

九州大学演習林に生育する95樹種の生材含水率, 飽和率と容積密度

誌名	九州大学農学部演習林報告 = Bulletin of the Kyushu University Forest
ISSN	04530284
著者	梅林, 利弘 古賀, 信也 内海, 泰弘 井上, 晋 椎葉, 康喜 長澤, 久視 大崎, 繁 久保田, 勝義 井上, 幸子 松村, 順司 小田, 一幸
巻/号	92号
掲載ページ	p. 33-44
発行年月	2011年3月

Green moisture content and basic density of 95 woody species growing in Kyushu University Forests, Japan

Toshihiro UMEBAYASHI*, Shinya KOGA**, Yasuhiro UTSUMI**, Susumu INOUE**, Yasuki SHIIBA**, Hisami NAGASAWA**, Shigeru OSAKI**, Katsuyoshi KUBOTA**, Sachiko INOUE**, Junji MATSUMURA*** and Kazuyuki ODA***

We investigated the green moisture content and basic density of 95 woody species growing in Kyushu University Forests. In softwood species, the green moisture content of heartwood ranged from 28% in *Cryptomeria japonica* to 67% in *Abies firma*, and in sapwood, from 75% in *Tsuga sieboldii* to 160% in *Cryptomeria japonica*. The green moisture content of softwood trees was greater in sapwood than heartwood. The green moisture content in the heartwood of hardwood species ranged from 34% in *Euonymus alatus* f. *striatus* to 83% in *Kalopanax pictus*, and in sapwood, from 45% in *Fraxinus sieboldiana* to 153% in *Actinidia polygama*. We found three radial variation pattern types in stems of hardwood species. The green moisture content was higher in heartwood than sapwood, in the first type, whereas in the second, it was higher in sapwood than heartwood. In a third type, differences between heartwood and sapwood were relatively small. The basic density of softwood species ranged from 378 kg/m³ in *Cryptomeria japonica* to 524 kg/m³ in *Tsuga sieboldii*. Most trees tended to decrease in basic density from corewood to outerwood. Basic density in hardwood species ranged from 266 kg/m³ in *Paulownia tomentosa* to 751 kg/m³ in *Rhaphiolepis indica* var. *umbellata*. We identified three types of radial variation pattern in stems of hardwood species. In the first type, basic density was higher in corewood than outerwood, whereas in second, it was higher in outerwood. In the third type, differences between corewood and outerwood were small. We also provided the information on the age and size of heartwood formation.

Keyword : green moisture content; basic density; Kyushu University Forests; Japan

国内に生育する樹木の木材性質に関するデータベースを作成する一環として、九州大学演習林（北海道演習林、宮崎演習林、福岡演習林）に生育するつる性木本植物3樹種を含む95樹種の生材含水率および容積密度数を測定した。針葉樹の生材含水率は辺材が心材より常に大きく、心材ではスギの28%からモミの67%の範囲にあり、辺材ではツガの75%からスギの160%の範囲にあった。一方、広葉樹の生材含水率は、心材ではヌルデの34%からハリギリの83%の範囲にあり、辺材ではアオダモの45%からマタタビの153%の範囲にあった。樹幹半径方向の生材含水率のパラツキについては、辺材よりも心材が高いタイプ、心材よりも辺材が高いタイプ、心材と辺材にほとんど差がないタイプの3タイプが認められた。針葉樹材の容積密度数は、スギの378 kg/m³からツガの524 kg/m³の範囲にあり、樹幹半径方向の変動では、中心部が外周部よりも高かった。広葉樹材の容積密度数は、キリの266 kg/m³からシャリンバイの751 kg/m³の範囲にあり、樹幹半径方向の変動では、外周部よりも中心部が高いタイプ、中心部よりも外周部が高いタイプ、中心部と外側部にほとんど差がないタイプの3タイプが認められた。最後に心材形成を開始する樹齢やサイズに係わる情報について記載した。キーワード：生材含水率、容積密度数、九州大学演習林、日本

1. Introduction

Wood moisture strongly affects wood quality characteristics, including physical and mechanical properties, dimensional stability, machining, drying performance, adhesion properties, durability, burning characteristics, and transport efficiency (e.g., Watanabe 1978; Fushitani *et al.* 1989; Forestry and Forest Products

Research Institute 2004). Thus, wood moisture content is of concern to foresters, wood processors, and users at every stage from standing trees to the service performance of various wood products.

Living trees contain a large amount of water in their stems, because they transport water from the soil to their leaves via their stems, and also store some water in their stems (Tyree & Zimmermann 2002). Previous studies

* Department of Forest and Forest Products Science, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University, Hakozaki, Fukuoka, 812-8581

(Present address: Research Team for Detection of Plant Pathogens and Nematodes, National Agricultural Research Center)

九州大学大学院生物資源環境科学府森林資源科学専攻

(現所属：中央農業総合研究センター病害虫検出同定法研究チーム)

** University Forests, Faculty of Agriculture, Kyushu University, Kasuya, Fukuoka, 811-2415
九州大学農学部附属演習林

*** Sustainable Bioresource science, Agro-Environmental Sciences, Faculty of Agriculture, Kyushu University, Hakozaki, Fukuoka, 812-8581
九州大学大学院農学研究院環境農学部門サステナブル資源科学

reported wood moisture content (green moisture content) of living trees growing in Japan. For example, Yazawa *et al.* (1965) reported interspecies variation in green moisture content distribution in the stems of nine hardwood species. Nakada (2006) investigated water distribution in the stems of 11 softwood species. Kawazumi *et al.* (1991) and Nakada *et al.* (1999) reported intraspecies variation in green moisture content in the stems of *Cryptomeria japonica*. Previous studies also have reported seasonal variations in *Fagus crenata* (Yazawa 1960), and *Fraxinus mandshurica* var. *japonica*, *Ulmus davidiana*, and *Populus maximowiczii* trees (Yazawa & Ishida 1965). Kano (1987), Miyajima (1992), and Forestry and Forest Products Research Institute (2004) documented the green moisture content for 27 species (14 softwood species and 13 hardwood species), 25 species (9 softwood species and 16 hardwood species), and 15 species (9 softwood species and 6 hardwood species), respectively. However, previous reports were mainly focused on commercial woody species. Thus, data from many woody species are required to determine green moisture content in various woody species growing in Japan. These data should be supplemented with additional information, because green moisture content varies with a number of factors, e.g., seasons, site conditions, geographical locations, inter-tree variation, and intra-tree variation (Gibbs 1958; Yazawa 1960; Forestry and Forest Products Research Institute 2004).

Wood density (or specific gravity) is an important characteristics of wood, which is strongly correlated with physical properties, mechanical properties, burning characteristics, biomass, and carbon stocking (Watanabe 1978; Zobel & van Buitenen 1989; Zhang 1997; Niklas 1997; Forestry and Forest Products Research Institute 2004). There are many previous investigations of wood density. Basic density data for woody species growing in Japan are summarized and listed in several reports and books (Nakai & Yamai 1982; Forestry and Forest Products Research Institute 2004). However, as with green moisture content, these data were mainly focused on commercial woody species. Data from many wood species are required to determine the basic density of various woody species growing in Japan. These data should be supplemented with additional information, for the same reasons as noted for variability in moisture content (Zobel & van Buitenen 1989).

