

## Evaluation of Selected Physical and Mechanical Properties of Multiple Leader *Acacia crassicarpa* A. Cunn. Ex. Benth. Genotypes

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### ABSTRACT

A study on the evaluation of the selected physical and mechanical properties of multiple leadered *Acacia crassicarpa* A. Cunn. Ex. Benth, genotype was carried out to maximize its utilization. The study involved two classes of multiple leaders (ML), namely; ML2 (two leadered stems) and ML3 more than two leadered stems and 4 provenances: Claudie River, and Chillie Beach from Queensland (QLD) and Bensbach WP and Bimadebum WP from Papua New Guinea (PNG). ML classes showed significant difference at  $P < 0.05$  for physical properties but not between provenances. ML2 produced better mean values of specific gravity, radial and tangential shrinkage, with the values of 0.48%, 1.4% and 2.89% respectively compared to ML3 with values of 0.45, 3.56%, and 5.83%, respectively. Similarly, the ML classes were found to be significantly different at  $P < 0.05$  for Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). Once again, ML2 produced higher mean values of 9858.4 N/mm<sup>2</sup> and 89.63 N/mm<sup>2</sup> for MOE and MOR, respectively, than ML3 (7557.7 N/mm<sup>2</sup> and 60.4 N/mm<sup>2</sup> respectively). Based on the physical and mechanical properties, it can be concluded that ML2 is more superior in terms of strength and stiffness than ML3.

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### INTRODUCTION

The national forest plantation project in Malaysia was launched in 1992 and it is aimed to supply the insufficient raw

materials required by the wood-based industries (Thai *et al.*, 1997). The species selected for this purpose are fast growing, multipurpose and with good attributes to supply merchantable timbers within fifteen years rotation (National Academy of Sciences, 1980; National Research Council, 1983; Turnbull, 1986; 1991; Chung, 1992; Pinyopusarerk, 1992; Ahmed & Kamis, 1999; Rimbawanto, 2002). Forest plantation in Malaysia is mainly planted with *Acacia spp.* especially *A. mangium* and *A. auriculiformis*. This is due to their good growth performance, multipurpose, well adaptability to our country's humid climate and able to improve degraded soil. The growing demand on wood has made *Acacia* as a valuable fast-growing resource in catering for local demand whilst venturing for global market potential. In addition, the toughness of *Acacia* wood makes it a good material in making items that require certain degree of ruggedness (Sharma, 2011). *Acacia crassicaarpa* A. Cunn. Ex. Benth. is one of the candidate species that has been proven to grow better than other fast growing *Acacia spp.* in terms of diameter, height, volume production and wood biomass (Kindo *et al.*, 2010).

Despite being fast growing with other positive attributes, this species is also without exception, as it has some limitation in its growth habit. In particular, it produces multiple leaders (ML), mainly of epicormic branches (Turnbull, 1986; Doran *et al.*, 1997). Cooper (1931) defines ML as the formation of more than one stem from the base of a planted tree which is possibly

caused by genetic and environmental factors. Trees in many genera such as *Acacia spp*, *Eucalyptus spp* and *Tilia spp* tend to produce multiple stems varying in numbers, which usually originate from the basal part of the main stem (Fewles, 2002). A trunk that forked at a height of less than 1.37 m from the ground is considered as multiple stemmed individual (Faber & Tester, 1997). Formation of multiple leaders is undesirable as they reduce the quality of timber. However, there is no report to support such postulation based on their wood properties. Thus, this study aimed to evaluate selected mechanical and physical properties of the multiple-leadered trees from different genotypes of *A. crassicaarpa*.

## MATERIALS AND METHODS

### *Sample Sources*

The wood samples were obtained from five year-old stems of multiple-leadered (ML) trees, which were removed from the singling operation of a progeny trial, established in Kampung Aur Gading, Pahang, Malaysia. They were from two classes of ML: (i) ML2 [with two leaders – Fig. 1(a)], and (ii) ML3 [with more than two leaders – Fig. 1(b) with three leaders and 1(c) with four leaders]. The study utilized trees of four provenances from two geographic regions, namely, Papua New Guinea (PNG) and Queensland Australia (QLD). Details of these provenances are given in Table 1.

