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Moisture Distribution in Stems of *Acacia mangium*, *A. auriculiformis* and Hybrid *Acacia* Trees

Koichi YAMAMOTO[1]*, Othman SULAIMAN[2], Crispin KITINGAN[3], Ling Wang CHOON[4] and Nguyen Trong NHAN[5]

[1] Forestry and Forest Products Research Institute (Tsukuba, Ibaraki 305–8687, Japan)
[2] School of Industrial Technology, University Science Malaysia (11800 Penang, Malaysia)
[3] Sabah Forestry Development Authority (Locked Bag 122, 88999 Kota Kinabalu, Sabah, Malaysia)
[4] Timber Research and Technical Training Centre, Forest Department (93660 Kuching, Sarawak, Malaysia)
[5] Forest Science Institute of Vietnam (Chem, TuLiem, Hanoi, Vietnam)

Abstract

Distribution of the moisture content across stem wood at breast height in *Acacia mangium, A. auriculiformis*, and hybrid *Acacia* trees grown in 3 Asian countries was evaluated. Moisture contents of the stems of *A. mangium* and hybrid *Acacia* were extremely high not only in sapwood but also in heartwood in most cases. Highest moisture content found in the inner heartwood was 253% for both *A. mangium* and hybrid *Acacia*. In sapwood, the moisture contents were 149% and 154%, respectively. Most trees of these 2 species had "wet-heartwood" which refers to the higher moisture content of heartwood compared to the surrounding sapwood. Stem wood of *A. auriculiformis* generally showed a slightly lower moisture content than that of *A. mangium* and hybrid *Acacia*. However, the highest moisture content found in the inner heartwood was 146% in *A. auriculiformis*. The large amount of water in stem wood, especially in the heartwood of these *Acacia* species hampers drying which is necessary for the production of sawn timber and processing to panel products. Several factors such as characteristics of clones or provenance of seeds, and amount of precipitation at plantation sites could be involved in the large fluctuations in the moisture contents of the stems of these *Acacia* trees. Further studies should be carried out to determine the conditions necessary for lowering the moisture content of stem wood in order to optimize the utilization of these plantation species.

Discipline: Forestry and forest products
Additional key words: wood properties, plantation forest, heartwood, sapwood, wood drying

Introduction

Acacia species such as *A. mangium* Willd, *A. auriculiformis* Benth. and hybrid *Acacia* are major fast-growing plantation species not only for pulp and timber production but also for greening purposes in the tropical Asia region[22,30]. Their importance as a plantation species can be attributed to rapid growth, rather good wood quality, tolerance to a range of soil types and pH values[26]. *A. mangium* occurs naturally in Queensland, Australia, Papua New Guinea, the islands of Sula, Ceram, Aru, and Irian Jaya, Indonesia[26], and *A. auriculiformis* in the Northern Territory and Queensland, Australia, Papua New Guinea, and Irian Jaya, Indonesia[7]. Hybrids of *A. mangium* and *A. auriculiformis* have been developed and biclonal orchards for mass production of the seeds of the inter-specific hybrids of these species have been established in Sabah, Malaysia[12].

In Asia, *A. mangium* was first introduced to Sabah from Queensland in 1966[23]. Industrial-scale plantation establishment of *A. mangium* in Sumatra and other parts of Indonesia began in the early 1980s[35]. *A. mangium* was introduced into Bangladesh in 1979[18]. *A. mangium* and *A. auriculiformis* were planted for trial in Sri Lanka in 1984[34]. In Thailand, *A. auriculiformis* was first introduced as an ornamental tree from Australia in 1935[19]. *A. auriculiformis* was first planted in India in 1946, and it has become a major species for afforestation, particularly in the southern states[8]. The species has also been grown

*Corresponding author: fax +81–298–73–1541; e-mail koichi@ffpri.affrc.go.jp
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in Guangdong province in China since 1961, and has become by far the most widely planted *Acacia* species[32]. Emphasis has recently been placed on hybrids between *A. mangium* and *A. auriculiformis* for plantation, due to their superior characteristics in terms of growth rate and wood properties required for pulp and paper production[13]. At present, these 3 *Acacia* species are planted in many areas of tropical Asia.

Wood properties such as wood density, fiber length and adhesive performance have been studied in order to achieve a better value for the utilization of fast-growing plantation species such as *A. mangium* mainly in Malaysia[22,28]. Some wood properties of natural hybrid *Acacia* between *A. mangium* and *A. auriculiformis* grown in Vietnam have also been studied[13–15].

