PLANTATION GROWN TROPICAL TIMBERS. 2. PROPERTIES, PROCESSING AND USES

A.N. Haslett, G.D. Young & R.A.J. Britton

Forest Research Institute, Private Bag 3020, Rotorua, New Zealand

Received September 1990

HASLETT, A.N., YOUNG, G.D. & BRITTON, R.A.J. 1991. **Plantation grown tropical timbers. 2. Properties, processing and uses.** Wood properties, timber processing characteristics, and potential timber uses of ten major tropical plantation species have been evaluated at the Forest Research Institute, New Zealand. The difference between short-rotation plantation grown and natural forest timbers, and the implications of these differences to the processor and user are highlighted in this paper. The major difficulties associated with plantation grown timbers are reductions of density, decay resistance, and lower timber recoveries due to growth stress, smaller log size and the higher frequency of knots. Mahogany (*Swietenia macrophylla*) is thought to have the highest potential for production of high-value decorative timber, and *Pinus caribaea* var. *hondurensis* the highest potential for producing utility timbers.

Key words: Wood density - shrinkage - strength - drying - plantation timbers - *Cocos nucifera* - *Pinus caribaea* - *Anthocephalus chinensis* - *Cedrela odorata* - *Cordia alliodora* - *Eucalyptus deglupta* - *Gmelina arborea* - *Swietenia macrophylla* - *Tectona grandis* - *Toona australis*

Introduction

Part I (Haslett & Young 1990) of this two-part series described the evaluation procedure used at the Forest Research Institute of New Zealand to determine the wood properties, processing characteristics, and appropriate uses of a range of tropical plantation timber species. The procedure is simple and although largely in accordance with recognised international standards, it has been modified where necessary to suit each individual situation. This paper, Part II of the series, details the results of evaluations of the major timber species and discusses the implications for future use of these tropical plantation species. The evaluations have been initiated either by the need to select a suitable plantation species for afforestation projects or alternatively to determine wood characteristics immediately prior to first commercial usage of a forest species.

Properties of plantation grown tropical timbers

Table 1 provides background information on the major tropical plantation timber species studied to date and their typical wood properties.

The large number of Fijian grown Caribbean pine (*Pinus caribaea*) and mahogany (*Swietenia macrophylla*) trees sampled includes less intensive examinations using increment core sampling. Of the total number of trees studied, 110 Caribbean pine and 16 mahogany trees were intensively examined.

Table 2 summarises the processing characteristics of each species and their potential uses. Potential end uses are cited on the basis of wood property tests and end user evaluation trials.

The wood of plantation grown mahogany is, with the exception of having slightly lighter colour and a finer texture, virtually identical to material grown in Central America. Plantations produce excellent yields of high grade timber in under 35 *y* and the timber is extremely easy to process. This species is considered to have the highest potential for high value sawn timber of the tropical plantation hardwoods so far tested by the Institute. Teak plantations can also produce timber with wood properties similar to those from traditional older stands but this species requires a considerably longer rotation, has inferior tree form, yields lower grades of timber, and is more difficult than mahogany to process into dry sawn timber. Despite the availability of a large resource, extreme processing difficulties with coconut (*Cocos nucifera*) palm stems are likely to restrict successful use of coconut to a small scale where no other sources of timber are available. Coconut has some potential for use as roundwood when preservative-treated with copper-chrome-arsenate. Of the medium-value timbers Caribbean pine is well suited to produce construction timber, treated roundwood, plywood, pulpwood, and timber for medium quality furniture and joinery. Caribbean pine can be grown on rotations of under 20 *y* and its ease of processing and good usage performance make it a substitute for other pines such as the southern pines and radiata pine (*Pinus radiata*). Yemane (*Gmelina arborea*) can produce pulpwood on very short rotations or sawn timber from a 15-*y* rotation. Its timber has low shrinkage and is stable, but very low surface hardness detracts from its use in high quality furniture. Problems with internal decay and growth stress are also common. Yemane is suitable for medium quality furniture and mouldings, while defecting and finger jointing provide means for improving recovery from knotty timber. Yemane is also suitable for use in light frame construction and utility uses; however, low durability and resistance to treatment will restrict its use to interior, protected situations.

