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PHYSICAL AND MECHANICAL PROPERTIES OF (*ACACIA AURICULIFORMIS* × *A. MANGIUM*) HYBRID *ACACIA*

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ABSTRACT

The physical and mechanical properties of hybrid *Acacia*, produced from natural crossing between two introduced timber species (*Acacia auriculiformis* and *Acacia mangium*) were studied. The timber hybrid *Acacia* is of medium dense having specific gravity 0.56 at green condition which is less than that of teak (*Tectona grandis*). The volumetric shrinkage of hybrid *Acacia* wood was found greater than that of teak but the specific gravity was found less than that of teak. From the study of physical and mechanical properties it is evident that the species is moderately strong. The species is suitable for making furniture and other household articles.

Key words: Hybrid *Acacia,* Specific gravity, Physical properties, Mechanical properties

INTRODUCTION

Acacia auriculiformis is a native tree to Papua New Guinea, Northern Australia and Indonesia whereas *Acacia mangium* is a native tree of Papua New Guinea and Indonesia. Tham (1976) documented that *A. Mangium* and *A. auriculiformis* can cross pollinate naturally resulting in a hybrid that grows much faster than that of its parent trees. Rufelds and Lapongan (1986) presented their findings on hybrid *Acacia* in Sabah at the Malaysian Forestry Conference in Kuching, Sarawak in 1986. In the following years, they published the results of a comparative study on hybrid *Acacia*. It is a fast growing medium-sized leguminous tree. Generally, hybrid *Acacia* is long and straight having clear bole with light branching. The hybrid *Acacia* also showed more resistance to heart rot disease - a diesease that occurs in *A. mangium* and it was observed that the species grows vigorously resisting heart rot disease in the forest plantations (Banik and Islam 1996). It has become a major industrial plantation species in Malaysia, Thailand and Indonesia. With increasing population and the economy of Southeast Asia, the needs for wood based industries for raw materials have been increased. Fast growing tree species are particularly important to meet the demand of wood and furniture industries, pulp and paper mills (Kijkar 1992). The hybrid tree possesses many characteristics of the parent species (Gani *et al.* 2001). Most of the reports state that hybrid *Acacia* is more productive than either of the parent species on different site types in Vietnam, Malaysia, and Thailand (Pinso and Nasi 1991) and in Bangladesh (Faizuddin 1998).

Acacia mangium and *A. auriculiformis* were introduced in Bangladesh as shade tree in tea gardens about 40 years ago. In 1980s, provenance trials of these species have been established at different Silvicultural Research Station (SRS) of Bangladesh Forest Research Institutes (BFRI). Subsequently, thousands of hectares of plantations have been raised by Bangladesh Forest Department (FD) with these two species. In recent years, naturally crossed hybrids of *Acacia auriculiformis* × *A. mangium* have been found in the plantations of these species in Bangladesh. Since 1995, such hybrid acacia trees were selected and propagated by using shoot cutting for establishing a hedge orchard. Copies shoots sprouted from this hedge orchard plants were used as stem cuttings for rooting trials, and successful cuttings from different clones provided planting materials for clonal trial experiment (Gani *et al.* 2001). Although, this species is used by the furniture industries, information regarding its strength properties is not adequately known. The present study was undertaken for the determination of physical and mechanical properties of hybrid *Acacia* in order to ensure their proper end uses.

MATERIALS AND METHODS

Three representative trees of hybrid *Acacia* species was collected from the Silviculture Research Station, Keochia, Chittagong. The age of the tree was 9 - 12 years and the height and girth were 8 - 12.5 m and 50 - 85 cm, respectively. Three samples per bole were selected randomly from each of three 2.50 m bolts above the stump height of each tree. All the bolts were fairly straight and free from natural defects. For determination of physical properties, namely moisture content, specific gravity and shrinkage, each tree was divided into its butt, middle and top position. The sizes of the samples are 2.54 cm × 2.54 cm × 5.08 cm and 5.08 cm × 5.08 × 15.24 cm, respectively. For determination of mechanical properties the bolts were marked into 6.35 cm^2 according to the standard sawing diagram and were sawn to 6.35 cm × 6.35 cm × 2.50 m sticks. The sticks were prepared in pairs. One stick was taken from each test in green condition and the other for air-dry condition. The sticks for air-dry tests were staked using suitable stickers inside a drying shed and allowed to attain the equilibrium moisture content of 12 - 14%.

Measurement of properties: Small clear specimens were tested, in both green and air-dry states, for the following physical and mechanical properties using the procedure given in ASTM (Anon. 1971).

