On the contrary, *Juglans mandschurica* subsp. *sieboldiana* (H-6),[18] *Alnus hirsuta* var. *sibirica* (H-117),[16] *Querqus serrata* (H-22),[16] *Passania edulis* (H-32),[16] *Aesculus turbinata* (H-92)[18] and *Elaeocarpus japonicus* (H-98)[19] were not so susceptible as expected. It is uncertain, at present stage, that such variances are attributed to the specificities in host-preference in *Ch. globosum.*

Among species designated as non-resistant (class IV) and perishable (class V), *Populus maximowiczii* (H-1),[18] *Populus nigra* var. *italica* (H-2),[19] *Pterocarya rhoifolia* (H-7, 7)[16,18] *Betula platyphylla* var. *japonica* (H-14, 14)[19] *Fagus crenata* (H-19, 19)[18,38] *Castanopsis cuspidata* (H-30),[18,19] *Ulmus davidiana* var. *japonica* (H-33, 33),[18] *Cercidiphyllum japonicum* (H-43),[18] *Albizzia julibrissin* (H-69),[18] *Phellodron amurense* (H-75),[18] *Tilia japonica* (H-99),[18] *Idesia polycarpa* (H-107)[16,19] and *Kalopanax septemlobus* (H-111)[18,19] have been known as non-durable or perishable species since long ago.

From the results obtained here, decay resistance of heartwood against *Ch. globosum* were classified by family as follows:

Moraceae (excepting *Bombycis*) and Ericaceae ; very burable.

Lauraceae and Leguminosae ; durable.

Fagaceae, Rosaceae and Aceraceae ; moderately durable to non-durable.

Betulaceae, Araliaceae and Oleaceae ; non-durable.

Salicaceae and Ulmaceae (excepting *Zelkova*) ; perishable.

Magnoliaceae and Theaceae ; variable durability involved.

Such variances of decay resistance among families and species could be considered not to be much different from those in the cases of Basidiomycetes.

Decay resistance of 44 softwood timber species against *Ch. globosum* and *Co. versicolor* was illustrated in Fig. 2. Very low decaying ability in *Ch. globosum* was confirmed here with various softwood species. Also *Co. versicolor* could not cause severe weight loss of softwoods, as expected from its hardwood-preference. For the convenience of discussion, decay resistance of softwoods was divided into four classes:

A: loss of weight 0 to 5 (%).

B: loss of weight 5 to 10 (%).