Kamarere (*Eucalyptus deglupta*) logs suffer internal decay and growth stress. Likely uses for sawn timber include construction and general utility uses. Difficulties in sawing and preservation treatment could be expected to limit use of kamarere to the country of production because it will probably be unable to compete on the international timber markets with timber of the *Pinus* species. Of the timber species in Table 1 and 2, cadamba (*Anthocephalus chinensis*) and red cedar (*Toona australis*) show the lowest potential for sawn timber production, the reasons being growth stress, poor working properties, low strength, and lack of natural durability.

Table 1. Summary of typical wood properties of tropical plantation timbers grown in the South Pacific Islands

Species	Density		Shrinkage green to air dry (%)		Air dry strength properties			Heartwood durability	Tree age (y)	Number of test trees	Country of origin
	Air dry* (*kg m*$^{-3}$)	Basic (*kg m*$^{-3}$)	Tangential (%)	Radial (%)	MOR (*MPa*)	MOE (*GPa*)	Compression parallel to grain (*MPa*)				
Cocos nucifera (coconut)											
inner zone	270	215	9.3	11.2	76	8.4	11		50 - 70	30	Tonga
outer zone	730	610	2.7	2.8	98	10.9	60	NA			
Pinus caribaea var. *hondurensis* (Caribbean pine)	620	515	3.9	2.5	94	12	45	non-durable	5 - 25	1250	Fiji
Anthocephalus chinensis (cadamba)	340	310	3.1	0.8	58	6.8	25	non-durable	14	7	W. Samoa
Cedrela odorata (cedar)	410	355	2.2	1.5	67	7.6	34	durable	27	9	W. Samoa
Cordia alliodora (cordia)	470	420	4.4	1.6	77	8.3	40	durable	6 and 10	15	Vanuatu
Eucalyptus deglupta	420	365	3.4	1.8	67	8	39	non-durable	13	10	W. Samoa
(kamarere)									7	16	Vanuatu
Gmelina arborea (yemane)	495	435	2.3	1.2	80	8.6	NA	non-durable	14	42	Solomon Is.
									9	10	Vanuatu
									4	3	W. Samoa
Swietenia macrophylla	535	460	2.2	1.4	90	9.3	43	mod. durable	29	11	W. Samoa
(mahogany)									20 - 36	736	Fiji
Tectona grandis (teak)	700	580	1.1	0.7	118	11.9	59	highly durable	80 - 90	8	W. Samoa
Toona australis (red cedar)	380	330	3.4	1.3	61	6.6	28	non-durable	14	6	W. Samoa

* Air-dry = test at 12% moisture content; NA = data not available

Table 2. Summary of processing properties and potential end uses of tropical plantation timbers grown in the South Pacific Islands