We aimed to provide data on green moisture content and basic density for 95 woody species, including three woody lianas, which were investigated in Kyushu University Forests between 2003 and 2006, as part of a project to develop wood properties database.

2. Materials and methods

Wood samples were collected from three Kyushu University sites, which ranged from warm temperate forest

to cool temperate forest, i.e., Kasuya Research Forest, Shiiba Research Forest, and Ashoro Research Forest (Table 1 and Fig.1).

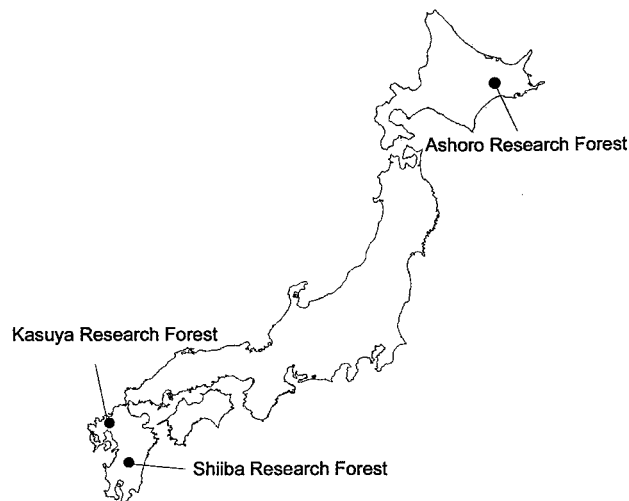


Fig.1 Location of sampling site

We sampled two to four trees for each of 95 species from three sites, comprised of five softwood species and 90 hardwood species. A total of 204 trees were cut down during July and August between 2003 and 2006, i.e., 35 species in Kasuya Research Forest, 58 species in Shiiba Research Forest, and nine species in Ashoro Research Forest. Table 2 shows species name, age, height, and diameter at breast height (DBH) for the trees sampled. DBH, tree height, and tree age ranged from 1 cm to 10 cm, 2 m to 12 m, and one year to 123 years, respectively.

We cut a short log (about 20 cm length) at breast height from each sample tree and vaseline was applied immediately to the cut sections at both ends, to prevent desiccation. Logs were wrapped in plastic and taken to the laboratory. A wood disc (3 cm thickness) was cut from the middle of each log immediately samples arrived in the laboratory. A wedge spanning from pith to bark was removed from the wood disc. The wedge was separated into inner sapwood and outer sapwood. If the wedge contained colored heartwood, it was separated into heartwood and sapwood based on visual demarcation. The heartwood and sapwood blocks were then separated into inner and outer sections. We did not separate the intermediate wood, which was usually recognized as a pale colored zone between the sapwood and heartwood. If heartwood was found in the stem, we regarded heartwood and sapwood as corewood and outerwood, respectively. When heartwood was not present in the stem, inner sapwood and outer sapwood were regarded as corewood

Table 1 Descripton of sampling sites.

	Kasuya Research Forest	Shiiba Research Forest	Ashoro Research Forest
Forest area	481ha	2916 ha	3713 ha
Latitude	33° 38'N	32° 22'N	43° 14'N
Longitude	130° 31'E	131° 08'E	143° 33'E
Altitude	30 m - 553 m	650 m - 1607 m	100 m – 450 m
Annual average temperatur	16.2°C	12.9°C	6.0°C
Warmth Index	134.9	101.6	60.0
Annual average precipitatic	1599 mm	3356 mm	749 mm
Forest type*	WTF	ITF	CTF

*WTF: warm temperate forest, ITF: intermediate temperate forest, CTF: cool temperate forest

and outerwood, respectively. We measured the green weight and volume of each block were measured before reweighting after drying the blocks in a 105°C oven until constant weight. Green volume was determined by the water displacement method.

Green moisture content (GMC) was calculated using formula 1.

$$\text{GMC}(\%) = \frac{\text{Green weight(g)} - \text{Over dry weight(g)}}{\text{Oven dry weight(g)}} \times 100 \quad (1)$$

Basic density (BD) was calculated using formula 2.

$$\text{BD}(\text{kg/m}^3) = \frac{\text{Oven dry weight(kg)}}{\text{Green volume(m}^3\text{)}} \quad (2)$$

3. Results and discussion

Table 3 shows the green moisture content and basic density values of heartwood and sapwood for each sample tree.

3. 1. Green moisture content

Average green moisture content for heartwood in softwood species ranged from 28% in *Chamaecyparis obtusa* to 67% in *Abies firma*. The minimum and maximum values for individual trees were 28% in *Chamaecyparis obtuse* (tree nos. 3 & 4) and 95% in *Abies firma* (tree no. 2), respectively. Average green moisture content for sapwood ranged from 75% in *Tsuga sieboldii* to 160% in *Cryptomeria japonica*. The minimum and maximum values for individual tree were 28% in *Tsuga sieboldii* (tree no. 14) and 202% in *Cryptomeria japonica* (tree no. 8).

It is well known that the green moisture content of softwood species is generally high in sapwood and low in heartwood (e.g. Fushitani *et al.* 1989). However the heartwood of some species also has high moisture content, including *Cryptomeria japonica* and *Abies sachalinensis* (Kano 1987; Kawazumi *et al.* 1991; Nakada *et al.* 1999; Forestry and Forest Products Research Institute 2004; Nakada 2006). Our study found that the green moisture content of sapwood was higher than that of heartwood in all softwood trees. The heartwood of *Abies firma* (tree no.2) had a higher moisture content than all other softwood trees.

Our study also showed that the green moisture content of outer sapwood was higher than that of inner sapwood in all softwood trees. This result may be attributable to intermediate wood, because we did not separate intermediate wood from the sapwood and heartwood. Further investigations testing the separation of intermediate wood from sapwood and heartwood are required.

Only 25 tree samples from 12 hardwood species contained heartwood. Average green moisture content in heartwood ranged from 34% of *Euonymus alatus* f. *striatus* to 83% in *Quercus crispula*. The minimum and maximum values for individual tree were 30% in *Rhus javanica* var. *roxburghii* (tree no.57) and 90% in *Kalopanax pictus* (tree no.32). Average green moisture content of sapwood ranged from 45% in *Fraxinus sieboldiana* to 153% in *Actinidia polygama*. The minimum and maximum values for individual trees were 45% in *Fraxinus sieboldiana* (tree no.27) and 159% in *Actinidia polygama* (tree no.15).

The difference in green moisture content between the heartwood and sapwood was relatively small in hardwood species (2% to 46%) compared with softwood species (31% to 95%). This result agreed with previous reports (Kano

1987; Fushitani *et al.* 1989).