The wood sample was evaluated for their moisture content, specific gravity, shrinkage and static bending test. Wood sample was cut into specimens of three sizes,

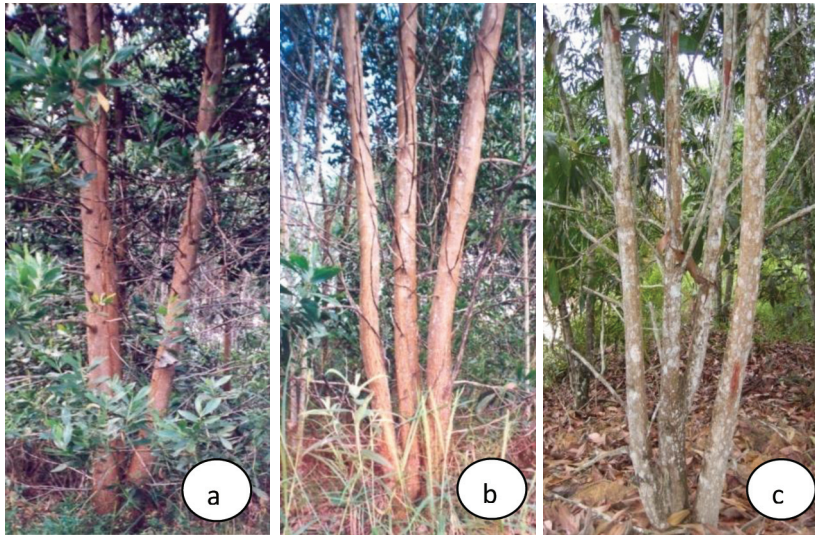


Fig.1: 60-month-old *Acacia crassicaarpa* showing a) ML 2 with two-leadered stems, b) ML 3 with three-leadered stems, and c) ML3 with four-leadered stems at the base.

TABLE 1  
Details of the sources used in this study

Multiple Leader	Region	Provenance	Latitude	Longitude	Altitude	No. of Trees	No. of Samples
2	PNG	Bensbach WP	05° 03'	141° 17'	25m	4	10
		Bimadebum WP	03° 08'	142° 03'	40m	3	10
	QLD	Claudie River	12° 48'	143° 18'	20m	7	10
		Chillie Beach	12° 38'	143° 24'	03m	3	10
3	PNG	Bensbach WP	05° 03'	141° 17'	25m	1	10
		Bimadebum WP	03° 08'	142° 03'	40m	1	10
	QLD	Claudie River	12° 48'	143° 18'	20m	1	10
		Chillie Beach	12° 38'	143° 24'	03m	1	10

Note: PNG-Papua New Guinea, QLD-Queensland

in dimensions of i) 20 mm (Longitudinal; L) x 20 mm (Radial; R) x 20 mm (Tangential; T), ii) 100 mm (L) x 20 mm (R) x 20 mm (T) and iii) 300 mm (L) x 20 mm (R) x 20 mm (T). All the testing carried out in this study were based on the British Standard (BS 373:1957-Testing small Clear Specimen of Timber).

### *Moisture Content Test*

The moisture content (MC) test was performed by measuring the difference in the weights of the specimens using the following formula after being kept in an oven at 103±2°C for 48 hours.

$$MC \% = \frac{\text{Initial weight} - \text{Final weight}}{\text{Final weight}} \times 100$$

### *Specific Gravity Test*

The most accurate method in determining the specific gravity of wood is to weigh the sample in liquid of known density. Paraffin wax was used in this study to coat the specimen from water absorption. The Specific Gravity (SG) test was conducted by placing the specimens in an oven at 103±2°C and immersing in hot paraffin wax while they were still warm. Then, the specimens were quickly removed from the paraffin wax to ensure that only a thin layer of wax was left on the surface of the specimens. Later, the specimens were immersed in water. Then, SG was determined using the following formula:

$$SG = \frac{\text{Oven-dry mass}}{\text{Density of water}}$$

### *Shrinkage Test*

The percentage of shrinkage was determined by measuring the dimensional changes of the specimens which had reached equilibrium moisture content (EMC) of 12%, before and after oven drying at 103±2°C for 24 hours. The dimensions of the changes were measured by using a digital calliper with 0.1 mm accuracy level. The radial and tangential

shrinkage was determined according to the following equation:

$$\text{Shrinkage \%} = \frac{\text{Initial dimension} - \text{Final dimension}}{\text{Initial measurement}} \times 100$$