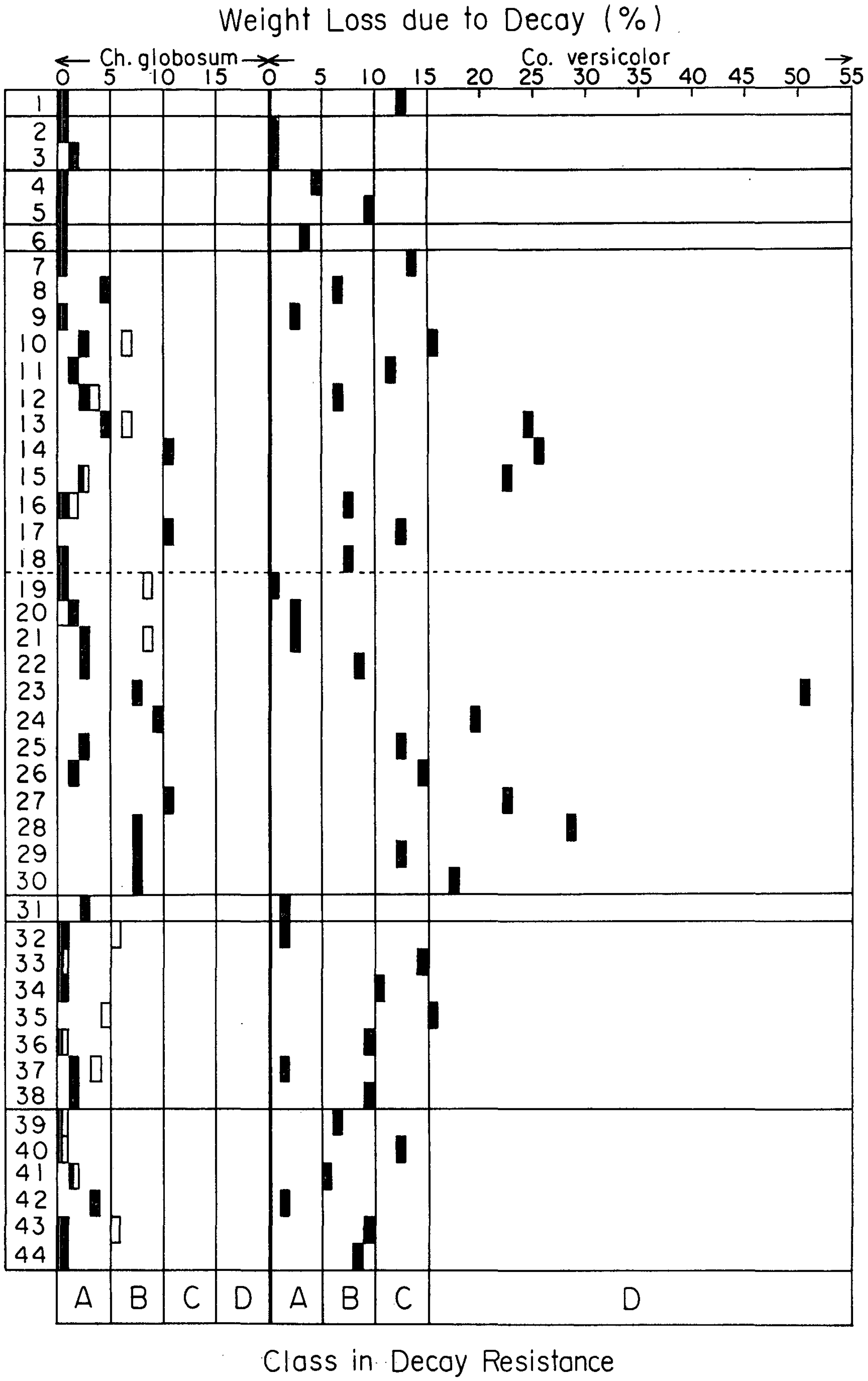

Fig. 2. Decay resistance of each softwood timber species against *Ch. globosum* and *Co. versicolor*.
Number at leftmost corresponds with the number of timber species shown in Table 2. Black and white rectangles are illustrated as the weight loss value in heartwood and sapwood samples, respectively.

C: loss of weight 10 to 15 (%).

D: loss of weight over 15 (%).

In this classification, order of resistance was not so emphasized as in that of hardwoods.

It is generally accepted, on the durability of softwood timbers, that most species in Pinaceae are more susceptible to fungal attack than those in Taxodiaceae and Cupressaceae. As seen in Fig. 2, such a tendency was apparent in both cases of *Ch. globosum* and *Co. versicolor*, though the magnitudes of variance in decay resistance were not in same scale. These results are discussed later in relation to the content of methanol extractives and the effect of methanol ex-

Table 3. Comparison in decay resistance between heartwood and sapwood samples against *Ch. globosum*. (Examined at 1% level of significance by t-distribution.)

No.*	Significant		Not significant	No.*	Significant		Not significant
	H**>S***	H**<S***			H**>S***	H**<S***	
H- 3		○		H- 89	○		
H- 5	○			H- 92			○
H- 7		○		H- 94			○
H- 9	○			H- 97	○		
H- 12			○	H- 98	○		
H- 13	○			H-104		○	
H- 14	○			H-109			○
H- 19	○			H-110			○
H- 22	○			H-112	○		
H- 25			○	H-113		○	
H- 27	○			H-117	○		
H- 31			○	H-118			○
H- 33			○	H-120	○		
H- 34			○	H-121			○
H- 35	○			H-126	○		
H- 38			○	H-129	○		
H- 39	○			H-131		○	
H- 42			○	H-132	○		
H- 43	○			H-134		○	
H- 49	○			10	○		
H- 50		○		12	○		
H- 52	○			13			○
H- 53	○			15			○
H- 54	○			16			○
H- 55			○	19	○		
H- 56			○	20			○
H- 58			○	21	○		
H- 60			○	32	○		
H- 61	○			33			○
H- 64			○	36			○
H- 71			○	37	○		
H- 72	○			39			○
H- 79		○		40			○
H- 82	○			41			○
H- 84			○	43	○		

* See Tables 1 and 2. ** Heartwood. *** Sapwood.

traction.

