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Physical, Mechanical and Anatomical Properties of Lein *(Terminalia pyrifolia)*

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လိမ်သစ်အင်အား နှင့် သစ်အင်္ဂါဗေဒကို လေ့လာခြင်း

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သစ်တောသုတေသနဌာန၊ရေဆင်း။

စာတမ်းအကျဉ်းချုပ်

လိမ်သစ်သည် လတ်တလောအားဖြင့် လူသိနည်းသော သစ်ဖြစ်ပါသည်။ ထိုသစ်၏အသုံးဝင်မှု အလားအလာကို ဖော်ထုတ်နိုင်ရန် ပဲခူးရိုးမတောများမှ လိမ်သစ်(၅)ပင်ကို ထုတ်ယူ၍ ၎င်း၏ အရည်အချင်း၊ သစ်အင်အားနှင့် သစ်အင်္ဂါဗေဒ တို့ကိုရှာဖွေဖော်ထုတ်ရရှိသော ရလဒ်များပေါ်မူတည်၍ လိမ်သစ်အသုံးဝင်နိုင်မှု အလားအလာများကို တင်ပြ ထားပါသည်။

Physical, Mechanical and Anatomical Properties of Lein *(Terminalia pyrifolia)*

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Abstract

Lein is one of the lesser known species in Burma. To promote the end use of this species, five trees from the Pegu Yoma Forest are selected and its properties on physical, mechanical and anatomical structure are investigated. Some possible end uses of the species are indicated from the test results thus obtained.

Introduction

There exists over a thousand species of woody trees in Burma, of which only about fifty species of naturally durable and strong species are commercially extracted at the moment. It is expected that many unextracted species or lesser known species may be placed into appropriate end uses if their technical properties are known. Strong, but non durable species could possibly be used as structural timber after proper preservative treatment. Some timber with fine appearance may be used indoor as panels where strength and durability are not the criteria to consider. To put these lesser known species into their suitable end uses, their technical properties such as physical, mechanical, and anatomical should be explored, together with seasoning properties, workability properties, and durability. With the object of promoting the end use of Lein (*Terminalia pyrifolia)* its physical, mechanical and anatomical properties are studied as an exploratory test in the first stage.

The availability of Lein is not known as proper enumeration has not been carried out by the Department, but the author observed that it occurred in a fairly large quantity in the Pegu Yoma forests, especially in the Prome side. Lein tree has an attractive volume per stand as it attains to a height of 80' and a girth of 8' in the plain forests of Burma. A clear bole of 30' is available in average and that could yield a volume of 1.5 tons to 2.4 tons per individual tree. This yield per tree has persuaded to explore the end use of this species. By exploring the suitability of this neglected species, it is hoped that,

(1) the output of timber for domestic and foreign market may be increased.
(2) the export of valuable species can be increased and, thus more earning of foreign money for the country.
(3) the extraction cost per acre will be lowered and so the cost of timber can be stable.
(4) the species composition of the forest will be improved by removing these presently lesser known species.

Part I. Morphological, Taxonomical And Anatomical Properties of Lein.

Morphological and taxonomical characteristics:

A large leaves simple, ovate or broadly lanceoloate, 6.7-14.6 cm long, 2.5-4.7 cm wide, coriaceous, glabrous, alternate, the tips acute, the margins entire, the bases acute; pertioles 1.9-3.2 cm long. Inflorescences solitary and axillary spikes, 9.8-15.7 cm long. Flowers small, greenish white, lower flowers of the spikes bisporangiate; sepals 5- lobed, campanulate; petals absent; stamens 10, inserted on the calyx tube, the shorter ones opposite the calyx lobes, alternating with the 5 longer, anthers 2- lobed; ovaries globoid, 1 celled, inferior, style long, filiform, ovules 2. Fruits 1.4 -2.7 cm long, angular, two lateral wings about 1.9 -2.6 cm long, broad, densely fine pubescent.

Microscopic characteristics:

Tracheids and fibres:

Fibre tracheids and non- septate fibres; thin to thick walled, 3-7 u thick, inter-fibre pits sparse, bordered, slit-like, nearly vertical orifice, length ranging from 385-1820 u and most frequently from 430-1684 u; mean length is 1428 u.