One of the most important characteristics necessary for utilizing wood is the moisture content of stem wood. Wood in growing trees contains a considerable amount of moisture, which accounts for about 50% of the fresh weight[17]. Most of the moisture should be removed to obtain satisfactory performance for most uses of wood. Wood with a higher moisture content dries more slowly than that with a lower moisture content, and is generally more susceptible to drying defects[5]. The removal of moisture from wood incurs cost in the form of heat energy and time[31]. It is, therefore, important to study the green moisture content of the stems of living trees in order to utilize wood effectively. There have been many studies on the green moisture content of stem wood in different species grown in temperate regions[5,31,37,38]. In the tropics, however, these studies are insufficient[1,2], especially for plantation species[4,6,16,27].

The objective of this study was to observe the variations in the moisture content of the stems of *A. mangium*, *A. auriculiformis*, and hybrid *Acacia* trees. The data on moisture distribution throughout stem wood are useful not only for the utilization of these plantation species as timber but also to determine the conditions that are suitable for the development of *Acacia* species which could provide wood with a lower moisture content.

Materials and methods

A total of 56 *A. mangium*, 14 *A. auriculiformis*, and 14 hybrid *Acacia* trees from Malaysia, Vietnam, and Philippines were surveyed to determine the moisture content of stem wood in living trees. The sampling sites of the examined trees are shown in Table 1. The origin or provenance of most trees sampled was not clear. In most of the sample trees, a semi-non-destructive method was applied to determine the moisture content of stem wood[20]. An increment core (5 mm in diameter) was taken as test specimen at breast height of the trees. The cores were wrapped tightly with a plastic film and brought back to the laboratory. To determine the radial distribution of the moisture content from sapwood to heartwood throughout stem wood, these green cores were immediately separated into small pieces (about 1 cm length) from the cambium to the pith, and green and oven-dry weight of each piece was measured[25]. To analyze the moisture distribution more precisely, several trees were harvested, and the disks collected at breast height were also cut into small blocks from sapwood to heartwood. Moisture content of the specimens was calculated gravimetrically. In this experiment, increment cores were used to determine the moisture content, although wood block specimens from harvested disks are generally used for this purpose. It was reported that increment cores could be used for the comparison of moisture contents among increment core samples of the same size[39].

Results and discussion

1. High moisture content in 3 species

Moisture contents of the stems of *A. mangium* and hybrid *Acacia* were extremely high not only in sapwood but also in heartwood in most cases (Table 1). The highest moisture content was mostly found in the inner-heartwood. The highest moisture content found in the inner-heartwood was 253% both in *A. mangium* and hybrid *Acacia*, while the contents in sapwood were 149% and 154%, respectively. Moisture content of *A. mangium* from Malaysia was around 100–110% in heartwood and 80–90% in sapwood[6]. Hon reported that the moisture content varied from 88% to 140% in 115 logs from Ulu Kukut, Sabah, Malaysia[11]. These values were generally slightly lower than those in this survey. Stem wood of *A. auriculiformis* usually showed a lower moisture content than that of *A. mangium* and hybrid *Acacia*. However, the highest moisture content found in the inner heartwood was 146% in this species. It was reported that the moisture content of *A. auriculiformis* in India ranged between 50 to 100% in logs containing sapwood and heartwood[27]. Fujimoto et al. compared the wood characteristics among *A. mangium*, *A. auriculiformis* and hybrid *Acacia*, and found that *A. mangium* showed the highest moisture content, followed by the hybrids[10].

Heartwood with a high moisture content is usually referred to as wetwood to designate an abnormal type of heartwood[9,33]. However, the heartwood of these *Acacia* species seemed to be normal because heart rot and high concentrations of inorganic elements in the heartwood were not recognized[36]. Heartwood of *A. mangium* and

Table 1. Average moisture contents of the stems of *A. mangium*, *A. auriculiformis*, and hybrid *Acacia* trees at various sites