Table 3 shows the comparison of decay resistance between heartwood and sapwood of 70 timber species (56 spp. of hardwoods and 14 spp. of softwoods). The higher resistance in heartwood was found significant for 33 species (26 spp. of hardwoods and 7 spp. of softwoods), and the lower resistance of heartwood was for 8 species (in hardwoods only). Significant difference was not found in 29 species (20 spp. of hardwoods and 9 spp. of softwoods). In comparing these numbers, it may be noted that a significant difference was not found in about 40 % of test species, although it is generally considered that heartwood is more durable than sapwood. Average weight loss values of heartwood and sapwood were 23.86 % and 30.86 % in hardwoods, and 1.31 % and 3.63 % in softwoods. As shown in these results, difference of decay resistance between heart-

Table 4. Effect of methanol extraction on the decay resistance of 31 hardwood timber species against *Ch. globosum*.

No.*	Content of methanol extractives (%)	Weight loss (%)		Effect of extraction on decay**
		Not treated	Extracted by methanol	
H-105	1.48	0.63	1.41	
H- 39	6.38	1.33	6.88	+
H- 77	2.18	1.36	9.95	+
H-117	1.73	1.80	0.20	
H-116	2.08	2.41	0.07	−
H-137	7.92	3.14	42.06	+
H-119	3.10	3.58	2.27	
H-134	0.85	3.69	2.89	−
H- 38	4.77	5.63	6.42	
H- 68	5.97	7.79	17.74	+
H- 81	12.22	7.79	2.40	−
H- 80	10.61	8.36	8.22	
H- 55	0.77	8.69	5.34	−
H- 71	4.83	8.69	7.82	
H-138	0.90	8.94	3.18	−
H- 83	2.72	9.92	5.61	−
H- 35	10.98	10.18	9.07	
H- 29	8.09	10.32	16.86	+
H-102	0.64	10.84	8.86	−
H-118	3.47	11.39	5.48	−
H-135	4.09	12.12	7.13	−
H- 47	2.00	12.44	25.26	
H- 53	1.41	12.68	10.69	
H- 41	0.67	13.53	6.72	−
H- 98	10.00	14.60	7.82	−
H- 74	1.46	16.63	8.80	−
H- 82	5.02	19.64	10.45	−
H-101	2.16	23.35	10.37	−
H- 72	2.78	24.88	18.69	
H- 19	1.02	36.63	32.47	
H- 45	0.77	42.01	14.40	−

* See Table 1.
** Examined at 1 % level of significance by t-distribution.

wood and sapwood was not so large, particularly in hardwoods.

Table 5. Effect of methanol extraction on the decay resistance of softwood timber species against *Ch. globosum* and *Co. versicolor* in class A*.

No.**	Content of methanol extractives (%)	*Ch. globosum*			*Co. versicolor*		
		Weight loss (%)		Effect of extraction on decay***	Weight loss (%)		Effect of extraction on decay***
		Not treated	Extracted by methanol		Not treated	Extracted by methanol	
1	1.36	0.68	2.08	+		class C	
2	13.34	0.51	0.04		0.00	7.34	+
3	5.21	1.94	0.00		0.51	6.52	+
4	1.45	0.00	2.01	+	4.92	6.10	
5	1.39	1.10	0.89			class B	
6	1.01	0.68	3.14	+	3.52	4.43	
7	1.12	0.94	1.31			class C	
8	2.76	4.37	1.72	−		class B	
9	7.47	0.59	5.81	+	2.09	21.23	+
10	2.76	2.61	4.81			class D	
11	1.11	1.46	0.00			class C	
12	3.88	2.87	2.10			class B	
13	3.13	4.12	3.24			class D	
15	1.19	2.83	8.34	+		class D	
16	1.83	0.82	3.14	+		class B	
18	0.93	0.19	0.53			class B	
19	8.68	0.00	6.45	+	0.00	14.48	+
20	7.72	1.64	3.00		2.93	17.38	+
21	7.17	2.02	5.53	+	2.81	9.59	+
22	1.58	2.27	2.37			class B	
25	1.16	2.37	0.34			class C	
26	1.67	1.22	3.69	+		class C	
31	8.54	2.41	0.15	−	1.35	10.08	+
32	10.18	0.06	0.00		1.19	11.23	+
33	4.28	0.03	0.00			class C	
34	4.48	0.21	0.00			class C	
35	0.83	4.92	4.22			class D	
36	6.68	0.00	1.44			class B	
37	6.05	1.24	0.84		1.63	7.57	+
38	10.72	1.84	0.13			class B	
39	5.32	0.31	0.00			class B	
40	6.97	0.87	0.03			class C	
41	4.52	1.59	0.00			class B	
42	9.03	3.14	1.54	−	1.09	9.49	+
43	3.36	0.00	0.06			class B	
44	2.48	0.00	0.14			class B	
Ave.	—	7.79	10.49		1.84	10.45	