Vessel elements:

Number per sq. mm. ranges from 2-10 and most frequently from 3-9; pores distribution solitary or pore multiples; diffuse porous; circular or oval in cross section; medium thin- walled; tangential diameter ranges from 102-296 u; tyloses absent; perforation plates simple; end walls truncate and the angles may range up to 50; intervascular pitting alternate, crowed, size of pits 6-8 u; shape of pits usually circular or oval; vessel parenchyma pitting alternate to opposite, size of pits between 7-10 u; shape of pits circular or oval; length of vessel elements 112-840 u and most frequently from 130-620 u; mean length is 562 u; pits to vessel alternate in arrangement, sparse or crowded; circular or angular in shape, 7- 12 u in size; pits to parenchyma opposite or alternate in arrangement; circular or oval in shape, 7-10 u in size.

Vascular rays:

Number per mm. ranges from 11-18; homogeneous; 1-2 cells wide; height of uniseriate rays ranges from 4.2-450 u and most frequently from 60-380 u; height of biseriate rays ranges from 125-480 u and most frequently from 160-340 u; pitting between ray cells and other parenchyma cells small in size and few or many in numbers; aggregate rays occasionally present.

Xylem parenchyma:

Abundant; paratracheal parenchyma sparse; paratracheal zonate parenchyma forming broad and conspicuous wavy bands; 2-9 seriate; metatracheal parenchyma extremely sparse confined to the concentric bands of fbrous tissue; pitting between xylem parenchyma cells larger in size and few in number.

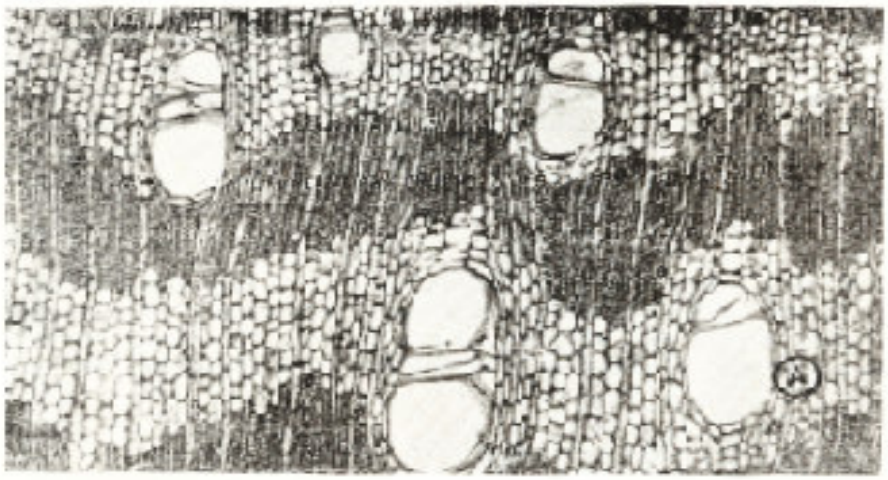
Explanation of the Plate

LEIN (*Terminalia pyrifolia)* (X 83)

A. Transverse section showing pores patten dominated by radial multiples of 2 or more and banded parenchyma.
B. Tangential longitudinal sectional view of homogeneous xylem rays.
C. Radial longitudinal section showing the individual rays are composed wholly procumbent cells.

Terminalia pyrifolia kurz. (Lein)

PLATE



Part II. Physical and Mechanical Properties.

Five trees from Ngalaik Reserved Forest in Yemethin Township are collected for test samples. The strength data so presented in this paper would be estimates of species mean values confined to Yemethin Forest Area. Nevertheless, as the test on Lein has never been carried out in Burma, the basic strength data presented in this paper will be of great value in assigning the end use of the species for the timber industry. It is intended, with the permission of staff and time, to investigate extensively so as to obtain the Burma strength data for the species.

Material and Method

Five tree of merchantable size (5' and over girth at breast height) were collected and prepared in accordance with the specifications mentioned in the American Society of Testing Materials (ASTM). Careful selection of wood samples to get clear and straight grain free from knots was carried out. The test samples were identified both anatomically and taxonomically.

