VARIATION IN WOOD DENSITY AND STRENGTH PROPERTIES AMONG MARKHAMIA LUTEA (SPRAGUE) HALF SIB FAMILIES FROM WESTERN KENYA

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ABSTRACT

Wood samples of forty two (42) half sib families of Markhamia lutea were drawn from a 4-year old progeny test at Kakamega and assessed for variation in wood properties. The mother plus trees had been selected from partially isolated populations in the Lake Victoria belt of Kenya. The main objective of the progeny trial was to test breeding values for various traits, including wood properties, of the selected trees for advanced breeding and to estimate genetic parameters. Incomplete block design in 3 replications with 8 tree line plots was used.

Results on growth performance and stem straightness revealed significant variations in diameter and height and no significant variation in stem straightness among the progenies, (ICRAF,1996)

The study reported here involved analysis of wood specific gravity, bending strength (modulus of elasticity [MOE] and modulus of rupture [MOR]), compression (crushing) strength. Wood samples for specific gravity determinations were obtained at 1.3 m height. Other properties were based on the butt logs. Specific gravity was determined using the water displacement method (Brown et al, 1952) while the other properties were determined according to British Standard No. 373:1957.

No significant differences ($P < 0.05$) were obtained for all the properties studied. Averages for specific gravity were highest for South Nyanza provenance and lowest for Busia provenance. The range in specific gravity was 0.37-0.44 (18.9%) while the ranges in strength values were: MOR 67.7-85.3 MPa (26.0%) and compression 31.9 - 40.9 MPa (28.2%).

It was concluded that at 4 years selection can be done for height and diameter but little gain may be expected from provenance and individual tree selection for specific gravity and strength properties, although it was recognised that the reported results relate to juvenile assessments (rotation age for this species is about 40 years). It is therefore recommended that these studies be repeated at later ages towards half rotation age.

Keywords: Agroforestry, specific gravity, strength values, Markhamia lutea, progeny tests, Kenya.

INTRODUCTION

Markhamia lutea (Sprague) is an indigenous tree common in the Lake Victoria belt and highland areas (up to 2000m above sea level) of Kenya. It is a fast growing and widely used Agroforestry tree grown by farmers in Western Kenya. Markhamia is present in many cropped fields as natural regenerants and are protected and typically managed as coppiced trees. More recently, it is also being planted and considered as one of the most important tree species in this region in almost all configurations, services and products (van Schaik, 1986). It is mainly used for timber, poles, posts, fuelwood, furniture, tool handles, medicine (leaves), bee forage, shade, mulch, ornamental, soil conservation, windbreaks, banana props, and tobacco curing (ICRAF, 1992).

Markhamia poles are harvested after about 5 years and can be found in nearly all traditionally constructed houses because of the durability of the wood and its resistance to termite attack (ICRAF, 1996). However, poles (7cm in diameter) suitable for truss rafters, support beams, and tool handles can be harvested after 1.5 to 4 years, depending on the growing site and soil fertility (van Schaik, 1986). Poles can be used immediately after felling but are in most cases air dried for some months.

By the time the tree is 15-20 years old, it produces sawn timber of high value for furniture and joinery. Its sawn timber is relatively cheap and has good working properties. The wood is hard, tough, moderately flexible, moderately close and straight grained, easily split, durable against decay and moderately resistant to termites (Eggling and Dale, 1951).

The Kenyan Forest Seed Centre has been unable to meet the demand for seed of markhamia since 1990. The shortfall amounted to about 1.5 million seeds in 1994 (ICRAF, 1996). In the early 1990s the International Centre for Research in Agroforestry (ICRAF) and her partners in the region began to collect germplasm of markhamia: for evaluation and planting; to characterise genetic diversity in the species and to make recommendations on production of germplasm for distribution to farmers. In 1991, 42 half-sib families from partially isolated mother plus trees in the Lake Victoria belt "Markhamia platycalyx provenance", in Western Kenya, were planted in a progeny trial in Kakamega District. The main objectives of the trial were: to test breeding values for various traits (growth performance, stem straightness and wood properties) of selected superior trees; to provide a base for selection for advanced breeding, and to estimate genetic parameters of superior phenotypes.