Species and site[a)]	Planted	Sampling time	No. of trees	Av. DBH[d)]	Av. height	Av. moisture content (%)			
						Sapwood	Out-heart	Mid-heart	In-heart
A. mangium									
Bidor, Perak (M)	1990	Apr. 1996	3[b)]	18.4	–	124	138	150	179
Byram, Penang (M)	1986	Dec. 1995	3[c)]	17.5	–	84	93	78	57
	1986	Sep. 1996	14[b)]	20	–	89	92	90	90
Rawang, Selangor (M)	1985	Mar. 1996	2[c)]	29.3	25	76	91	116	135
	1985	Oct. 1996	6[b)]	25.2	25	81	94	115	131
Kota Kinabalu, Sabah(M)	1988	Oct. 1996	1[b)]	22	14	113	128	127	160
	1988	Jan. 1997	1[c)]	19.4	18	106	112	100	70
Sampadi, Sarawak (M)	1984	Jun. 1997	10[b)]	29.6	25.3	104	106	145	204
Laguna (P)	1986	Feb. 1998	2[b)]	26	18	111	122	114	70
	1990	Feb. 1998	1[b)]	27.4	18	101	98	116	227
Xuan Mai, Ha Tay (V)	1992	Oct. 2001	2[c)]	18.3	16.1	134	136	157	172
Bavi (V)	1994	Mar. 2000	1[b)]	16.9	17	108	114	108	99
Vinh Phuc (V)	1988	Mar. 2000	2[b)]	15.6	11.5	85	96	96	62
	1995	Mar. 2000	1[b)]	19.7	14.5	130	128	113	253
Cau Hai (V)	1992	Mar. 2000	3[b)]	21.6	19	124	125	145	159
Dong Nai (V)	1990	Mar. 2000	2[b)]	23.4	20	89	84	102	113
Tan Tao (V)	1986	Mar. 2000	1[b)]	26.4	20	84	101	109	135
Dalat (V)	1990	Mar. 2000	1[b)]	20.7	16.5	149	140	172	166
A. auriculiformis									
Kota Kinabalu, Sabah(M)	1988	Jan. 1997	1[c)]	13.7	18	57	64	72	77
Pantabangan (P)	1984	Feb. 1998	3[b)]	16.3	13	61	64	69	71
Laguna (P)	1990	Feb. 1998	2[b)]	18.9	14.5	62	65	79	97
	1990	Feb. 1998	1[b)]	14.6	14.5	88	107	125	146
Xuan Mai, Ha Tay (V)	1992	Oct. 2001	2[c)]	15.1	16.6	97	94	109	126
Bavi (V)	1994	Mar. 2000	1[b)]	15.1	17	104	104	93	100
Vinh Phuc (V)	1988	Mar. 2000	2[b)]	16.8	17.8	92	92	104	124
Dong Nai (V)	1994	Mar. 2000	1[b)]	11.8	14.5	86	80	–	83
Tan Tao (V)	e)	Mar. 2000	1[b)]	34.1	21	93	75	82	65
Hybrid *Acacia*									
Kota Kinabalu, Sabah(M)	1988	Jan. 1997	1[c)]	19.1	18	79	96	112	67
Xuan Mai, Ha Tay (V)	1992	Oct. 2001	2[c)]	17.4	18	120	134	137	154
Bavi (V)	1994	Mar. 2000	2[b)]	22.3	17	114	119	114	95
Hoa Binh (V)	1997	Mar. 2000	2[b)]	11.3	15.3	146	–	–	109
Vinh Phuc (V)	1996	Mar. 2000	2[b)]	9.6	11	115	131	–	253
	1995	Mar. 2000	1[b)]	25.4	14.5	154	142	134	153
Dong Nai (V)	1995	Mar. 2000	2[b)]	17.1	18.8	101	98	–	90
Tan Tao (V)	e)	Mar. 2000	1[b)]	22.6	15	100	106	140	239
Dalat (V)	1990	Mar. 2000	1[b)]	27.2	19	136	156	180	102

a): (M), Malaysia; (P), The Philippines; (V), Vietnam. b): Cores removed. c): Sample trees harvested.
d): Diameter at breast height. e): Year of planting not known.