1. Physical Properties

Twelve samples of size 1" x 1 " x 4 " were taken at random from the total samples collected for the determination of radial and tangential shrinkage. Eighteen samples of size 2 " x 2 " x 6" were taken for the volumetric shrinkage and specific gravity determination. The number of rings per inch were not counted as the rings were not conspicuous. So also the percentage of sap-wood has not been evaluated.

Linear measurements of samples were made nearest to the thousandth of an inch and weights were taken correct to 001 gram.

2. Mechanical Properties

The mechanical properties of Lein tested are given in table (3) For comparison strength values of other timber species of similar properties are also given.

The dimensions of specimens tested for various tests were shown in table 1. Impact Bending Test and Cleavage test could not be carried out as the proper fittings for such tests are not aviable at the Institute at the moment. The Avery Universal Testing Machine was used for the rest of the tests.

Table (1) Dimension of test specimens for various tests.

	Tests	Size of specimens
1.	Static Bending	2" x 2"x 30"
2.	Compression parallel to a grain	2" x 2"x 8"
3.	Compression perpendicular to grain	2" x 2"x 2"
4.	Hardness	2" x 2"x 6"
5.	Shear	2" x 2"x 2"
6.	Tension	2" x 2"x 2½"

The major tests made and the properties computed were:-

(1) Static Bending test
   (i) Fibre stress at Elastic Limit (FS at EL)
   (ii) Modulus of Rupture (MR)
   (iii) Modules of Elasticity (ME)
   (iv) Work to Elastic Limit

(2) Compression parallel to grain test
   (i) Fibre Stress at Elastic Limit (FS at EL)
   (ii) Maximum Stress
   (iii) Modulus of Elasticity

(3) Compression perpendicular to grain test
   (i) Fibre Stress at Elastic Limit (FS at EL)

(4) Hardness test
   (i) Radial
   (ii) Tangential
   (iii) End surface

(5) Shear test
   (i) Radial
   (ii) Tangential

(6) Tension perpendicular to grain test
   (i) Radial
   (ii) Tangential

The tests for green condition were made as soon as possible and the tests for dried condition were done approximately at 12% moisture content. The testing room could not be maintained to a required temperature, but testing were carried out as quickly as possible to prevent great variation in room temperature.

The methods of testing followed the specification laid down by the American Society for Testing Materials as close as possible.

Results

(1) Physical Properties

Test results on physical properties are given in table (2), compared with other Burmese timber species. Teak and Pyinkado data are included to compare the properties of Lein with the most popular two Burmese species.

(2) Mechanical Properties

The mechanical properties of Lein tested are given in table (3) for comparison strength values of other timber species of similar properties are also given.

In table (4), the suitability index for different utility is given, taken teak as 100% suitable in every respect. This table compared the combined strength values of different species by adjustment and applying weighting factors, rather than direct comparison of individual values (Limaye and Seamen). It is presented for a quick reference to compare the test data of Lein with other allied species.

Table 2. Physical properties of Lein and other species.

Name		Seasoning	Species gravity	Moisture Content Percent	Weight lb per c.ft	Shrinkage percent			Shrinkage ratio Tan./Rad.	Adj: Sp.r.
Local	Scientific					Radial	Tangential	Volume		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Lein	*Teminalia*	Green	.625	75	69	4.8	9.1	15.1	1.89	.73
	pyrifolia	Air Dry	.658	16	50					
In *	*Dipterocarpus*	Green	.726	50.3	68	4.4	9.1	14.0	2.07	.822
	tuberculatus	Air Dry	.755	19.4	56					
Kanyin*	*Dipterocarpus*	Green	.655	65.7	68	4.2	8.9	15.0	2.12	.732
	turbinatus	Air Dry	.689	14.3	49					
Teak*	*Tectona*	Green	.586	49.4	55	2.1	3.3	6.8	1.57	.647
	grandis	Air Dry	.568	14.1	40					
Pyinma *	*Lagersrtoemia*	Green	.518	118.1	70	4.4	6.8	12.7	1.55	.555
	speciosa	Air Dry	.567	8.5	38					
Pyinkado*	*Xylia*	Green	.779	48.6	72	3.3	6.7	11.1	2.03	.891
	dolaprifomis	Air Dry	.816	10.3	56					

* Source - Rodger's A Hand Book of Forest products of Burma .