Results on growth performance and stem straightness revealed significant variations in diameter and height and no significant variation in stem straightness among the progenies (ICRAF,1996). The study reported here mainly involved analysis of wood density (specific gravity) and strength properties (clear wood strength values). The objectives of the study were:

1. To determine the variation in specific gravity among the progenies and provenances of *Markhamia lutea*.

2. To correlate the specific gravity of *Markhamia lutea* mother plus trees with those of the progenies.
3. To establish the correlation of specific gravity of *Markhamia lutea* with growth factors (height and diameter at breast height).
4. To assess the variation in compression strength and static bending properties among the progenies and provenances of this species.

MATERIALS AND METHODS

Trial site

Wood samples were taken from a half-sib progeny trial of Markhamia lutea planted in April 1991 at Kakamega (Malava) in Western Kenya. The Malava site (0'40^o N, 35'50^o E; 1623m.a.s.l.) slopes gently (less than 5 %). The mean annual precipitation is 1600 - 2000mm, bimodally distributed. The mean annual temperature is about 20^{o}C. The soils are very fine, kaolinitic, (according to US taxonomy, U.S.D.A, 1995.)

Plant materials

The trial incorporated stands representing 42 half-sib families from mother plus trees selected from partially isolated populations from the Lake Victoria belt "Markhamia Platycalyx provenance" in Western Kenya. Selection of superior phenotypes of Markhamia lutea was accomplished in Western Kenya in 1989. Germplasm was collected in 1991 from superior trees in 5 districts in Western Kenya. In 1992, 42 open pollinated families were planted in the field in a progeny trial in Malava (Kakamega).

Experimental design

The experiment was performed in an incomplete block design in 3 replications with eight tree line plots at 2 x 4 m initial spacing between trees.

Management of the experiment

An initial pruning to half height followed by clean weeding was done. Maize and beans inter crop without fertilizer application were used.

Wood sampling and analysis

The wood samples were obtained from 4 year old trees that had been removed during a systematic thinning in May 1995. A total of twelve trees per family were removed, four from each replicate. Total height, merchantable height and diameter at breast height of each tree were assessed as well.

Trees from replicates 1 and 2 were used for the analysis of the wood properties. Four trees (two from each replicate) and two trees (one from each replicate) per family were used for the determination of specific gravity and strength values respectively. Samples for specific gravity determination were obtained from all the 42 families while those for strength tests from 22 families representing the five provenances.

Wood billets 10 cm in length were obtained at the breast height (1.3m) of the felled trees for specific gravity determination and 1m bolts from the butt logs for strength tests. The samples were labelled using permanent ink. The family, tree and replicate numbers were clearly marked on the cut surfaces. The labelled billets and bolts were transported to Kenya Forestry Research Institute (KEFRI)'s Forest Products laboratories at Karura, Nairobi for analyses.

Core samples
Increment core samples were obtained at breast height from randomly selected progenies and mother plus trees. Two cores from N-S and E-W directions were obtained, labelled, sealed in polythene bags and transported to the KEFRI laboratory for analysis of the specific gravity.

Specific gravity determination
Billet samples
Discs each of 1 cm thickness were obtained from the green 10 cm billets and four wedges cut from each of these and used for determination of specific gravity. Water displacement method (Brown et al, 1952) was used. The specific gravity was calculated as follows:-

Specific gravity = Oven dry weight / weight of the displaced volume of water

Increment core samples
Samples 10 mm in length were obtained from the ends and at centre of each of the two cores per tree to ascertain that samples close to the bark and at the pith were included as shown in Figure 1. The remaining samples were obtained at an interval of 10 mm. The specific gravity of the cores was measured by using the maximum moisture content method as described by Smith (1954). The specific gravity of each tree was computed as the mean of the specific gravity of all the 10 mm samples derived from the two cores. The specific gravity was computed as shown below:

Fig.1. Sampling of the 10 mm specimen from each core for determination of specific gravity.

$Sg = 1/\{[(ws/wo)-1] + [1/1.53]\}$ (Smith, 1954).

Where:
Sg = wood specific gravity
ws = saturated weight of wood sample
wo = oven dry weight of wood sample
1.53 =reciprocal of specific gravity of wood substance.