Yazawa *et al.* (1965) studied radial variation in green moisture content in the stem of nine hardwood species and reported three types of distribution pattern. In the first type, the moisture content was higher in the heartwood than sapwood. In the second type, the moisture content was higher in the sapwood than in heartwood. In the third type, only small differences in moisture contents were detected in the sapwood and heartwood. We found the following species belong to the first type: *Castanea crenata*, *Fraxinus mandshurica* var. *japonica*, *Kalopanax pictus*, *Maackia amurensis* subsp. *buergeri*, *Phellodendron amurense*, and *Quercus crispula*. *Rhus javanica* var. *roxburghii* and *Euonymus alatus* f. *striatus* were of the second type, whereas *Morus australis* belonged to the third type. The attribution of *Fraxinus mandshurica* var. *japonica* to type 1 agreed with the results of Yazawa *et al.* (1965), but our classification of *Morus australis* as type 3 was not agreement.

The outer sapwood had a higher green moisture content than the inner sapwood in the majority of the 173 hardwood trees tested. This finding may be attributed to the fact that the region involved in water transport does not include the entire sapwood in broad-leaved species (Umebayashi *et al.* 2007; 2010).

Our study was limited by the short sampling season (July to August) and limits on sampling, i.e., low sample number per species, small tree size, and restriction of tree sampling mainly to Kasuya Forest and Shiiba Forest. Further green moisture content data collection is required.

3. 2. Basic density

The basic density of whole stems showed large interspecies variations, especially in hardwood species. In softwood species, the mean basic density ranged from 378 kg/m³ in *Cryptomeria japonica* to 524 kg/m³ in *Tsuga sieboldii*. The minimum and maximum values for individual trees were 326 kg/m³ in *Cryptomeria japonica* (tree no. 8) and 536 kg/m³ in *Tsuga sieboldii* (tree no. 13). In contrast, the mean basic density of hardwood species ranged from 266 kg/m³ in *Paulownia tomentosa* to 725 kg/m³ in *Rhaphiolepis indica* var. *umbellata*. The minimum and maximum values for individual trees were 251 kg/m³ in

Zanthoxylum ailanthoides (tree no. 191) and 751 kg/m³ in *Rhaphiolepis indica* var. *umbellata* (tree no. 163).

Numerous reports indicate that basic density varies with radial variations from the pith to bark in the stem of woody species (Fushitani *et al.* 1989; Zobel & Sprague 1998). In all but one of softwood trees (tree no.1), basic density tended to decrease from corewood to outerwood. We observed three types of radial variation patterns in the basic density of hardwood species. In the first type, basic density was higher in corewood than outerwood (e.g., *Kalopanax pictus* and *Maackia amurensis* subsp. *buergeri*). In the second type, basic density was higher in outerwood than corewood (e.g., *Betula grossa* and *Litsea acuminata*). Only small differences in the basic density of corewood and outerwood were detected in the third type (e.g., *Magnolia obovata* and *Dendropanax trifidus*). Further basic density data are required to determine radial variation patterns for each species.

3. 3. Information on the age and size of heartwood formation

It is well known that heartwood formation begins after trees reach a certain age or size (Watanabe 1978). However, there is little information on the starting size and age of heartwood formation for woody species growing in Japan. We derived data on the age and size of heartwood formation from the presence or absence of heartwood (Table 3), tree age and DBH (Table 2). Heartwood was observed in the stems of three species of five softwood species (16 trees) and 12 of 90 hardwood species (26 trees). Among the softwood species, the smallest size and ring number (cambial age) for a stem containing heartwood was 6 cm and seven growth rings in *Chamaecyparis obtuse* (tree no. 3). Among the hardwood species, this was 4 cm in *Euonymus alatus* f. *striatus* (tree no. 104) and seven growth rings in *Rhus javanica* var. *roxburghii* (tree nos.55, 56 and 57). In contrast, the largest size and ring number for a hardwood species stem containing no heartwood was 9 cm in *Chamaecyparis obtuse* (trees no. 6) and 11 growth rings in *Pinus densiflora* (tree no.11), whereas among the hardwood species, this was 10 cm in *Ilex crenata* var. *fukasawana* (tree no.120) and 80 growth rings in *Fraxinus sieboldiana* (tree no.27).

Table 2 Description of sample trees.