* Weight loss due to decay, 5—10 %.
** See Table 2.
*** Examined at 1 % level of significance by t-distribution.

The higher resistance in heartwood was pronounced in the following species:

Carpinus japonica (H-9), *Querqus mongolica* (H-21), *Querqus hondai* (H-27), *Zelkova serrata* (H-35), *Morus bombycis* (H-39), *Cercidiphyllum japonicum* (H-43), *Cinnamomum camphora* (H-49), *Lindera erythrocarpa* (H-52), *Neolitsea aciculata* (H-53), *Actinodaphne lancifolia* (H-54), *Rhus verniciflua* (H-82) and *Pterostyrax hipsida* (H-126).

Difference in resistance found in these species was possibly attributed to the occurrence of toxic extractives in most cases.

Table 4 shows the results with the effect of methanol extraction on decay resistance of heartwood samples of various hardwoods. Among 32 species, classified in class I and class II, 25 species were tested in this experiment. In addition, 4 species in class III, 1 species in class IV and 1 species in class V were tested for purpose of comparison. Contrary to expectation, a positive effect (higher percentage weight loss of extracted blocks than that of non-extracted blocks) was found significant only in five species: H-29, H-39, H-68, H-77 and H-137. Such an effect was most pronounced in *Paulownia tomentosa* (H-137). A negative effect (lower percentage weight loss of extracted blocks) was found in nearly half of species tested. In a similar test[39] with Southeast Asian timbers using *Ch. globosum*, a positive effect was found in 17 species among the 43 in class I and class II (at the same classification scheme), whereas a negative effect only in 4 species. A positive effect may be possibly due to removal of toxic materials from wood. A non-significant effect, found in durable species, may be attributed to: (1) insolu-

Table 6. Effect of methanol extraction on the decay resistance of softwood timber species against *Ch. globosum* and *Co. versicolor* in class B*.

No.**	Content of methanol extractives (%)	*Ch. globosum*			*Co. versicolor*		
		Weight loss (%)		Effect of extraction on decay***	Weight loss (%)		Effect of extraction on decay***
		Not treated	Extracted by methanol		Not treated	Extracted by methanol	
5	1.39	class A			9.46	11.50	
8	2.76	class A			6.81	11.98	
12	3.88	class A			6.80	16.29	+
16	1.83	class A			7.06	9.71	
18	0.93	class A			7.22	9.43	
22	1.58	class A			8.58	15.83	
23	1.35	7.30	6.60		class D		
24	0.97	9.00	17.00	+	class D		
28	2.21	7.34	9.97		class D		
29	1.39	7.94	2.87	−	class C		
30	0.90	7.39	16.00	+	class D		
36	6.68	class A			9.50	9.42	
38	10.72	class A			9.71	11.88	
39	5.32	class A			6.11	18.67	+
41	4.52	class A			5.91	9.17	
43	3.36	class A			9.87	16.86	
44	2.48	class A			8.62	10.74	
Ave.	—	7.79	10.49		7.97	12.62	

* Weight loss due to decay, 5—10 %.

** See Table 2.

*** Examined at 1 % level of significance by t-distribution.

Table 7. Effect of methanol extraction on the decay resistance of softwood timber species against *Ch. globosum* and *Co. versicolor* in class C*.