Table 2. (Cont) Physical properties of Lein and other species.

Name		Seasoning	Species gravity	Moisture Content Percent	Weight lb per c.ft	Shrinkage percent			Shrinkage ratio	Adj: Sp.r.
Local	Scientific					Radial	Tangential	Volume	Tan./Rad.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Lein	*Teminalia*	Green	.625	75	69	4.8	9.1	15.1	1.89	.73
	pyrifolia	Air Dry	.658	16	50					
Binga*	*Mitragyna*	Green	.553	58.4	55	3.8	7.3	12.0	1.92	.607
	rotundifolia	Air Dry	.586	12.8	41					
Hnaw*	*Adina*	Green	.583	81.4	66	2.8	5.6	8.7	2.00	.643
	cordifolia	Air Dry	.592	12.2	41					
Nabe*	*Lannea*	Green	.497	94.0	60	3.0	5.4	8.4	1.80	.540
	grandis	Air Dry	.497	17.0	36					
Sagawa *	*Michelia*	Green	.486	112.9	57	3.2	5.2	8.2	1.63	.457
	champaca	Air Dry	.441	8.8	30					
Taungthayet *	*Swintonia*	Green	.551	58.5	54	3.2	6.0	10.8	1.88	.605
	floribunda	Air Dry	.575	13.7	41					
Yemane *	*Gmelina*	Green	.419	151.2	66	2.4	4.9	8.8	2.04	.449
	arborea	Air Dry	.432	12.1	30					

* Source - Rodger's A Hand Book of Forest products of Burma .

Table 3. Mechanical properties of Lein as compared to some other species

Name	Seasoning	Moisture content %	STATIC BENDING				Comp : Paral: to grain		Comp : Par:al to grain	HARDNESS		
			FS (a) EL p.s.i	M.R. p.s.i	M.E p.s.i	Work to EL lb/c. ft	FS (a) ELp.s.i	Max: Cr : p.s.i	FS (a) EL p.s.i	Radial lb load	Tan : lb load	End: lb load
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Lein	Green	85.2	5470	9880	1690	1.12	3165	4875	698	985	1005	995
	Air Dry	15.6	9735	13560	1995	2.58	6290	6770	1095	1286	1295	1220
In*	Green	50.3	6990	11595	1754	1.57	3670	5640	1220	1420	1420	1455
	Air Dry	19.4	7205	13925	19645	1.49	3540	6785	900	1615	1565	1575
Kanyin*	Green	65.7	6935	11020	2020	1.35	3890	5865	950	1020	1010	1060
	Air Dry	14.3	8095	15605	2240	1.66	3730	7745	1185	1395	1285	1315
Teak*	Green	49.4	6935	11460	1640	1.65	3815	5710	930	980	960	910
	Air Dry	14.1	9425	14465	1830	2.73	5385	8350	1280	960	990	860
Pyinma*	Green	118.1	5525	8590	1285	1.36	3335	4275	1225	1100	1085	1080
	Air Dry	8.5	6565	13255	1534	1.60	5210	7250	1385	1050	1060	1375
Pyinkado*	Green	48.6	9635	15555	2265	2.43	6445	8015	1700	1925	1915	1825
	Air Dry	10.3	11330	20580	2530	3.02	7420	11515	2240	2165	2085	2080

* Source :- A Hand Book of the Forest Products of Burma by Rodger

Table 3. (Cont) Mechanical Properties of Lein as compared to some other species

Name	Seasoning	SHEAR		TENSION	
		Rad. p.s.i	Tan. p.s.i	Rad. p.s.i	Tan. p.s.i
(1)	(2)	(3)	(4)	(5)	(6)
Lein	Green	1120	1295	710	895
	AD	1395	1775	770	805
In*	Green	4495	1345	590	955
	AD	4380	1600	805	1075
Kanyin*	Green	885	1055	740	885
	AD	1160	1345	1260	880
Teak*	Green	990	1080	515	685
	AD	895	1390	505	570
Pyinma*	Green	1040	1195	745	735
	AD	1390	1685	685	735
Pyinkado*	Green	1525	1965	840	1190
	AD	2130	2300	485	870