### *Static Bending Test*

The static bending test was performed using Universal Testing machine in 3-point bending configuration. The specimens were placed between two supporting pins over a span of 300 mm. The inelastic response of the specimen to apply uniaxial loading was measured in the tangential direction of the specimen. The cross-head speed was maintained at 1.25 mm/min until the sample fails. The maximum load of each specimen was recorded and the values of MOE and MOR were calculated as follows:

$$MOE (N/mm^2) = PL^3$$

Where,  $\Delta$  = deflection at proportional limit (mm)

P = maximum load (N)

L = span length (mm)

b = width of specimen (mm)

d = depth of specimen (mm)

$$MOR (N/mm^2) = 3PL^3$$

Where, P = maximum load (N)

L = span length (mm)

b = width of specimen (mm)

d = depth of specimen (mm)

## **DATA ANALYSIS**

The data were analyzed for variance using SAS Statistical Analysis System package (ANOVA procedures, SAS Institute, Inc

2000). Least Significant Difference (LSD) was calculated following the ANOVA test to compare the means of each ML class and provenance. The statistical analysis was conducted at the probability of 0.05. If the data were considered as highly significant, the P-value would indicate less than 0.05. Meanwhile, the ANOVA output, which exceeded p-value > 0.05, would signify that the data consisted with the null hypothesis. In this case, the population means are regarded as identical.

## RESULTS AND DISCUSSION

The results of the analysis of variance showed that there were significant differences at  $P < 0.05$  for both the physical and mechanical properties between the ML classes but not between the provenances (Table 2). Generally, ML2 produced better mean values of 0.48%, 1.4% and 2.89% for specific gravity, radial and tangential shrinkage as compared to those produced by ML3. Similarly, the ML classes also differed significantly at  $P < 0.05$  in their Modulus of Elasticity (MOE) and Modulus of Rupture (MOR). Once again, ML2 produced higher mean values of 9858.4 N/mm<sup>2</sup> and 89.63 N/mm<sup>2</sup> for MOE and MOR, respectively than ML3 (Fig.2).

It is evident that ML formation reduces the overall wood strength of a tree. Results of the mechanical properties from this study verified that ML2 trees were stronger than ML3 trees. Obviously, trees with many stems tend to have weaker physical strength when compared to those with a few stems. This is in line with the energy

allocation theory where the energy or nutrient has to be distributed equally to all development tissues for growth and development purposes. Having multiple stems would mean less energy/nutrient being allocated to the respective stems as it has to be shared equally among these stems. Thus, in this study, ML2 tree was expected to experience a better growth than ML3 tree. This is because ML3 tree has to share its nutrient or energy among more stems, thus resulting in lesser energy/nutrient being allocated to every stem it has. The insufficient nutrient supply in ML3 tree may have resulted in a poorer growth in terms of diameter size. Field observation also revealed and supported this postulation and ML3 tree generally had smaller average diameter than ML2 tree. Such a variation could also be associated with the anatomical differences depicted by the distribution and formation of heartwood, sapwood and cell wall of this ML tree. On the other hand, ML2 tree which normally has bigger diameter tends to have higher portion of heartwood constituting higher amount of wood substances to cell cavity ratio. This in turn has an implication on the physical properties of a wood such as on its specific gravity. On the other hand, Zhang (1997) and Kang *et al.* (2005) also reported that specific gravity is highly correlated with the strength and stiffness of wood. Similarly, the results of this study also revealed that ML2 tree produced higher MOE and MOR values than the ones recorded by ML3 tree; thus, this is in agreement with what has been reported Zaidon *et al.* (2004).