Japanese common name (Scientific name)	Tree no.	Tree age (year)	DBH (cm)	Tree height (m)	Sampling date	Sampling site*	Japanese common name (Scientific name)	Tree no.	Tree age (year)	DBH (cm)	Tree height (m)	Sampling date	Sampling site*
Softwood							Ring-porous wood						
Momi (<i>Abies firma</i>)	1	69	8.9	7.8	2004/7/16	S	Nogurumi (<i>Platycarya strobilacea</i>)	43	4	3.0	3.8	2005/8/8	K
	2	26	9.0	5.9	2004/7/16	S		44	5	2.5	3.7	2005/8/8	K
Hinoki (<i>Chamaecyparis obtusa</i>)	3	8	6.2	4.7	2005/8/30	S	Kunugi (<i>Quercus acutissima</i>)	45	20	6.8	7.6	2003/8/19	S
	4	7	5.7	4.1	2005/8/30	S		46	20	7.3	6.2	2003/8/19	S
	5	10	7.5	5.6	2005/8/26	K	Abemaki (<i>Quercus variabilis</i>)	47	18	6.8	7.5	2003/8/19	S
	6	10	8.6	6.0	2005/8/26	K		48	20	9.3	8.2	2003/8/19	S
Sugi (<i>Cryptomeria japonica</i>)	7	5	2.8	3.3	2005/8/25	S		49	22	6.5	6.1	2005/8/10	K
	8	8	3.7	4.7	2005/8/25	S		50	16	5.5	4.4	2005/8/10	K
	9	10	3.5	4.1	2005/8/26	K	Mizunara (<i>Quercus crispula</i>)	51	27	7.0	9.2	2003/8/22	S
	10	10	8.1	5.9	2005/8/26	K		52	23	5.5	8.8	2003/8/22	S
Akamatsu (<i>Pinus densiflora</i>)	11	11	4.6	4.4	2004/8/24	S		53	44	9.8	11.1	2004/8/12	A
	12	9	4.8	4.2	2004/8/24	S		54	41	9.7	8.8	2004/8/12	A
Tsuga (<i>Tsuga sieboldii</i>)	13	76	7.5	7.3	2004/8/24	S	Nurude (<i>Rhus javanica</i> var. <i>roxburghii</i>)	55	7	6.4	5.1	2004/8/31	S
	14	76	8.2	10.0	2004/8/24	S		56	7	6.4	7.8	2004/8/31	S
Hardwood													
Ring-porous wood													
Matatabi (<i>Actinidia polygama</i>)	15	12	1.9	8.3	2004/7/16	S	Yamaurushi (<i>Toxicodendron trichocarpum</i>)	59	33	4.7	4.7	2004/8/7	A
	16	9	2.0	10.9	2004/7/16	S		60	43	6.4	6.0	2004/8/7	A
Urinoki (<i>Alangium platanifolium</i> var. <i>trilobum</i>)	17	22	2.3	4.4	2003/8/10	S	Kurozuru (<i>Tripterygium regelii</i>)	61	10	5.8	9.4	2004/8/31	S
	18	25	4.4	7.3	2003/8/10	S		62	11	6.4	7.9	2004/8/31	S
Taranoki (<i>Aralia elata</i>)	19	4	3.5	2.8	2004/7/16	S	Yamafuji (<i>Wisteria brachybotrys</i>)	63	19	2.5	9.2	2003/7/25	S
	20	4	4.9	2.7	2004/7/16	S		64	22	3.5	11.5	2003/7/25	S
Kuri (<i>Castanea crenata</i>)	21	20	5.8	6.9	2005/8/22	K	Inuzansho (<i>Zanthoxylum schinifolium</i>)	65	7	3.3	4.8	2004/7/7	S
	22	18	5.7	4.1	2005/8/22	K		66	10	2.5	4.5	2004/7/7	S
Aodamo (<i>Fraxinus lanuginosa</i> f. <i>serrata</i>)	23	23	5.7	5.8	2004/8/9	A	Semi-ring-porous wood						
	24	35	6.0	8.1	2004/8/9	A	Kakuremino (<i>Dendropanax trifidus</i>)	67	23	3.5	5.1	2006/7/28	K
Yachidamo (<i>Fraxinus mandshurica</i> var. <i>japonica</i>)	25	22	6.4	7.8	2003/8/13	A		68	36	5.5	6.8	2006/7/28	K
	26	10	4.9	8.7	2003/8/13	A	Nawashirogumi (<i>Elaeagnus pungens</i>)	69	10	4.7	5.2	2005/8/16	K
Marubaaodamo (<i>Fraxinus sieboldiana</i>)	27	80	7.5	11.1	2003/8/31	S		70	9	1.1	2.2	2005/8/16	K
	28	34	4.7	10.2	2003/8/31	S	Diffuse-porous wood						
Harigiri (<i>Kalopanax pictus</i>)	29	60	5.8	5.8	2003/8/25	S	Chidorinoki (<i>Acer carpiniifolium</i>)	71	26	6.0	5.5	2003/8/22	S
	30	15	4.7	4.9	2003/8/25	S		72	21	5.6	6.1	2003/8/22	S
	31	48	9.7	11.5	2004/8/12	A	Irohamomiji (<i>Acer palmatum</i>)	73	31	4.5	5.3	2003/7/30	S
	32	69	8.3	10.3	2004/8/12	A		74	23	3.3	3.5	2003/7/30	S
Inuenjyu (<i>Maackia amurensis</i> subsp. <i>buengeri</i>)	33	51	7.9	7.4	2004/8/12	A	Itayakaede (<i>Acer pictum</i> subsp. <i>dissectum</i>)	75	29	7.2	5.9	2003/7/31	S
	34	52	9.8	8.7	2004/8/12	A		76	33	7.2	7.0	2003/7/31	S
Yamaguwa (<i>Morus australis</i>)	35	48	5.4	7.5	2004/8/25	S	Ezoitaya (<i>Acer pictum</i> subsp. <i>mono</i> f. <i>mono</i>)	77	28	6.2	8.2	2004/8/11	A
	36	33	5.5	7.4	2004/8/25	S		78	32	6.8	9.4	2004/8/11	A
Kiri (<i>Paulownia tomentosa</i>)	37	1	4.2	5.5	2005/8/17	K	Enkoukaede (<i>Acer pictum</i> subsp. <i>dissectum</i> f. <i>dissectum</i>)	79	21	7.6	6.6	2003/8/1	S
	38	3	5.1	5.0	2005/8/17	K		80	15	6.8	5.5	2003/8/1	S
Kihada (<i>Phellodendron amurense</i>)	39	21	9.4	8.3	2004/7/16	S	Kohauchiwakaede (<i>Acer sieboldianum</i>)	81	57	9.7	9.4	2003/7/22	S
	40	19	8.6	6.5	2004/7/16	S		82	54	9.0	6.8	2003/7/22	S
Kobannoki (<i>Phyllanthus flexuosus</i>)	41	9	3.9	2.3	2005/8/30	K	Yashabushi (<i>Alnus firma</i>)	83	5	2.9	4.0	2005/8/28	K
	42	9	2.4	2.4	2005/8/30	K		84	8	6.8	5.0	2005/8/28	K

* S: Shiiba Research Forest, K: Kasuya Research Forest, A: Ashoro Research Forest

Table 2 (Continued)