Determination of strength properties

The bolts were air dried for about eight months. Due to the small diameter of the bolts, Lavers (1969) procedure for selection of strips could not be used. Two strips were therefore obtained from each bolt by bisecting the bolts at the pith and four test specimens prepared from these. The sizes of the test specimens from the strips and test methods were based on the British standard No. 373:1957 (Lavers, 1969) - for the following physical and mechanical properties: Moisture content, nominal specific gravity, static bending - centre point loading and compression parallel to the grain. The mechanical properties were determined using a universal strength testing machine with a capacity of 500 KN supplied by Avery Kenya Limited.

Statistical analysis

Plot means were used for the analysis of variance and determination of correlation coefficients using Statsview graphics programme.

RESULTS AND DISCUSSIONS.

Specific gravity

Variation among progenies

The mean specific gravity values for the 5 provenances and the mean total height and DBH are shown in Table 1. The means for the six most-dense and the six lightest families are also recorded in Table 2. The overall mean specific gravity for the 42, 4-year old Markhamia lutea families is 0.41 with a range of 0.37 to 0.44. No significant difference ($p< 0.05$) in specific gravity was found among the families and provenances. Families from South Nyanza provenance had the highest mean specific gravity while those from Busia provenance the least. The most-dense family was from South Nyanza provenance while the lightest was from Siaya provenance.

In general, results from this study indicate a low specific gravity (0.41). At mature age, Markhamia lutea has a moderate specific gravity ranging from 0.52 to 0.55. However, the specific gravity (0.41) is reasonable as it is the same as that for mature cypress (C*upressus lusitanica*) (0.40), the main structural timber in Kenya, (Ngang'a, 1992).

The five districts from where the progenies were obtained are in the same ecological region and therefore the insignificant difference in specific gravity is not very surprising. However, the high wood density of families from South Nyanza provenance and the low density for the families from Busia provenance could be due to slow and fast growth respectively as indicated by the growth factors in Table 1.

Variation in specific gravity among the mother plus trees

The mean specific gravity values for the mother plus trees and siblings of Markhamia lutea from the three provenances /districts are as indicated in Table 4. The specfic gravity values ranged from 0.43-0.51 and 0.40- 0.46 for the mother plus trees and the siblings respectively. The mother plus trees plus trees from the Busia provenance had the highest mean specific gravity (0.48) and those from the Siaya provenace the lowest (0.46). However, these differences among the provenances for the mother plus trees were insignificant. Siblings from the Busia provenance had lower mean specific gravity (0.41) than that for those from Siaya and Kakamega provenances (0.43). These differences in the mean specific gravity among the siblings were also insignificant. This confirms the results for specific gravity obtained using the water displacement method though the overall mean specific gravity for the core samples (0.43) is slightly higher than that for the wedges (0.41) probably due to the smaller number of samples used in the former measurement. There was a strong correlation ($r>0.70$) between the specific gravity of the mother plus trees and those of the siblings. However, the predictive value of the regression equations, as indicated by the coefficient of determination (COD), ranged from 42 % (for Kakamega provenance) to 72 % (for Siaya). This indicates that only about 42 to 72 % of the variability in specific gravity among the siblings can be attributed to the original mother plus trees. The remaining 28 to 58 % could be due to other factors such growth and environmental parameters.

Correlation of specific gravity with growth factors (height and diameter at breast height).

Clear wood strength values.

The mean clear wood strength values for the five provenances and the mean modulus of rupture for the strongest five and weakest five families are recorded in Tables 3 and 4 respectively. The mean values and ranges for modulus of elasticity (MOE), modulus of rupture (MOR), and compression strength (CS) were: 74.2 and 67.7 - 85.3 MPa; 6563.4, 5100 - 7529.2 and 37 and 31.9 - 40.9 MPa respectively. Families from South Nyanza and Kakamega provenances had the highest strength values. Kakamega provenance had the highest mean bending strength and South Nyanza provenance the highest mean crushing strength; families from Busia had the least mean strength. However, there were no significant differences (P< 0.05) in the strength values among the families and provenances. This is expected as specific gravity, the most important determinant of the strength properties of wood, (Panshin and Carl de Zeeuw, 1980; Keith, 1961; Bamber, 1978) did not vary significantly among the families and provenances.

These results generally indicate a moderate strength. It appears that the four-year old, air dried, markhamia poles have attained reasonable strength close to that of mature green markamia of 0.50 specific gravity (MOR= 82.0 MPa and compression strength of 41.9 MPa respectively), (Peterson, 1963). At mature age, Markhamia lutea is moderately strong in bending (MOR 104.1 to 110 MPa) but on failure the fracture is sudden and complete (Wimbush, 1957; Paterson, 1963; Bryce, 1966).