TABLE 2  
Analysis of Variance of the Physical and Mechanical Properties of Multiple Leadered *A. crassicarpa* Provenances

Source of Variation	df	Physical			Mechanical	
		Specific Gravity	Radial Shrinkage	Tangential Shrinkage	Static Bending MOE (N/mm <sup>2</sup> )	Static Bending MOR (N/mm <sup>2</sup> )
		F Value	F Value	F Value	F Value	F Value
Multiple Leader	1	367.57*	732.63*	1002.47*	482.02*	630.2*
Provenance	3	0.73 <sup>ns</sup>	0.15 <sup>ns</sup>	0.41 <sup>ns</sup>	1.73 <sup>ns</sup>	1.12 <sup>ns</sup>
CV (%)		1.37	14.38	9.52	5.38	6.94

Note: \* - significant at  $p \leq 0.05$ , <sup>ns</sup> - not significant

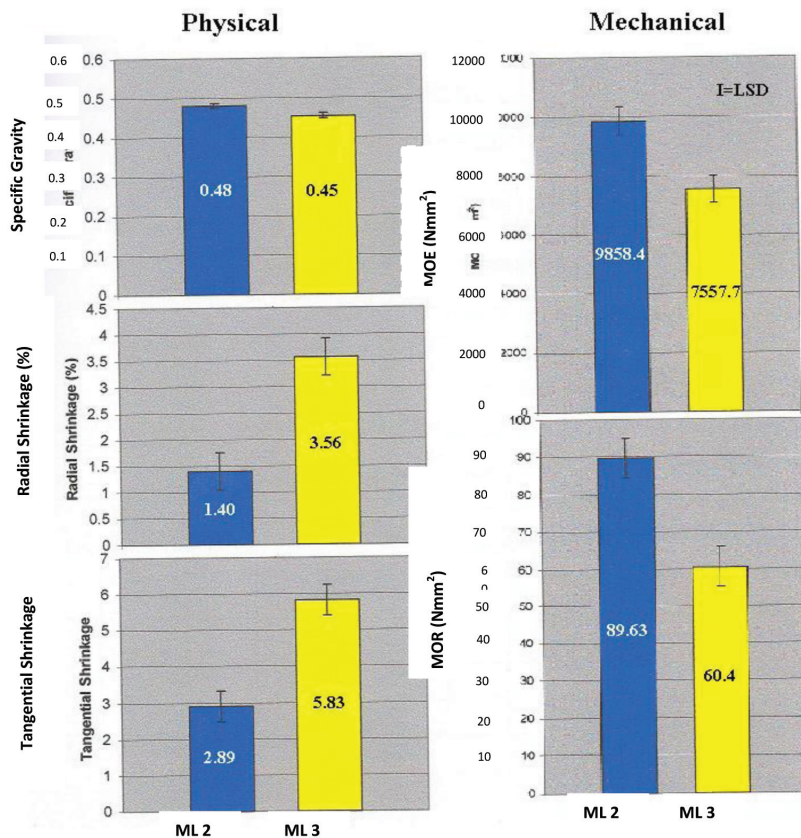


Fig.2: The mean values of physical properties: Specific Gravity (SG), Radial and Tangential Shrinkages and Mechanical Properties: Modulus of Elasticity (MOE) and Module of Rupture (MOR) of Multiple Leader Class 2 (ML 2) and Class 3 (ML 3)

One interesting point that needs to be highlighted in this study is the stem formation of multiple-leadered stems. Compared to a single-stem tree which stands upright and vertical, multiple-leadered stems tend to lean sideways from the base. This mechanism is likely due to the inherent behaviour of each stem to space out in order to support its crown development. There is a possibility that the angle of stem displacement is directly related to the number of stem. This subsequently leads to the development of reaction wood within multiple-leadered stems. The reaction was formed as a result of induced stress in order for the stem to recover to vertical position. Alfred (2007) and Shmulsky and Jones (2011) indicate on the sensitivity of the stem with regards to the angle of lean and the formation of reaction wood. In hardwood species such as *Acacia*, tension wood normally occurs on the upper (tension) side of leaning stem. It was also stated that mechanical stress and formation of reaction wood are most conspicuous in fast growing species as has been presented in numerous studies (see Isebrands & Parham, 1972; Timel, 1986; Balatinecz & Kretschman, 2001). Meanwhile, studies by Jourez *et al.* (2001), Coutand *et al.* (2004) and Zaidon *et al.* (2004) have indicated the unfavourable properties of tension wood which include inferior mechanical strength, high shrinkages and poor machining properties. A study on microscopic evaluation by Scurfield (1973) revealed that tension wood consists of smaller and fewer vessels and ray cells compared to normal wood. Fewer ray cells