Moisture content: Moisture content is the amount of water in wood expressed as a percentage of its oven dry weight.

$$\text{Moisture content (\%)} = \frac{\text{Original weight} - \text{Oven dry weight}}{\text{Oven dry weight}} \times 100$$

Specific gravity: The specific gravity was determined based on oven dry weight and volumes at green, 12% moisture content and oven dry conditions.

Shrinkage: The volumetric shrinkage was determined from the data for density measurements. The volume values at green, 12% moisture content and oven dry conditions were used for the determination of volumetric shrinkage.

Mechanical properties: All the test sticks were dressed to 5.08 cm × 5.08 cm × 2.50 m strips and clear specimens to the sizes specified by the American Society for Testing of Materials (ASTM) standards D 143-52 (Anon. 1971). The specimens of various parameters were tested in accordance with the specifications of ASTM except toughness. The tests for mechanical properties were carried out in a Riehle screw power type universal testing machine. Toughness tests were performed in a toughness testing machine designed by the US Forest Products Laboratory, Madison, Wisconsin.

Static bending: It furnishes data on bending strength and stiffness for such uses as beams, joists, etc. Specimen of 2 × 2 × 30 cm is tested on a 28 cm span with centre loading. The parameters of static bending are as follows:

(a) Stress at proportional limit the numerical value of бPL can be obtained in equation (eqn.1)

$$БPL = \frac{3\ P^1}{2bh^2} \quad (1)$$

The modulus of rupture R (eqn. 2) can be found by substituting the maximum load, P_1 for the load at the proportional limit

$$R = \frac{3\ P_1 1}{2bh^2} \quad (2)$$

The modulus of elasticity (eqn. 3) can be determined and substitution

$$E = \frac{P1^3}{4\ ybh^3} \quad (3)$$

where, P – load at the limit of proportionality, l – span of the test specimen, b – breadth of the test specimen, h – depth of the test specimen and, y – deflection at the limit of proportionality.

RESULTS AND DISCUSSION

*General properties and description of wood***:** The sap wood and heart wood of hybrid *Acacia* were distinct. The heart wood is dark brown and sap wood is light coloured. The wood is moderately hard and moderately dense, with shallowly interlocked grain and medium texture. Fine lines of parenchyma simulate the presence of growth rings; the actual growth rings are in distinct.

Physical properties: The average values of physical properties such as moisture content, specific gravity and volumetric shrinkage of hybrid *Acacia* determined in green and air-dry conditions are presented in the Table 1. It is evident from data that the specific gravity and volumetric shrinkage of hybrid *Acacia* is 0.56 and 9.71, respectively. On the other hand, the specific gravity and volumetric shrinkage for *A. auriculiformis* is 0.61 and 8.01, and for *A. mangium* is 0.52 and 7.01 (Sattar *et al.* 1993). In a study in Malaysia the specific gravity of four years hybrid *Acacia* was found to be 0.51 (Laurila 1995). Data also indicate that the volumetric shrinkage of *Hybrid acacia* is more than that of *Tectona grandis* (Yakub *et al.* 1978).

Table 1. Physical properties of hybrid *Acacia.*

Species	Locality of timber with age	Number of trees sampled	Seasoning condition	Moisture content (%)	Specific gravity based on oven dry weight		Shrinkage (%) from green to oven dry condition based on green dimension volumetric	
1	2	3	4	5	6	7	8	9
Chittagong teak (*Tectona randis*)	Kaptai, Chittagong Hill Tracts, 40 years	3	Green	155.0	0.58	0.61	4.50	5.0
			Air-dry	12.0	0.59	-	-	-
Hybrid *Acacia*	Keochia, Chittagong 9 - 12 years	3	Green	98	0.56	0.60	9.71	13.0
			Air-dry	12.0	0.58	-	-	-

Mechanical properties: In respect to mechanical properties the individual strength value was computed from the data collected for nine different tests like static bending, compression parallel to grain, compression perpendicular to grain, hardness, shear parallel to grain; nail withdrawal, cleavage and toughness. The average values of various strength properties including co-efficient of variation (CV%) in the both green and air dry conditions are shown in the Table 2.