The modulus of rupture (74.2 MPa) is significantly higher than that for timber from mature cypress (44.6 MPa), the main structural timber in Kenya, (Ngang'a, 1992). This confirms the suitability of timber from four- year old markhamia trees for poles, posts, tool handles and truss rafters.

*A weak but significant (P<0.05) correlation of specific gravity with modulus of rupture (r= 0.36) and very low correlation with the other strength properties **and growth factors were found**. The correlation between the specific gravity and MOR (r= 0.36) indicates that the differences in MOR between different specimen or progenies cannot be attributed fully to differences in specific gravity. It is also possible that the specific gravity values of butt logs of some progenies were abnormally higher than expected for their MOR values probably due to high extractive content or tension wood, rather than that the MOR values were abnormally low. Related studies on *P. taeda* established that MOR values of butt logs tend to be much lower than those of wood of similar specific gravity from higher in the tree. This reduction was more marked for low-density material and decreased as specific gravity increased with an indication that there would be little reduction for material with a specific gravity of about 0.6 and higher (Pearson and Gilmore, 1971).
*A low but significant (P< 0.05) correlation coefficient was found between MOE and MOR (r = 0.44). The low correlation could be probably due to the butt log factor and also as a result of some factor operating in some specimens or progenies, but probably not in others, which causes variation in one property and not the other.

Table 1. The mean specific gravity, diameter at breast height (DBH) and total height for the 42, 4-year old *Markhamia lutea* families planted at Malava (Western Kenya).

Provenance/ District	Total height (m)	Diameter at breast height (cm)	Specific gravity		
			Mean	S.D.	C.V. (%)
Kakamega	8.9	8.6	0.41	0.02	4.9
Busia	8.7	9.2	0.40	0.04	10
Siaya	8.9	9.0	0.41	0.02	4.9
South Nyanza	7.6	7.7	0.43	0.01	2.3
Kisii	8.0	8.3	0.40	0.02	5.0
Overall means	8.4	8.6	0.41	0.02*	4.9

Table 2. Ranking of the 4 year old *Markhamia lutea* families in terms of the mean specific gravity (S. G) values.

Family code	Provenance and Village	Specific gravity
The six families with highest S.G. values		
K6M043	South Nyanza, Piny Owacho	0.44
K6M045	South Nyanza, Kolwal	0.44
K6M044	South Nyanza,Migori	0.43
K6M046	South Nyanza,Mukuyu	0.43
K6M049	South Nyanza,Rongo	0.43
K1M025	Kakamega, Kakamega	0.43
The ten families with lowest S.G. values		
K4M003	Siaya, Got Abayo	0.37
K7M003	Kissi, Nyamatutu	0.38
K7M031	Kissii, Kissii	0.38
K7M032	Kissii, Nyachenge	0.39
K7M034	Kisii, Mbale	0.39
K1M012	Kakamega, Mbale	0.39
K1M021	Kakamega,Mbihi	0.39
K1M023	Kakamega, Chavakali	0.39

K1M024	Kakamega, Chavakali	0.39
K3M005	Busia, Lerolimo	0.39
Mean of families (n=42)		0.41
Standard error of differences		0.002
Coefficient of variation (%)		5.8
F-ratio of Families		1.38
Range		0.37-0.44

Table 3: The mean strength properties for 4-year old *Markhamia lutea* familes from 5 districts (provenances) planted at Malava (Western Kenya).

District (Provenance)	No. of progenies tested	Wood properties										
		M.C %	N.D. (gcm^{-3})	MOE (MPa)		MOR (MPa)		M.C %	N.D. (gcm^{-3})	Crushing Strength (MPa)	
Kakamega	6	12.4	0.45	6846	1239	77.9	8.6	13.5	0.46	38.4	3.1
Busia	3	12.6	0.42	6561	1408	68.7	10.7	13.8	0.45	35.0	3.6
Siaya	6	12.6	0.43	6246	854	73.8	5.8	15.1	0.44	36.2	2.4
S. Nyanza	3	12.6	0.45	6631	839	75.9	5.8	14.5	0.47	38.6	3.0
Kisii	3	12.6	0.44	6533	1040	72.0	7.4	13.5	0.43	36.8	4.3

Overall mean	22	12.6	0.44	6551	709	74.1	6.0	14.1	0.45	36.7	2.6

Table 4. Ranking of the 4 year old Markhamia lutea families grown at Malava in terms of the mean values of modulus of rupture (MOR).