would mean lesser cell composition in restraining radial shrinkages. Tension wood fibres are thick walled with small lumen. Secondary wall of tension wood is normally loosely connected to the cell wall due to the cells low lignin content. Unlike normal wood which has stiff wall layer, the cell wall of tension wood consists of a gelatine-like cell layer (G layer). The G layer does not provide restraint during shrinkage due to the absence of S2 layer within the secondary wall layer. This observation supports the finding of this study which indicates inferior mechanical properties and high shrinkage of multiple-leadered stems. Due to its high cellulose and low lignin content, tension wood is considered as highly suitable for dissolving and mechanical pulping, as well as for non-structural applications (Razali & Hamami, 1992; Haslett *et al.*, 1999; Raor *et al.*, 2011).

The analysis of variance of the physical and mechanical properties of this study however did not show any significant differences among provenances (see Table 2). According to John (1999), Nor Aini and John (2003) and John and Nor Aini (2005), who conducted a study on genetic diversity of *A. crassicarpa* plus trees of a provenance trial in Serdang, Selangor, Malaysia, a strong genetic similarity was reported among eight provenances from two geographic regions, namely, Papua New Guinea (PNG) and Queensland (QLD). Those provenances involved are Bimadebum WP, Bensbach WP, and Claudie River, Jardine River, Old Zim, Limal-Malam, Samlleberr and Olive River, whereby the first three are actually the

same provenances used in this study. John and Nor Aini (2005) reported that a cluster analysis based on unbiased genetic distance (Nei, 1978) and the UPGMA dendrogram revealed that all eight provenances in their study showed high level of genetic similarities or close relatedness to each other with the mean values ranging between 0.8878 and 0.9736 as well as between 0.8263 and 0.9429, based on biochemical isozyme and molecular Random Amplified Polymorphic DNAs (RAPDs) analyses, respectively. Two clusters were formed based on isozyme data but no clustering was observed according to the geographic regions. On the other hand, only one cluster was formed using RAPD, and similarly, there was no specific grouping according to the geographic regions. Thus, all the provenances were assumed to be genetically related to each other and possibly shared the same ancestor. In addition, similar findings were also reported by Wickneswari and Norwati (1993) on *Acacia auriculiformis*; this further suggested that the provenances of Queensland are genetically related to Papua New Guinea provenances, which are in the same landmass. This result could help to explain the small genetic distance between the provenances obtained in this study. Furthermore, Boland *et al.* (1984) indicated the land connection of PNG and Australia about 10,000 years ago. However such an assumption can also be biased due to the small sample size of mother trees being represented by each provenance as well as the insufficient data available in the present study.

## CONCLUSION

The present study indicated that ML2 trees produced better physical and mechanical properties compared to ML3. In particular, strength and stiffness are affected by the number of leaders but not in terms of provenances. Thus, suitable applications of fibre resources from multiple-leadered trees of *Acacia crassicarpa* are for pulp and paper and non-structural purposes. ML2 can be used specifically for furniture making, panelling and flooring, whereas ML3 for special wood ware manufacturing.