Japanese common name (Scientific name)	Tree no.	Tree age (year)	DBH (cm)	Tree height (m)	Sampling date	Sampling site*	Japanese common name (Scientific name)	Tree no.	Tree age (year)	DBH (cm)	Tree height (m)	Sampling date	Sampling site*
Diffuse-porous wood							Diffuse-porous wood						
Mukunoki (<i>Aphananthe aspera</i>)	85	12	1.8	4.3	2005/7/19	K	Nezumimochi (<i>Ligustrum japonicum</i>)	129	26	3.0	3.3	2005/8/23	K
	86	10	5.5	5.6	2005/7/19	K		130	29	2.5	3.2	2005/8/23	K
Mizume (<i>Betula grossa</i>)	87	23	8.6	9.5	2003/8/22	S	Kanakuginoki (<i>Lindera erythrocarpa</i>)	131	21	5.6	7.0	2003/8/4	S
	88	20	6.8	8.0	2003/8/22	S		132	29	9.7	6.3	2003/8/4	S
Yabutsubaki (<i>Camellia japonica</i>)	89	61	7.8	6.0	2003/8/22	S	Aburachan (<i>Lindera praecox</i>)	133	14	3.8	5.5	2003/8/1	S
	90	33	5.0	5.8	2003/8/22	S		134	19	2.6	4.0	2003/8/1	S
	91	15	2.6	3.4	2005/8/28	K	Shiromoji (<i>Lindera triloba</i>)	135	27	6.0	6.9	2003/8/9	S
	92	18	2.3	3.3	2005/8/28	K		136	15	2.9	5.2	2003/8/9	S
Akashide (<i>Carpinus laxiflora</i>)	93	11	4.9	6.6	2003/8/27	S	Baribarinoki (<i>Litsea acuminata</i>)	137	15	3.8	4.9	2005/7/19	K
	94	10	5.1	5.4	2003/8/27	S		138	15	3.8	4.8	2005/7/19	K
Inushide (<i>Carpinus tschonoskii</i>)	95	11	5.0	6.9	2003/8/27	S	Kagonoki (<i>Litsea coreana</i>)	139	9	2.8	3.2	2005/8/6	K
	96	10	5.0	4.6	2003/8/27	S		140	9	3.1	4.1	2005/8/6	K
Isunoki (<i>Distylium racemosum</i>)	97	14	3.9	6.2	2005/8/27	K	Tabunoki (<i>Machilus thunbergii</i>)	141	13	4.1	4.7	2006/8/3	K
	98	14	3.3	5.5	2005/8/27	K		142	12	3.6	3.5	2006/8/3	K
Yamagaki (<i>Diospyros kaki</i> var. <i>syvestris</i>)	99	9	4.9	6.5	2005/8/18	K	Hoonoki (<i>Magnolia obovata</i>)	143	17	4.8	5.8	2003/8/28	S
	100	9	4.1	4.9	2005/8/18	K		144	17	5.0	5.4	2003/8/28	S
Utsugi (<i>Deutzia crenata</i>)	101	7	2.5	4.2	2004/8/22	S	Tamushiba (<i>Magnolia salicifolia</i>)	145	16	4.0	5.2	2003/8/6	S
	102	9	2.9	4.3	2004/8/22	S		146	16	6.3	5.7	2003/8/6	S
Komayumi (<i>Euonymus alatus</i> f. <i>striatus</i>)	103	57	6.4	5.1	2004/7/16	S	Awabuki (<i>Meliosma myriantha</i>)	147	16	6.9	6.5	2003/8/4	S
	104	43	4.0	5.0	2004/7/16	S		148	23	7.5	6.0	2003/8/4	S
Fusazakura (<i>Euptelea polyandra</i>)	105	11	4.0	7.3	2003/8/6	S	Shirodamo (<i>Neolitsea sericea</i>)	149	28	7.5	6.2	2003/8/20	S
	106	17	4.1	7.4	2003/8/6	S		150	29	8.5	5.9	2003/8/20	S
Hisakaki (<i>Eurya japonica</i>)	107	28	3.9	3.3	2005/8/11	K		151	8	2.6	3.2	2005/8/25	K
	108	25	2.2	3.6	2005/8/11	K		152	7	3.9	3.3	2005/8/25	K
Buna (<i>Fagus crenata</i>)	109	19	5.5	6.3	2003/8/19	S	Asebi (<i>Pteris japonica</i>)	153	9	5.3	5.4	2003/8/5	S
	110	24	6.4	8.2	2003/8/19	S		154	10	6.2	5.4	2003/8/5	S
Inubuna (<i>Fagus japonica</i>)	111	16	5.6	5.6	2003/8/5	S	Tobera (<i>Pittosporum tobira</i>)	155	8	3.2	4.2	2006/8/9	K
	112	17	5.2	6.4	2003/8/5	S		156	15	5.6	6.0	2006/8/9	K
Hosobainubiwa (<i>Ficus erecta</i> f. <i>sieboldii</i>)	113	10	2.5	4.2	2006/7/20	K	Yamanarashi (<i>Populus sieboldii</i>)	157	36	8.6	8.5	2004/8/12	A
	114	9	3.3	4.0	2006/7/20	K		158	30	7.7	7.3	2004/8/12	A
Nanaminoki (<i>Ilex chinensis</i>)	115	15	3.2	6.0	2006/8/8	K	Kamatsuka (<i>Pourthiaea villosa</i> var. <i>laevis</i>)	159	32	7.2	7.0	2003/8/6	S
	116	15	3.4	4.9	2006/8/8	K		160	35	4.5	5.2	2003/8/6	S
Inutsuge (<i>Ilex crenata</i>)	117	10	1.5	2.2	2005/8/13	K	Asagara (<i>Pterostyrax corymbosa</i>)	161	21	8.5	6.2	2003/7/25	S
	118	12	2.0	2.7	2005/8/13	K		162	21	5.0	5.1	2003/7/25	S
Tsukushiinutsuge (<i>Ilex crenata</i> var. <i>fukasawana</i>)	119	43	6.6	6.2	2004/7/16	S	Sharinbai (<i>Rhaphiolepis indica</i> var. <i>umbellata</i>)	163	22	3.1	4.9	2003/8/6	K
	120	51	9.9	6.8	2004/7/16	S		164	30	5.2	6.3	2003/8/6	K
Soyogo (<i>Ilex pedunculosa</i>)	121	38	5.1	5.0	2003/8/22	S	Nekoyanagi (<i>Salix gracilistyla</i>)	165	25	6.2	5.2	2004/8/23	S
	122	38	5.0	7.0	2003/8/22	S		166	16	3.3	4.0	2004/8/23	S
Kuroganemochi (<i>Ilex rotunda</i>)	123	10	4.3	4.2	2005/7/22	K	Yamayanagi (<i>Salix sieboldiana</i>)	167	22	6.0	5.6	2003/8/30	S
	124	11	5.8	3.5	2005/7/22	K		168	23	3.9	4.1	2003/8/30	S
Inuumemodoki (<i>Ilex serrata</i> f. <i>argutidens</i>)	125	41	3.0	4.1	2004/8/27	S	Shiraki (<i>Sapium japonicum</i>)	169	17	4.2	6.2	2003/7/31	S
	126	34	2.2	3.8	2004/8/27	S		170	9	3.7	3.9	2003/7/31	S
Shikimi (<i>Illicium anisatum</i>)	127	18	3.6	3.7	2003/8/22	S	Nankinnanakamado (<i>Sorbus gracilis</i>)	171	29	1.8	4.9	2003/8/22	S
	128	45	4.6	3.5	2003/8/22	S		172	26	2.0	5.8	2003/8/22	S

Table 2 (Continued)