No.**	Content of methanol extractives (%)	*Ch. globosum* Weight loss (%) Not treated	*Ch. globosum* Weight loss (%) Extracted by methanol	*Ch. globosum* Effect of extraction on decay***	*Co. versicolor* Weight loss (%) Not treated	*Co. versicolor* Weight loss (%) Extracted by methanol	*Co. versicolor* Effect of extraction on decay***
1	1.36		class A		12.94	7.02	
7	1.12		class A		13.76	10.64	
11	1.11		class A		11.48	9.35	
14	1.68	10.95	11.99			class D	
17	2.35	10.54	16.27	+	12.16	12.77	
25	1.16		class A		12.59	21.03	
26	1.67		class A		14.98	24.02	
27	1.52	10.20	24.80	+		class D	
29	1.39		class B		12.94	20.46	
33	4.28		class A		14.41	16.35	
34	4.48		class A		10.85	13.92	
40	6.97		class A		12.08	20.64	+
Ave.	—	10.56	17.69		12.82	15.62	

* Weight loss due to decay, 10—15 %.
** See Table 2.
*** Examined at 1 % level of significance by t-distribution.

Table 8. Effect of methanol extraction on the decay resistance of softwood timber specices against *Ch. globosum* and *Co. versicolor* in class D*.

No.**	Content of methanol extractives (%)	*Ch. globosum* Weight loss (%) Not treated	*Ch. globosum* Weight loss (%) Extracted by methanol	*Ch. globosum* Effect of extraction on decay***	*Co. versicolor* Weight loss (%) Not treated	*Co. versicolor* Weight loss (%) Extracted by methanol	*Co. versicolor* Effect of extraction on decay***
10	2.76		class A		15.84	19.67	
13	3.13		class A		24.89	18.36	
14	1.68		class C		25.07	30.56	
15	1.19		class A		22.87	16.21	
23	1.35		class B		50.53	46.05	
24	0.97		class B		19.16	12.35	
27	1.52		class C		22.38	9.98	−
28	2.21		class B		28.44	15.73	
30	0.90		class B		17.02	14.88	
35	0.83		class A		15.42	14.77	
Ave.	—	—	—		24.16	19.86	

* Weight loss due to decay, over 15 %.
** See Table 2.
*** Examined at 1 % level of significance by t-distribution.

bility of toxic materials in methanol, (2) insufficient removal of toxic materials soluble in methanol, and (3) presence of factors other than toxic materials. A negative effect in durable species may be due to : (1) inhibiting action of methanol remaining in wood after extraction treatment, and (2) change in pH value caused by methanol extraction. However, at present stage, such a different ratio in positive and negative effect could not be considered as a different nature in temperate and tropical woods. A negative effect, found in less-durable species, pro-

Table 9. Summarized data for the decay resistance of 44 softwood timber species against *Ch. globosum* and *Co. versicolor*.

Fungus	*Ch. globosum*				*Co. versicolor*			
Class in decay resistance*	A	B	C	D	A	B	C	D
Number of species	36	5	3	0	12	12	10	10
Pinaceae	16	5	3	0	4	5	6	9
(Abietoideae)	(10)	(0)	(2)	(0)	(1)	(4)	(3)	(4)
(Pinoideae)	(6)	(5)	(1)	(0)	(3)	(1)	(3)	(5)
Taxodiaceae	7	0	0	0	2	2	2	1
Cupressaceae	6	0	0	0	1	4	1	0
Others	7	0	0	0	5	1	1	0
Average content of methanol extractives (%)	4.48	1.36	1.85	—	7.15	3.79	2.59	1.65

* Weight loss due to decay, A: 0—5 (%), B: 5—10 (%), C: 10—15 (%), D: over 15 (%).

Table 10. Summarized data for the effect of methanol extraction on the decay resistance of 44 softwood timber species against *Ch. globosum* and *Co. versicolor*.