## REFERENCES

- Ahmad, E., & Kamis, A. (1999). Site Adaptability of *Acacia mangium*, *Acacia auriculiformis*, *Acacia crassicarpa* and *Acacia aulacocarpa*. APAFRI Publication Series No. 3. Kuala Lumpur, Malaysia: APAFRI. 72p, p. 2-3.
- Alfred, B. (2007). Structure of Stress and Non-stress Wood of *Acacia* Hybrid and its Relation to Physical Properties. (PhD Thesis dissertation). Universiti Putra Malaysia.
- Balatinecz, J. J., & Kretschmann, D. E. (2001). Properties and Utilization of Poplar Wood. In D. Dickmann (Eds), *Popular Culture in North America* (pp. 277-279). Canada: National Research Council on Canada.
- Boland, D. J., Brooker, M. I. H., Chippendale, G. M., Hall, N., Hyland, B. P. M., Johnston, R. D., Klenig, D. A., & Turner, J. D. (1984). *Forest Trees of Australia*. Nelson and CSIRO. Melbourne, Australia. Pp.147 -149.
- Chung, H. H. (1992). Research on Economics and Marketing of *Acacias*. p 92-95. In the Proceeding of a first meeting of the Consultive Group for Research and Development of *Acacia* (COGREDA) (Kamis Awang & David A. Taylor Eds.). Phuket, Thailand. 106p.



- Cooper, W. S. (1931). The Layering Habit in Sitka Spruce and Two Western Hemlocks. *Botanical Gazette*, 91, 41-51.
- Coutand, C., Jeronimidis, G., Chanson, B., & Loup, C. (2004). Comparison of Mechanical Properties of Tension and Opposite Wood in Populus. *Wood Science and Technology*, 38(1), 11-24.
- Doran, J. C., Turnbull, J. W., Martensz, P. N., Thompson, L. A. J., & Hall, N. (1997). Australian Trees and Shrubs: Species for Land Rehabilitation and Farm Planting in the Tropics. 2<sup>nd</sup> Edition, J. C. Doran, & J. W. Turnbull (Eds.). Canberra, Australia. Australian Centre for International Agriculture Research. 136-137.
- Faber, D. L., & Tester, J. R. (1997). Oak Mortality in Sand Savannas Following Drought at Cedar Creek. *Minnesota Bull Torey Club*, 16, 143-144.
- Fewles, G. (2002). *Tree of Wisconsin*. Cofrin Centre of Biodiversity and University of Wisconsin. Retrieved from <http://www.treeofwisconsin.html>
- Haslett, A. N., Young, G. D., & Britton, R. A. J. (1999). Plantation Growing Tropical Timbers; Properties, Processing and Uses. *Journal of Tropical Forest Science*, 3(3), 229-237.
- Isebrands, J., & Parham, R. A. (1974). Tension Wood Anatomy of Short Rotation *Populus spp.* Before and After Kraft Pulping. *Wood Science*, 6(3), 256-265.
- John, K. C. (1996). Genetic Variation of *Acacia crassicarpa* A. Cunn. Ex. Benth, by Isozyme and RAPD Analysis. (Bac. Sc. Thesis dissertation). Faculty of Forestry, Universiti Putra Malaysia.
- John, K. C., & Nor Aini, A. S. (2005). *Genetic Diversity in Random Amplified Polymorphic DNA Analysis of Acacia crassicarpa Plus Tree*. Paper presented at Seminar on Synergistic Approach to Appropriate Forestry Technology for Sustaining Rainforest Ecosystem, Universiti Putra Malaysia Bintulu Campus Bintulu, Sarawak. 7<sup>th</sup> – 9<sup>th</sup> March 2005.
- Jourez, B., Riboux, A., & Leclercq, A. (2001). Comparison of Basic Density and Longitudinal Shrinkage in Tension Wood and Opposite Wood in Young Stems of *Populus euramericana* cv. Ghoy When Subjected to Gravitational Stimulus. *Canadian Journal of Forest Research*, 31(10), 1676-1683.
- Kang, K. Y., Zhang, S. Y., & Mansfield, D. (2005). The effect of initial spacing on wood density, fibre and pulp properties in jack pine (*Pinus banksiana* Lamb). *Holzforchung*, 58(5), 455-463.
- Kindo, A. I., Mndolwa, M. A., Edward, E., & Chamshama, S. A. O. (2010). Performance of Four Year –old Australian and Papua New Guinean *Acacia* Species/Provenances at Kongowe, Kibaha, Tanzania. *Southern Forest. A Journal of Forest Science*, 72(1), 13-22.
- National Academy of Sciences. (1980). *Fire crops: Shrubs and Trees for Energy Production*. National Academy Press, Washington D.C. p. 2-3.
- National Research Council. (1983). *Mangium and Other Fast-growing Acacias for the Humid Tropics*. National Academy Press, Washington D.C. p 2-3.
- Nei, M. (1978). Estimation of Average Heterozygosity and Genetic Distance From a Small Number of Individuals. *Genetics*, 89, 583-590
- Nor Aini A. S., & John K. C. (2003). Genetic Variation in Isozyme of *Acacia crassicarpa* A. Cunn Ex Benth. *Journal of Tropical Forest Science*, 15(1), 74-81.
- Pinyopusarek, K. (1992). Australian Collaborative Research on Tropical Acacias. pp 8-14 . In the Proceeding of a First Meeting of the Consultive Group for Research and Development of *Acacia* (COGREDA). Kamis Awang and David A. Taylor (Eds.). Phuket, Thailand. 106p.
- Raor, V., Anoop, E. V., Sheena, V. V., Aruna, P., & Ajayghosh, V. (2011). Anatomical Variation in the Juvenile Wood of *Acacias* Grown in the