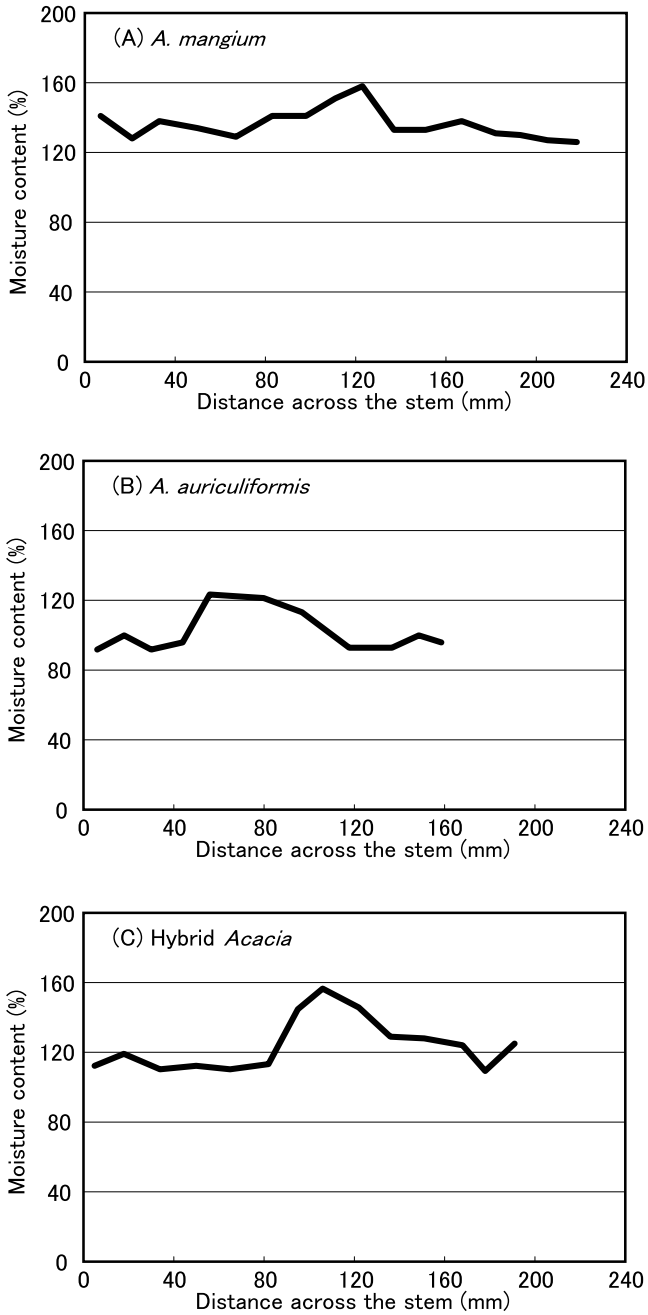

Fig. 1. Moisture distribution across stem wood
(A): *A. mangium*, (B): *A. auriculiformis*, (C): Hybrid *Acacia*.

hybrid *Acacia* especially near the pith would be referred to as "wet-heartwood" due to the higher moisture content than that of the surrounding sapwood[10,37,38].

Existence of "wet-heartwood" in the stem of these *Acacia* species should be well recognized before the development of large-scale plantations for timber production in future. Wetwood or "wet-heartwood" causes problems during drying of timber. Due to the large amount of water in stem wood, especially in the heartwood of these *Acacia* species, drying time becomes much longer[33], which may cause problems for the production of sawn timber and processing to industrial products[24].

2. Moisture distribution from sapwood to heartwood

Fig. 1 shows moisture distributions from the sapwood to heartwood in the harvested stems of *A. mangium, A. auriculiformis* and hybrid *Acacia* trees grown in the same area in Xuan Mai, Ha Tay, Vietnam. The samples were cut in January during the later part of dry season in Ha Tay, Vietnam. Moisture contents were very high throughout stem wood from sapwood to heartwood in the specimens of all 3 species even in the dry season. The amount of water in stem wood may not be related closely to the time of harvest in this case. Although there are some references about the seasonal variations in the moisture content of stem wood[38], only few deal with tropical timber species. Moisture content in stem of *Acacia nilotica* rose to a maximum level from October to February, and the seasonal differences in the moisture content between maximum and minimum values were less than 30% in this species[16].

3. Variation in moisture content

Moisture content of stem wood of all 3 species examined was generally high compared with that of naturally grown tropical species[1,2]. According to the literature, the moisture contents of heartwood of light-red meranti and ramin, for example were 60–70% and 61–70%, respectively. There are few reports on the comparison of the moisture contents between naturally grown and plantation-grown wood[3,4]; moisture content of heartwood of the plantation-grown *Eucalyptus deglupta* was around 200%, a value which was much higher than the 82–113% moisture content found in naturally grown *E. deglupta*.

Moisture content of the stem also varies depending on the height of the stem. The moisture content of the stem of *A. mangium* grown in Ulu Kukut, Sabah, Malaysia ranged from 88 to 140% at breast height, whereas that at the first branch ranged from 52 to 95%[11]. It usually decreases from the bottom of stem to the upper part[6,38]. The high moisture content observed in this study was partially attributed to the sampling position, namely at breast height.

Moisture content of the stem could be related to the ecology of tree growth. *A. mangium* showed the highest stomatal conductance and net photosynthetic rate in the sun leaf, among the 32 tropical tree species sampled in Malaysia, reflecting the highest water requirement for rapid growth[21]. It was suggested that excess absorption of water from soil by fast-growing plantation species

such as *Eucalyptus camaldulensis, A. mangium*, and *A. auriculiformis* could have a negative effect on the soil properties[29].

Conclusion

Distribution of the moisture content across stem wood at breast height in *Acacia mangium, A. auriculiformis*, and hybrid *Acacia* grown in 3 Asian countries was evaluated. Moisture contents of the stems of *Acacia mangium* and hybrid A*cacia* were extremely high not only in sapwood but also in heartwood in most cases. Highest moisture content found in the inner heartwood was about 250% in both species. Stem wood of *A. auriculiformis* generally showed a slightly lower moisture content than that of *A. mangium* and hybrid *Acacia*. The large amount of water in stem wood, especially in the heartwood of these *Acacia* species hampers drying for timber production. Fast-growing species such as these *Acacia* species probably absorb excessive water from soil and could thus have a negative effect on the soil properties. Further studies should be carried out to identify suitable conditions for the production of wood with a lower stem moisture content, for better utilization of these plantation species.

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