Fungus	*Ch. globosum*			*Co. versicolor*		
Effect of extraction on decay*	+	±	−	+	±	−
Number of species	13	27	4	13	30	1
Pinaceae	10	12	2	5	18	1
(Abietoideae)	(4)	(7)	(1)	(2)	(10)	(0)
(Pinoideae)	(6)	(5)	(1)	(3)	(8)	(1)
Taxodiaceae	0	7	0	2	5	0
Cupressaceae	0	5	1	3	3	0
Others	3	3	1	3	4	0
Average content of methanol extractives (%)	2.89	4.24	5.43	7.66	2.31	1.52

* Examined at 1% level of significance by t-distribution.

Table 11. Statistical significance among four classes in decay resistance (see Table 9.) and effects of methanol extraction (see Table 10.) in relation to the content of methanol extractives in 44 softwood timber species exposed to *Co. versicolor*.

	Class	A	B	C	D
Class in decay resistance	A	—	2.553*	3.688**	4.914**
	B	2.553*	—	1.141	2.348*
	C	3.688**	1.141	—	1.382
	D	4.914**	2.348	1.382	—
	Effect	+	±	−	
Effect of extraction on decay	+	—	7.337**	2.425*	
	±	7.337**	—	0.372	
	−	2.425*	0.372	—	

* Significant at 5% level by t-distribution.
** Significant at 1% level by t-distribution.

bably resulted mainly from a removal of nutrient substances during the extraction treatment.

Although different natures in softwoods and hardwoods, particularly those of lignins and hemicelluloses, have been considered for a poor action of soft rot fungi against softwoods, heartwood extractives was considered to be still worth examining as a causal agent for such a poor action. Effect of methanol extraction of heartwood samples of various softwoods was shown in Tables 5-8. Table 9 and Table 10 show the summarized data for decay resistance and effect of methanol extraction both related to content of methanol extractives in wood.

A positive effect was found significant in *Abies sachalinensis* (No. 9), *Pinus densiflora* (No. 19) and *Pinus thunbergii* (No. 21) in both cases of *Ch. globosum* and *Co. versicolor*. In *P. densiflora*, a positive effect was found again, when tested with other wood decaying fungi :[40]

Fungus	Type	Loss of weight (%) Not treated	Loss of weight (%) Methanol treated
Coniophora puteana	brown rot	3.02	26.33
Serpula lacrymans	brown rot	9.81	40.55
Ganoderma lucidum	white rot	2.62	8.06
Lenzites betulina	white rot	2.82	17.67

As is evident from Table 10, frequencies of positive effect were equal in both cases of *Ch. globosum* and *Co. versicolor*. However, positive effect common to both fungi occurred in only 3 species described above. In the case of *Ch. globosum*, a positive effect was found mainly in the species of Pinaceae (10 species among the 13), and was not found in those of Taxodiaceae and Cupressaceae. In the case of *Co. versicolor*, a positive effect occurred scattering in several families. Different effects of extraction in a species were found in a few species (Nos. 27, 31 and 42). Such a phenomenon was pronounced in *Pinus nigra* (No. 27). Different sensitivities to wood extractives in the two test fungi were suggested in tropical woods, too.[39]

As shown in Table 5, average weight loss values of nontreated and treated blocks were 1.44 and 1.92 (%) in the case of *Ch. gobosum*, and 1.84 and 10.45 (%) in *Co. versicolor*, respectively. This suggests that methanol extraction was more significant for species in class A when decayed by *Co. versicolor* than decayed by *Ch. globosum*.

Average content of methanol extractives in the species in class A was higher than that of other classes in the case of *Co. versicolor* (Table 9). Such a trend was confirmed statistically as shown in Table 11. Furthermore, average content of methanol extractives in the species in which a positive effect was found significantly, was higher than in those in which other effects were found (Table 10). This was also confirmed statistically (Table 11). Consequently, in the case of *Co. versicolor*, it can be considered that extractive-rich species are more resistant and the greater part of extractive-rich species become less resistant after methanol extraction. However, such tendencies did not hold for both hardwoods and softwoods in the case of *Ch. globosum*. From the results obtained, it may be possible to conclude, at least in softwoods, that the roll of methanol extractives on the higher resistance against soft rot fungi is generally poor. However, it is not clear whether such a poor role is associated with the tolerance of soft rot fungi to extractives in wood or not. With respect to this, decay and growth retarding effect of isolated extractives should be investigated in detail.

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