Japanese common name (Scientific name)	Tree no.	Tree age (year)	DBH (cm)	Tree height (m)	Sampling date	Sampling site*	Japanese common name (Scientific name)	Tree no.	Tree age (year)	DBH (cm)	Tree height (m)	Sampling date	Sampling site*
Diffuse-porous wood							Diffuse-porous wood						
Himeshara (<i>Stewartia monadelphica</i>)	173	21	6.4	6.1	2003/8/19	S	Karasuzanshou (<i>Zanthoxylum ailanthoides</i>)	191	10	6.8	4.1	2005/8/8	K
	174	28	5.8	5.8	2003/8/19	S		192	3	5.1	3.7	2005/8/8	K
Egonoki (<i>Styrax japonica</i>)	175	22	5.5	5.5	2003/8/23	S	Fuyuzanshou (<i>Zanthoxylum armatum</i> var. <i>subtrifoliatum</i>)	193	9	4.0	3.8	2006/8/5	K
	176	22	6.2	5.8	2003/8/23	S		194	13	3.0	4.6	2006/8/5	K
Kohakuunboku (<i>Styrax shiraiana</i>)	177	7	2.9	3.8	2004/7/7	S	Radial-porous wood						
	178	9	3.7	5.8	2004/7/7	S	Sudajii (<i>Castanopsis sieboldii</i>)	195	22	5.0	4.6	2005/8/27	K
Kurominosawafutagi (<i>Symplocos tanakana</i>)	179	21	3.7	5.7	2006/7/31	K		196	18	3.3	3.6	2005/8/27	K
	180	14	2.2	3.7	2006/7/31	K	Matebashii (<i>Lithocarpus edulis</i>)	197	16	4.0	5.5	2006/8/2	K
Kuroki (<i>Symplocos lucida</i>)	181	6	2.4	2.9	2005/8/13	K		198	16	3.3	5.0	2006/8/2	K
	182	7	2.7	2.8	2005/8/13	K	Arakashi (<i>Quercus glauca</i>)	199	13	6.2	7.6	2005/8/6	K
Kumanomizuki (<i>Swida macrophylla</i>)	183	11	3.7	4.4	2003/8/25	S		200	8	5.0	6.3	2005/8/6	K
	184	11	7.4	5.2	2003/8/25	S	Shirakashi (<i>Quercus myrsinaefolia</i>)	201	16	2.9	5.5	2006/8/9	K
Oobabodaijyu (<i>Tilia maximowicziana</i>)	185	34	6.5	7.4	2004/8/11	A		202	23	5.9	6.7	2006/8/9	K
	186	30	6.0	7.8	2004/8/11	A	Urajirogashi (<i>Quercus salicina</i>)	203	24	7.4	7.0	2004/7/16	S
Shashanbo (<i>Vaccinium bracteatum</i>)	187	18	3.2	4.1	2006/7/29	K		204	9	3.5	5.4	2004/7/16	S
	188	22	4.1	3.3	2006/7/29	K	Wood vesselless						
Koyabudemari (<i>Viburnum plicatum</i> var. <i>parvifolium</i>)	189	23	4.0	5.3	2004/7/16	S	Yamaguruma (<i>Trochodendron aralioides</i>)	205	85	6.8	5.8	2003/8/22	S
	190	27	3.9	5.3	2004/7/16	S		206	123	7.0	4.8	2003/8/22	S

Table 3 Green moisture content and basic density (kg/m³) of the trees. (-: No observation of heartwood)

Japanese common name (Scientific name)	Tree no.	Green moisture content (%)								Basic density (kg/m ³)								Japanese common name (Scientific name)	Tree no.	Green moisture content (%)								Basic density (kg/m ³)													
		Heartwood				Sapwood				Heartwood				Sapwood						Heartwood				Sapwood				Heartwood				Sapwood									
		Inner	Outer	All	stem	Inner	Outer	All	stem	Inner	Outer	All	stem	Inner	Outer	All	stem			Inner	Outer	All	stem	Inner	Outer	All	stem	Inner	Outer	All	stem										
Softwood																																									
Momi (<i>Abies firma</i>)	1	42	35	39	43	113	84	61	453	422	438	492	473	481	458	Ring-porous wood																									
	2	115	75	95	155	181	167	152	373	356	364	337	309	323	331	Yamaguiwa (<i>Morus australis</i>)																									
	AVG	79	55	67	99	147	126	106	413	389	401	415	391	402	394	35 68 69 69 65 76 71 70 594 600 597 582 569 574 584																									
Hinoki (<i>Chamaecyparis obtusa</i>)	3	32	26	28	100	148	123	78	481	489	486	460	446	453	468	Kiri (<i>Paulownia tomentosa</i>)																									
	4	36	24	28	92	135	115	81	501	503	502	467	401	430	456	37 - - - 68 113 91 91 - - - 244 283 263 263																									
	5	-	-	-	109	162	131	131	-	-	-	458	387	426	426	38 - - - 72 142 107 107 - - - 260 275 269 269																									
	6	-	-	-	123	155	138	138	-	-	-	458	398	428	428	AVG - - - 70 127 99 99 - - - 252 279 266 266																									
	AVG	34	25	28	106	150	127	107	491	496	494	461	408	434	444	Kihada (<i>Phellodendron amurense</i>)																									
Sugi (<i>Cryptomeria japonica</i>)	7	-	-	-	123	200	154	154	-	-	-	444	331	391	391	39 51 63 57 67 101 87 68 377 398 387 446 378 403 393																									
	8	-	-	-	162	247	202	202	-	-	-	357	297	326	326	40 42 42 42 43 77 61 48 397 467 433 423 388 403 423																									
	9	-	-	-	116	206	154	154	-	-	-	427	321	375	375	AVG 46 53 50 55 89 74 58 387 433 410 434 383 403 408																									
	10	-	-	-	122	142	131	131	-	-	-	444	394	420	420	Kobannoki (<i>Phyllanthus flexuosus</i>)																									
	AVG	-	-	-	131	199	160	160	-	-	-	418	336	378	378	42 - - - 57 73 64 64 - - - 752 640 708 708																									
Akamatsu (<i>Pinus densiflora</i>)	11	-	-	-	152	169	160	160	-	-	-	397	372	385	385	AVG - - - 58 75 66 66 - - - 733 632 688 688																									
	12	-	-	-	121	159	139	139	-	-	-	411	369	390	390	Nogurumi (<i>Platycarya strobilacea</i>)																									
	AVG	-	-	-	137	164	150	150	-	-	-	404	371	387	387	43 - - - 94 116 105 105 - - - 415 442 429 429																									