- South Indian State of Kerala. *Journal Indian Academic Wood Science*, 8(2), 130-135.
- Razali, A. K., & Hamami, S. M. (1992). Processing and Utilization of *Acacia* Focusing on *Acacia mangium*. Pp. 86-91. In the Proceeding of a First Meeting of the Consultive Group for Research and Development of *Acacia* (COGREDA) (Kamis Awang and David A. Taylor Eds.). Phuket, Thailand. 106p.
- Rimbawanto, A., (2002). Plantation and Tree Improvement Trends in Indonesia. In K. Barry (Ed.), *ACIAR Technical Reports No. 51e* (pp. 6). Canberra, Australia.
- SAS Institute inc (2000) SAS/STAT User's Guide. Cary, NC: SAS Institute, Inc
- Sharma, S. K., Kumar, P., Rao, R. V., Sujatha, M., & Shulda, S. R. (2011). Rational Utilization of Plantation Grown *Acacia mangium* willd. *Journal of The Indian Academy of Wood Science*, 8(2), 97-99.
- Shmulsky, R., & Jones, P. D. (2011). Juvenile Wood, Reaction Wood and Wood of Branches. In *Forest Product and Wood Science : An Introduction*. West Sussex, UK. 128p.
- Thai, S. K., Mahdan, B., & Ridzuan, S. (1997). *Planting of Acacia mangium for General Utility Timber and Reconstituted Wood Products*, pp 10 -19. In the Proceedings of Seminar on Commercial Cultivation of Teak, Sentang, *Acacia* and *Hevea* for Timber, Kuala Lumpur. Ahmad Zuhaidi, Y., Ab Rasip, G., Mohd Noh, M., Wikneswari, R., & Nik Zanariah N.M. (Eds) FRIM.
- Timel, T. E. (1986). *Compression Wood in Gymnosperms, Vols.I, II, and III*. Berlin: Springer-Verlag.
- Turnbull, J. W. (1986). Australian *Acacias* in Developing Countries. pp 17-26. In the Proceedings of an International Workshop, Queensland, Australia.
- Turnbull, J. W. (Ed). (1991). *Advances in Tropical Acacia Research*. In the Proceedings of an International Workshop, Bangkok, Thailand. ACIAR Proceedings No. 35.
- Wikneswari, R., & Norwati, M. (1993). Genetic Diversity of Natural Populations of *Acacia auriculiformis*. *Australian Journal of Botany*, 41, 65 -77.
- Zaidon, A., Nobuchi, T., Mohd Hamami, S., & Farizan, M. (2004). *Anatomical Features and Chemical Characterisation of Wood Cut from Leaning Stem of Acacia spp. Sustainable Production and Effective Utilization of Tropical Forest Resources*. Proceedings of the 5<sup>th</sup> International Wood Science Symposium JSPS-LIPI Core University Program in the Field of Wood Science, p. 229-235.
- Zhang, S. Y. (1997). Wood Specific Gravity-Mechanical Property Relationship at Species Level. *Journal of Wood Science and Technology*, 3,181-191.