Family code	Provenance and Village	MOR (MPa**)**
Five strongest families		
K1M028	Kakamega, Butali	85.3
K1M002	Kakamega, Bukura	84.4
K1M021	Kakamega, Mbihi	82.8
K4M046	Siaya, Ligega	80.5
K6M046	South Nyanza, Mukuyu	80.4
Five weakest families		
K3M006	Busia, Kurala	67.7
K7M036	South Nyanza	67.8
K4M013	Siaya, Sagam	68.7
K1M004	Kakamega, Lerolimo	68.4
K4M003	Siaya, Got Abayo	69.4
Mean of FAMILIES (n=22)		74.2
Standard error of differences		1.2
Coefficient of variation (%)		10.8
F-ratio of Families		1.2
Range		67.7-85.3

Table 4. The mean specific gravity (S.G.) values for *Markhamia lutea* mother plus trees and siblings from Western Kenya.

Specimen code	District/ provenance	Mother plus trees			Siblings		
		Mean S.G.	Standard deviation	Coefficient of variation (%)	Mean S.G.	Standard deviation	Coefficient of variation (%)
K1M011	KAKAMEGA	0.49	0.01	2.5	0.44	0.03	6.4
K1M012	“	0.47	0.01	1.7	0.42	0.02	3.7
K1M026	“	0.44	0.01	3.0	0.42	0.02	3.6
K1M027	“	0.45	0.02	4.5	0.43	0.03	5.9
K1M028	“	0.47	0.02	4.9	0.41	0.01	3.1
K1M029	“	0.47	0.01	2.3	0.40	0.04	9.3
Mean		**0.47**	**0.02**	**4.7**	**0.43**	**0.02**	**5.6**
K3M050	BUSIA	0.49	0.02	3.8	0.40	0.02	5.4
K3M004	“	0.48	0.04	7.5	0.44	0.02	4.1
K3M005	“	0.51	0.03	5.3	0.46	0.01	2.0
K3M006	“	0.46	0.02	3.7	0.43	0.03	6.3
Mean		**0.48**	**0.03**	**5.6**	**0.41**	**0.03**	**8.0**
K4M013	SIAYA	0.46	0.02	5.0	0.41	0.02	3.7
K4M014	“	0.43	0.02	3.4	0.41	0.03	7.2
K4M017	“	0.43	0.01	3.0	0.42	0.02	4.4
K4M018	“	0.49	0.02	3.9	0.44	0.02	4.2
K4M019	“	0.47	0.02	5.1	0.42	0.01	1.7
K4M020	“	0.44	0.02	4.0	0.42	0.02	5.0
Mean		**0.46**	**0.03**	**7.1**	**0.43**	**0.03**	**6.1**
Overall mean		**0.47**	**0.02**	**4.3**	**0.43**	**0.02**	**4.7**

Table 6. The correlation and regression coefficients for the specific gravity of *Markhamia lutea* mother plus trees and siblings.

Provenance	R	R^2	Coefficient of Determination (%)	Standard Error of Estimate
Kakamega	0.73	0.53	42	0.01
Busia	0.75	0.75	63	0.01
Siaya	0.78	0.78	72	0.01

CONCLUSIONS AND RECOMMENDATIONS

At 4 years, provenance and individual tree selection can be done for Markhamia lutea for height and diameter but little gain may be expected from selections for strength properties and wood density. However, poles with reasonable wood density and moderate strength suitable for posts, tool handles and truss rafters can be harvested at this age. The mean specific gravity, MOR, MOE and compression strength for four year old Markhamia are 0.41, 74.2 MPa, 6563 MPa and 37.0 MPa respectively.

The reported results, however, relate to juvenile assessments (rotation age for this species is about 40 years) based on the butt logs. It is therefore recommended that these studies be repeated at later ages towards half rotation age, with samples obtained from different heights. There is also need to examine the variation in tension wood and extractive contents among the families and determine their effect on strength properties.

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