AD= Air Dry

* Source :- A Hand Book of the Forest Products of Burma by Rodger

Table 3. (Cont) Mechanical properties of Lein as compared to some other species

Name	Seasoning	Moisture content	STATIC BENDING				Compression parallel : to grain		Comp : Paral: to grain	HARDNESS		
			FS (a) EL p.s.i	M.R. p.s.i	M.E p.s.i	Work to EL lb/c. ft	FS (a) EL p.s.i	Max: Cr : p.s.i	FS (a) EL p.s.i	Radial lb load	Tan : lb load	End: lb load
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Lein	Green	85.2	5470	9880	1690	1.12	3165	4875	698	985	1005	995
	AD	15.6	9735	13560	1995	2.58	6290	6770	1095	1286	1295	1220
Binga*	Green	58.4	6425	10525	1330	1.75	4030	5280	990	1075	2055	1230
	AD	12.8	7695	14030	1603	2.11	5710	7525	1345	1265	1255	1580
Hnaw*	Green	81.4	5645	9450	1215	1.50	3955	4925	1085	1060	1100	1255
	AD	12.2	6535	11305	1362	1.76	4175	6550	1475	1165	1295	1440
Nabe*	Green*	94.0	3290	6065	801	0.78	1935	2790	555	700	685	740
	AD	17.0	4570	8145	940	1.30	2555	3805	845	795	770	870
Sagawa*	Green	112.9	4790	8010	1194	1.11	2985	4020	630	610	649	640
	AD	8.8	6215	9250	1387	1.58	4250	6420	985	760	840	1005
T' thayet*	Green	58.5	4655	8625	1638	0.77	2885	4095	565	750	735	755
	AD	13.7	6085	11435	1852	1.19	3460	5590	865	845	860	1030
Yemane*	Green*	115.2	4060	6940	1118	0.86	2410	3300	680	755	760	670
	AD	12.1	6335	9375	1287	1.74	3205	4850	685	490	560	525

AD = Air Dry

* Source :- Rodger's A Hand Book of the Forest Products of Burma.

Table 3. (Cont) Mechanical Properties of Leza as compared to some other species

Name	Seasoning	SHEAR		TENSION	
		Rad. p.s.i	Tan. p.s.i	Rad. p.s.i	Tan. p.s.i
(1)	(2)	(3)	(4)	(5)	(6)
Lein	Green	1120	1295	710	895
	Air Dry	1395	1775	770	805
Binga*	Green	1190	1300	650	935
	Air Dry	1460	1445	710	575
Hnaw*	Green	1150	1300	645	685
	Air Dry	1505	1490	370	615
Nabe*	Green	740	905	330	395
	Air Dry	955	1175	565	750
Sagawa*	Green	940	1005	510	545
	Air Dry	1070	1225	345	380
T' thayet*	Green	1100	1090	345	595
	Air Dry	1325	1530	695	885
Yemane*	Green	890	950	595	650
	Air Dry	1035	1050	480	415

* Source :- Rodger's A Hand Book of the Forest Products of Burma.

Table 4. Relative suitability of Lein and other Selected Species Percentage of Strength of Teak (Teak = 100 in every property)

Species / Strength	Teak	Lein	In	Kanyin	Pyinma	Pyinkado	Binga	Hnaw	Nabe	Sagawa	T' thayet	Yemane
Strength as a beam	100	95	104	99	73	128	90	77	55	62	73	60
Stiffness as a beam	100	105	110	122	78	135	83	74	51	72	100	68
Suitability as a post	100	100	100	102	76	135	92	81	51	69	80	61
Renation of shape	100	60	57	56	67	70	69	88	85	88	74	85
Shear	100	115	105	91	100	155	111	111	76	83	108	80
Hardness	100	100	147	112	110	187	107	110	76	68	77	65

Discussion

Lein as a light to moderately heavy timber with a density of 50 lb/ c- ft and a specific gravity of .65. It's dry weight is as heavy as Kanyin, but a bit lighter than In. It is heavier than Teak, Pyinma, Binga, Nabe, Sagawa, Taung-thayet and Yemane, but obviously much lighter than Pyinkado. Density and specific gravity are the simple index on the end-uses of species.

The magnitude of shrinkage of Lein is pretty high among the compared species but almost the same as In and Kanyin.