Data shows that all the parameters of static bending and compression parallel to grain have lower values in both green and air-dry conditions for hybrid *Acacia* as compared to teak. Modulus of rupture and modulus of elasticity of hybrid *Acacia* was found greater than that of *A. auriculiformis* and *A. mangium* i.e. 658 and 652 kg/cm^2; 83 and 79 kg/cm^2, respectively (Sallas *et al.* 1993). The studies in Malaysia with four years hybrid *Acacia* show that modulus of rupture and modulus of elasticity was 713.47 and 82.83 kg/cm^2, (Laurila 1995). Table indicates that the strength values of wood for compression perpendicular to grain, hardness and shear parallel to grain in air–dry condition are higher than that of the green values except nail withdrawal. From data (9) it was found that the hardness of hybrid *Acacia* is less (458 kg) than that of *A. auriculiformis* (572 kg), but the value is greater than that of *A. mangium* (337 kg). The mechanical properties of hybrid *Acacia* for cleavage in both green and air dry conditions are found to follow the normal trend in timber testing values. The values of cleavage both radial and tangential in air dry condition are higher than those of green conditions. However, in case of tension perpendicular to grain and toughness the values are lower. As compared to *Tectona grandis* the recognized standard timber species for comparing the wood properties has been considered for evaluation of hybrid *Acacia.* In general, the tested species has been found to be a very good timber for utilization of different purposes.

Table 2. Mechanical properties of hybrid *Acacia.*

Properties	Species / Seasoning conditions / values			
	Hybrid *Acacia*		Teak (*Tectona grandis*)	
	Green (CV %)	Air-dry (CV %)	Green	Air-dry
Static bending (kg / cm^2)				
Stress at proportional limit	377 (13.58)	391 (24.74)	514	628
Modulus of rupture	734 (14.57)	756 (20.34)	867	1008
Modulus of elasticity	97 (18.09)	117 (16.32)	120	131
Compression parallel to grain				
Stress at proportional limit (kg / cm^2)	230 (15.83)	253 (17.73)	288	374
Maximum crushing strength (kg / cm^2)	313 (15.98)	337 (17.73)	383	513
Compression perpendicular to grain				
Stress at proportional limit (kg/cm^2)	82 (13.20%)	110 (20.33)	67	119
Hardness, load required to embed a 1.13 cm ball at half its dia				
Radial (kg)	400 (12.5)	457 (17)	495	532
Tangential (kg)	402 (12.7)	458 (18.5)	518	550
End (kg)	429 (9)	488 (15)	495	532
Shear parallel to grain				
Radial (kg)	71 (12)	124 (11)	86	197
Tangential (kg)	69 (16)	131 (11)	103	115
Nail withdrawal				
Radial (kg)	77 (27.1)	62 (43)	145	82
Tangential (kg)	74 (29)	61 (44)	132	77
End (kg)	48 (30)	33 (47)	95	64
Cleavage load to cause splitting				
Radial (kg/cm of width)	49 (24)	56 (28)	68	66
Tangential (kg/cm of width)	46 (31)	52 (20)	77	78
Tension perpendicular to grain				
Tensile strength radial (kg/cm^2)	47 (22.21)	28 (17.17)	44	41
Tensile strength tangential (kg/cm^2)	51 (27.09)	33 (24.27)	49	47
Toughness				
Radial (cm/kg - specimen)	313 (27.89)	309 (37.8)	387	321
Tangential (cm/kg - specimen)	365 (29.45)	362 (32 .45)	419	326

The values of physical and mechanical properties were also compared with the physical and mechanical properties of teak to find out the suitability of hybrid *Acacia* expressed in percentage (Table 3).

Table 3. Physical and mechanical properties of hybrid *Acacia* relative to teak expressed as percentage.

Properties	Species / Seasoning conditions / values	
	Hybrid *Acacia*	
	Green	Air-dry
Specific gravity based on oven dry weight		
Volume at test	96	98
Volume at oven dry	98	-
Volumetric shrinkage (%) from green to oven dry condition based on green dimension	194	-
Static bending		
Stress at proportional limit	73	62
Modulus of rupture	85	75
Modulus of elasticity	81	89
Compression parallel to grain		
Stress at proportional limit	80	68
Maximum crushing strength	82	66
Compression perpendicular to grain		
Stress at proportional limit	122	92
Hardness, load required to embed a 1.13 cm ball at half its dia.		
Radial	81	86
Tangential	78	83
End	87	92
Shear parallel to grain		
Shearing stress radial	82	63
Shearing stress tangential	67	114
Nail withdrawal		
Radial	53	76
Tangential	56	79
End	50	48
Cleavage load to cause splitting		
Radial	72	85
Tangential	60	67
Tension perpendicular to grain		
Tensile strength radial	107	68
Tensile strength tangential	104	70
Toughness		
Radial	181	96
Tangential	187	90

CONCLUSION

Hybrid *Acacia* is a fast growing and productive tree with more resistance to heart rot disease. The heart wood is dark brown and sap wood is light coloured. It is a moderately heavy and moderately strong wood species. The species is fine grained and may be used for making furniture, small hand tools, cabinet door frame, window frame, for pulp and paper, and other purposes.

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