Tsuga (<i>Tsuga sieboldii</i>)	13	58	47	53	60	108	83	64	600	540	569	532	452	491	536	44 - - - 84 101 93 93 - - - 473 486 480 480																									
	14	30	32	31	32	97	66	46	563	498	534	503	471	486	513	AVG - - - 89 109 99 99 - - - 444 464 455 455																									
	AVG	44	39	42	46	103	75	55	581	519	552	518	461	488	524	Kunugi (<i>Quercus acutissima</i>)																									
Hardwood																																									
Ring-porous wood																																									
Matatabi (<i>Actinidia polygama</i>)	15	-	-	-	116	206	159	159	-	-	-	463	310	374	374	45 - - - 65 70 68 68 - - - 628 611 619 619																									
	16	-	-	-	100	192	146	146	-	-	-	414	316	358	358	AVG - - - 70 74 72 72 - - - 659 646 652 652																									
	AVG	-	-	-	108	199	153	153	-	-	-	439	313	366	366	50 - - - 70 79 74 74 - - - 685 645 663 663																									
Urinoki (<i>Alangium platanifolium</i> var. <i>trilobum</i>)	17	-	-	-	58	59	58	58	-	-	-	648	605	627	627	AVG - - - 77 87 82 82 - - - 655 591 622 622																									
	18	-	-	-	50	59	55	55	-	-	-	567	551	558	558	Mizunara (<i>Quercus crispula</i>)																									
	AVG	-	-	-	54	59	57	57	-	-	-	607	578	593	593	51 - - - 67 72 69 69 - - - 638 565 600 600																									
Taranoki (<i>Aralia elata</i>)	19	-	-	-	86	113	105	105	-	-	-	183	455	322	322	53 80 82 81 67 60 63 74 634 630 632 596 537 558 600																									
	20	-	-	-	48	65	60	60	-	-	-	184	402	304	304	54 83 87 85 65 71 68 78 649 647 648 598 527 555 607																									
	AVG	-	-	-	67	89	83	83	-	-	-	184	428	313	313	AVG 82 84 83 68 72 70 75 641 639 640 603 549 571 594																									
Kiri (<i>Castanea crenata</i>)	21	71	85	78	83	87	85	82	502	493	498	484	495	490	494	Nurude (<i>Rhus javanica</i> var. <i>roxburghii</i>)																									
	22	66	79	73	84	101	93	83	517	513	515	495	463	479	496	55 67 57 62 72 122 99 80 371 361 366 365 372 369 367																									
	AVG	69	82	75	83	94	89	82	509	503	506	490	479	485	495	56 67 71 69 89 136 111 86 377 452 416 488 272 356 390																									
Aodamo (<i>Fraxinus lamiginosa</i> f. <i>serrata</i>)	23	-	-	-	49	63	57	57	-	-	-	622	604	612	612	57 36 24 30 40 113 76 76 410 420 415 472 426 450 450																									
	24	-	-	-	49	56	53	53	-	-	-	640	610	625	625	Yamaurushi (<i>Toxicodendron trichocarpum</i>)																									
	AVG	-	-	-	49	60	55	55	-	-	-	631	607	619	619	59 46 41 43 60 83 73 53 422 484 455 434 472 454 455																									
Yachidamo (<i>Fraxinus mandshurica</i> var. <i>japonica</i>)	25	72	87	80	45	66	56	68	502	486	493	487	479	483	488	60 51 56 53 50 85 68 59 535 542 539 521 476 496 523																									
	26	74	89	82	49	70	61	72	609	613	611	616	547	575	591	AVG 48 48 48 55 84 70 56 479 513 497 478 474 475 489																									
	AVG	73	88	81	47	68	58	70	555	550	552	552	513	529	539	Kurozuru (<i>Tripterygium regelii</i>)																									
Marubaaodamo (<i>Fraxinus sieboldiana</i>)	27	-	-	-	43	46	45	45	-	-	-	608	627	618	618	61 - - - 129 129 129 129 - - - 630 375 482 482																									
	28	-	-	-	42	50	46	46	-	-	-	597	599	598	598	62 - - - 77 136 101 101 - - - 656 412 528 528																									
	AVG	-	-	-	43	48	45	45	-	-	-	602	613	608	608	AVG - - - 103 132 115 115 - - - 643 393 505 505																									
Harigiri (<i>Kalopanax pictus</i>)	29	77	75	76	58	95	79	77	498	506	502	525	405	451	474	Yamafuji (<i>Wisteria brachybotrys</i>)																									
	30	-	-	-	67	115	90	90	-	-	-	558	408	474	474	63 - - - 121 204 149 149 - - - 394 265 338 338																									
	31	57	67	62	86	101	94	76	540	538	539	481	394	431	485	64 - - - 100 173 136 136 - - - 380 337 357 357																									
	32	80	99	90	92	102	98	92	498	465	481	389	313	342	436	AVG - - - 111 188 143 143 - - - 387 301 347 347																									
	AVG	72	80	76	76	103	90	84	512	503	507	488	380	424	467	Inuzansho (<i>Zanthoxylum schinifolium</i>)																									
Inuenjyu (<i>Maackia amurensis</i> subsp. <i>buergeri</i>)	33	29	64	46	85	92	90	53	567	533	550	453	424	429	528	65 - - - 40 63 52 52 - - - 567 544 555 555																									
	34	63	80	71	89	97	95	75	585	545	565	466	471	470	546	66 - - - 40 52 46 46 - - - 560 551 555 555																									
	AVG	46	72	59	87	94	93	64	576	539	558	460	447	450	537	AVG - - - 40 57 49 49 - - - 563 547 555 555																									
Semi ring porous wood																																									
	67	-	-	-	72	93	83	-	-	-	-	481	488	486	486	Kakuremomi (<i>Dendropanax trifidus</i>)																									
	68	-	-	-	75	100	87	-	-	-	-	431	428	430	430	68 - - - 74 96 85 85 - - - 456 458 458 458																									
	AVG	-	-	-	74	96	85	85	-	-	-	456	458	458	458																										