Static Bending test results showed that modulus of rupture of Lein is slightly lower than Teak, In and Kanyin, but not significantly. Other species compared in the table (3) are lower than Lein.

Compression parallel to grain tests showed that, apart from Pyinkado, the Fibre Stress at Elastic Limit is pretty high, which indicates that it is suitable for use as posts.

In hardness, Lein is inferior to most of the species compared and it is similar to Teak and Binga.

Shear test showed that Lein is higher in shear strength than the species mentioned in the tables except Pyinkado.

Conclusions

Lein, with regard to physical and mechanical properties could be used as a structural material. It is as strong as Teak and In/ Kanyin to be used as a post. Fairly strong enough to be utilized as a bcam. Nevertheless the it should be given great attention to get this timber properly preservative treated as it is easily perishable to decay and insects. Preservative treated Lein could be used anywhere in indoor structures. Another precaution should be taken to properly season these species as soon as it is sawn. Light framing, wall framing, flooring, walling are the place where Lein could be put into use.

Lein in term of strength is definitely inferior to Pyinkado and as nearly strong as In and Kanyin. It is stronger than Hnaw, Nabe, Sagawa, Taungthayet and Yemane. So durability being the same, Lein could be substituted in place of the above species.

Lesser known species are normally non durable and liable to insect attack and hence it is advisable to speed up the process of extraction and conversion. At the same time, proper handling and storage at mill sites are essential to reduce degradation by natural agencies.

Movement in dimension of Lein is comparable to In and Kanyin, but it is pretty high to make Lein into fine furniture. Lein is as good as In and Kanyin to make second class furniture. Up grating of quality of furniture could be made only with careful and proper coating with moisture retardent varnishes.

Lein is fairly good for making tool handles, masts, oars and shafts as the fibre stress at elastic limit compression parallel to grain in rather high.

More consideration has been given to the physical, mechanical properties and anatomical properties for the exploration of the potential end use of Lein in this paper. Although strength properties is an essential require to assess the end use of a species, other technological knowledge on seasoning, preservation, chemistry durability, and working properties should also be studied. It is therefore necessary to work together with other sections of the Forest Products Research Division of the Institute to promote the use of so called lesser-known species of the country.

Botanical Names of Some Tree Species

Sr. No.	Burmese Name	Botanical Names
1.	Binga	*Mitragyna rotundifolia*
2.	Hnaw	*Adina cordifolia*
3.	In	*Dipterocarpus tuberculatus*
4.	Kanyin	*Dipteriocarpus turbinatus*
5.	Lein	*Terminalia pyrifolia*
6.	Nabe	*Lannea grandis*
7.	Pyinma	*Lagerstroemia speciosa*
8.	Pyinkado	*Xylia dolabriformis*
9.	Sagawa	*Michelia champaca*
10.	Taungthayet	*Swintonia floribunda*
11.	Teak	*Tectona grandis*
12.	Yemane	*Gmelina arborea*

Appendix I

Notes on Lein

Botanical Name	-	*Terminalia pyrifolia* Kurz
Other Names :-	-	Lein
The Tree	-	A large tree attaining to a height of 80-100 feet and a girth of 5-8 feet. A clear bole of up to 50 feet long is obtainable. Found in the plain forests of Lower Burma and common in Pegu Yoma Forests, specially in Prome forest area. The bark is light grey to pale brownish grey, 4"-6" thick; outer dead bark persistant on the entire trunk and larger branches; moderately furrowed; irregularly shallow fissures separated by narrow interlacing ridges.
The Timber	-	
Colour		No heartwood an light yellow to yellowish grey. Lustrous when freshly cut with rough feel.
Specific gravity		.65. Light to moderately heavy timber. Weighed about 50 lb/ c.ft . air dry.
Strength		Fairly strong ,fairly straight grain, coarse texture .
Movement		Pretty high, Volumetric shrinkage is about 15%.
Seasoning		Refractory. Tends to warp and stain in seasoning. Careful handling is needed. Immediate conversion after felling and rapid open stacking after sawing is needed.
Working properties		It is easy to saw and works fairly well. Takes a good polish.
Durability		Moderately durable, but it is essential to preservation treatment.