Table 3 (Continued)

Japanese common name (Scientific name)	Tree no.	Green moisture content (%)							Basic density (kg/m ³)							Japanese common name (Scientific name)	Tree no.	Green moisture content (%)							Basic density (kg/m ³)										
		Heartwood			Sapwood			stem	Heartwood			Sapwood			stem			Heartwood			Sapwood			stem	Heartwood			Sapwood			stem				
		Inner	Outer	All	Inner	Outer	All		Inner	Outer	All	Inner	Outer	All				Inner	Outer	All	Inner	Outer	All		Inner	Outer	All	Inner	Outer	All		Inner	Outer	All	Inner
Diffuse-porous wood																		Diffuse-porous wood																	
Egonoki (<i>Styrax japonica</i>)	175	-	-	-	86	104	95	95	-	-	-	479	463	471	471	Fuyuzanshou (<i>Zanthoxylum armatum</i> var. <i>subtrifoliatum</i>)	193	-	-	-	69	76	73	73	-	-	-	441	531	486	486				
	176	-	-	-	98	98	98	98	-	-	-	463	485	472	472		194	-	-	-	59	87	72	72	-	-	-	503	475	489	489				
	AVG	-	-	-	92	101	96	96	-	-	-	471	474	472	472		AVG	-	-	-	64	82	72	72	-	-	-	472	503	488	488				
Kohakuunboku (<i>Styrax shiraiana</i>)	177	-	-	-	75	95	85	85	-	-	-	533	492	513	513	Radial-porous wood																			
	178	-	-	-	92	100	97	97	-	-	-	484	487	486	486	Sudajii (<i>Castanopsis sieboldii</i>)	195	-	-	-	83	96	89	89	-	-	-	628	559	591	591				
	AVG	-	-	-	84	97	91	91	-	-	-	509	489	499	499		196	-	-	-	82	79	81	81	-	-	-	544	564	554	554				
Koyabudemari (<i>Viburnum plicatum</i> var. <i>parvifolium</i>)	179	-	-	-	69	72	71	71	-	-	-	686	660	672	672		AVG	-	-	-	83	87	85	85	-	-	-	586	561	573	573				
	180	-	-	-	65	73	69	69	-	-	-	671	635	653	653	Matebashii (<i>Lithocarpus edulis</i>)	197	-	-	-	82	75	78	78	-	-	-	593	599	596	596				
	AVG	-	-	-	67	72	70	70	-	-	-	678	647	663	663		198	-	-	-	77	80	79	79	-	-	-	605	582	595	595				
Kurominosawafutagi (<i>Symplocos tanakana</i>)	181	-	-	-	85	92	89	89	-	-	-	613	547	578	578		AVG	-	-	-	80	78	78	78	-	-	-	599	591	595	595				
	182	-	-	-	89	87	88	88	-	-	-	618	557	588	588	Radial-porous wood																			
	AVG	-	-	-	87	90	88	88	-	-	-	615	552	583	583	Arakashi (<i>Quercus glauca</i>)	199	-	-	-	67	60	63	63	-	-	-	653	701	676	676				
Kuroki (<i>Symplocos lucida</i>)	183	-	-	-	104	127	116	116	-	-	-	523	467	492	492		200	-	-	-	70	68	69	69	-	-	-	647	673	661	661				
	184	-	-	-	90	132	109	109	-	-	-	556	442	498	498		AVG	-	-	-	68	64	66	66	-	-	-	650	687	668	668				
	AVG	-	-	-	97	129	112	112	-	-	-	540	454	495	495	Shirakashi (<i>Quercus myrsinaefolia</i>)	201	-	-	-	62	73	67	67	-	-	-	722	661	692	692				
Kumanonizuki (<i>Swida macrophylla</i>)	185	-	-	-	106	134	118	118	-	-	-	523	480	504	504		202	-	-	-	68	74	71	71	-	-	-	659	625	642	642				
	186	-	-	-	83	114	96	96	-	-	-	573	523	551	551		AVG	-	-	-	65	74	69	69	-	-	-	691	643	667	667				
	AVG	-	-	-	94	124	107	107	-	-	-	548	502	527	527	Urjirogashi (<i>Quercus salicina</i>)	203	-	-	-	75	77	76	76	-	-	-	670	689	679	679				
Oobabodajiyu (<i>Tilia maximowicziana</i>)	187	-	-	-	117	122	120	120	-	-	-	296	325	310	310		204	-	-	-	67	68	67	67	-	-	-	634	641	638	638				
	188	-	-	-	115	112	113	113	-	-	-	295	362	331	331		AVG	-	-	-	71	73	72	72	-	-	-	652	665	659	659				
	AVG	-	-	-	116	117	116	116	-	-	-	295	344	321	321	Wood vesselless																			
Shashanbo (<i>Vaccinium bracteatum</i>)	189	-	-	-	106	107	106	106	-	-	-	540	525	532	532	Yamaguruma (<i>Trochodendron aralioides</i>)	205	-	-	-	86	93	89	89	-	-	-	574	538	556	556				
	190	-	-	-	98	103	101	101	-	-	-	552	534	542	542		206	-	-	-	86	85	85	85	-	-	-	562	539	550	550				
	AVG	-	-	-	102	105	104	104	-	-	-	546	530	537	537		AVG	-	-	-	86	89	87	87	-	-	-	568	538	553	553				
Karasuzanshou (<i>Zanthoxylum ailanthoides</i>)	191	-	-	-	85	186	132	132	-	-	-	239	265	251	251																				
	192	-	-	-	94	154	127	127	-	-	-	289	286	287	287																				
	AVG	-	-	-	89	170	130	130	-	-	-	264	275	269	269																				

Conclusion

This paper presents green moisture content and basic density data for 95 woody species, including three woody lianas, collected from Kyushu University Forests, which ranges from a warm temperate forest zone to a cool temperate forest zone, during July and August from 2003 to 2006. Many data are previously unreported, which means this dataset contains scientifically important information.

References

- Forestry and Forest Products Research Institute (2004) Wood industry handbook (tentative translation by the authors from the original Japanese title). 4th revised edition. Maruzen Company, Tokyo, 192
- Fushitani M, Kikata Y, Okano T, Sado T, Takemura T, Norimoto M, Arima T, Tsutsumi J & Hirai N (1985) Textbook of wood physics (tentative translation by the authors from the original Japanese title). Buneido Publishing, Tokyo
- Gibbs RD (1958) Patterns in the seasonal water content of trees. In: The physiology of forest trees. Thimann KV (ed) The Ronald Press, New York, 43-69
- Kano T (1987) Tree breeding considering wood quality (tentative translation by the authors from the original Japanese title). Forestry Science and Technology Institution, Ibaraki, 99 pp
- Kawazumi K, Oda K & Tsutsumi J (1991) Heartwood properties of sugi (*Cryptomeria japonica*): moisture content of green wood, hot water extractives and lightness (in Japanese with English summary). Bull Kyushu Univ For 64:29-39
- Miyajima H (1992) Understanding wood: For forester and wood users (tentative translation by the authors from the original Japanese title). Hoppou Ringyo Kai, Sapporo, 176 p.
- Nakada R (2006) Within-stem water distribution in living trees of some conifers. IAWA J. 27(3): 313-327
- Nakada R, Fujisawa Y & Hirakawa Y (1999) Soft X-ray observation of water distribution in the stem of *Cryptomeria japonica* D. Don I: General description of water distribution. J Wood Sci 45: 188-193
- Nakai T & Yamai Ryozauro (1982) Properties of the important Japanese woods. The mechanical properties of 35 Japanese important woods (in Japanese). Bull For & For Prod Res Inst 319:13-46
- Tyree MT & Zimmermann MH (2002) Xylem structure and the ascent of sap. Springer-Verlag, Berlin. 283 p.
- Umabayashi, T., Utsumi, Y., Koga, S., Inoue, S., Fujikawa, S, Arakawa, K., Matsumura, J., & Oda, K. (2008) Xylem water conducting pathways of deciduous broadleaved trees growing in a northern temperate zone. IAWA J 29 (3): 247-263
- Umabayashi, T., Utsumi, Y., Koga, S., Inoue, S., Matsumura, J., Oda, K., Fujikawa, S, Arakawa, K. & Otsuki, K. (2010) Xylem water-conducting pattern of 34 broadleaved evergreen species in southern Japan. Trees 24: 571-583
- Watanabe H (1978) General wood science (tentative translation by the authors from the original Japanese title), Nourin shuppan, Tokyo, 627 p.
- Yazawa K (1960) The seasonal water content of sapwood and heartwood of broad-leaved trees, especially of beech (*Fagus crenata Blume*) (in Japanese with English abstract). Mokuzai Gakkashi 6(4): 170-175
- Yazawa K, Ishida S, Miyajima H (1965) On the wet-wood of some broad-leaved trees grown in Japan I. Mokuzai Gakkaishi 11(3):71-76
- Yazawa K, Ishida S (1965) On the wet-heartwood of some broad-leaved trees grown in Japan II. J Fac Agr Hokkaido Univ 54(2):123-136
- Zhang SY (1997) Wood quality: Its definition, impact, and implications for value-added timber management and end uses. Part I: Its definition and impact. Proceedings of the CTIA/IUFRO International Wood Quality Workshop (ed) Zhang SY *et al.* Forintek Canada, Quebec city, I: 17-39
- Zobel, BJ., van Buijtenen, JP (1989) Wood Variation. Its Causes and Control. Springer-Verlag, Berlin, Heidelberg, 363 pp
- Zobel, BJ., van Sprague, JR (1999) Juvenile wood in forest trees. Springer-Verlag, Berlin, 300 pp