Species	Drying properties	Machining properties	Preservative treatment properties (*Bethell Full Cell process*)	General properties	Uses
Cocos nucifera	Low density wood collapses and warps. Air drying best but subject to stain and mould, needs dipping.	Requires tungsten tipped blades. Low density tears.	Dry wood treats well.	Segregate out low density core wood by frequency of vascular bundles.	Untreated: mouldings, panelling, temporary construction. Preservative treated: shingles, weatherboards, posts, poles.
Pinus caribaea var. *hondurensis* (Caribbean pine)	Dries readily, requires careful stacking to restrict twist and crook.	Good, but resin can cause problems.	Readily treated.	High incidence of spiral grain.	Untreated: mouldings, panelling, furniture, boxing, packaging, panel products. Preservative treated: poles, posts, construction, exterior joinery.
Anthocephalus chinensis (cadamba)	Can be rapidly kiln dried from green. Air drying not recommended because of susceptibility to stain, mould and decay.	Planes well, poor turning and boring properties.	Dry wood treats well with good uptake and penetration	Sapwood and heartwood indistinguishable, both have creamy colour and medium-coarse texture. Unpleasant sharp odour when freshly sawn.	Untreated: mouldings, panelling, boxes, crates. Preservative-treated: exterior joinery, weatherboards. Others: plywood core, chemical pulp.
Cedrela odorata (cedar)	Suffers slight to moderate collapse and splitting if kiln dried from green. dry to 30% m.c. then kiln dry.	Turns well, very good Air planing. Sand paper tends to clog. Dust can irritate nose.	Heartwood resistant to pressure treatment.	Narrow sapwood band. Straight grained, moderately coarse texture. Some tension wood. Severe growth stress. Flatsawn boards have strong figure due to growth rings. Strong odour.	Light furniture, mouldings, panelling, crates, exterior joinery, weatherboards, turnery, face veneers, match boxes, speciality woodware.
Cordia alliodora (cordia)	Corewood suffers some collapse and splitting if kiln dried from green. Air dry before kilning.	Works well.	Not tested.	Wide sapwood clearly differentiated from streaky brown heartwood. Grain straight, some interlocking, medium texture.	Furniture, cabinetry, panelling, joinery, veneers.
Eucalyptus deglupta (kamarere)	Collapse susceptible, should be air dried to 30% m.c. prior to kiln drying. Needs steam reconditioning if kiln dried from green.	Some chipping and tearout in planing and turning.	Dry heartwood treats moderately.	Moderately coarse texture, light brown with pink flecks, and occasional discoloured areas. Pipe rot of trees common. Severe growth stress.	General construction, boxes, pallets, light furniture, plywood core, pulp.
Gmelina arborea (yemane)	Slow variable drying, susceptible to stain. Low temperature dry prior to final kilning at conventional temperatures.	Excellent turning and planing properties.	Heartwood resistant, only sapwood treatable. Heartwood amenable to boron diffusion.	Sapwood difficult to distinguish, medium texture, some interlocked grain. Pale brown colour. Moderate growth stress.	Medium quality furniture, and joinery. Turnery, carving, shaping, light construction.
Swietenia macrophylla (mahogany)	Can be kiln dried from green without difficulty. Sapwood can suffer staining if drying delayed.	Excellent machining properties, epicormic knots present no problems.	Heartwood resistant to treatment.	Wide sapwood zone, medium texture, some interlocked grain. Red-yellow colour darkens on exposure to air to a reddish colour. Moderate growth stress.	A very high quality timber for furniture, sliced veneers, turnery, carving, mouldings, interior joinery, firewood.
Tectona grandis (teak)	Slow variable drying. Recommend air drying to 30% m.c. then final kilning.	Turns extremely well.	Heartwood resistant to treatment.	Light brown sapwood, golden brown heartwood, with occasional grey flecks. Distinct growth rings. Medium-coarse texture.	A high quality timber similar to Burmese teak with the same uses. High quality furniture, exterior joinery, boat building, veneers, turnery, firewood.
Toona australis (red cedar)	Slightly collapse prone, can be kilned from green. Careful stacking to restrict twist.	Sharp tools essential or can give fuzzy finish. Poor turning.	Heartwood and sapwood resistant to treatment.	Wide sapwood zone lighter colour than pink heartwood. Coarse texture commonly interlocked. Defined growth rings.	Interior uses only, panelling, moulding, joinery, finishing.

Implications of wood properties in use of tropical plantation timbers

Our evaluations have identified several major differences between the wood properties and processing characteristics of plantation grown versus naturally grown timbers of the same species. Recognition of these differences will be critical to the successful use of plantation grown timbers. Failure to adapt processing of plantation timbers accordingly will result in lower recoveries and poorly processed timber. Differences in wood properties will also modify end use options for plantation timbers, and failure to match the new properties to appropriate uses will mean poorer performance of plantation grown timber. The major areas of concern in processing plantation grown timbers are discussed below.

Sapwood proportions

Short rotation fast grown trees have a higher proportion of sapwood than those from older stands. For example, 36-*y*-old mahogany has only 63% heartwood by total log volume. Heartwood proportion can be critical because the reputation of hardwoods such as mahogany and teak is based solely on the desirable properties of the heartwood. The international timber market expects to pay a premium for all heart of these species, and the producers are then left to sell the sappy timber on their local markets for a significantly lower return.

Density

Wood density has a major impact on strength. It also affects processes such as drying, preservation, machining, and pulping. Compared with wood from natural stands, wood from plantation crops grown on rotations of 10 to 20 *y* can be of significantly lower density. For example, 14-*y*-old plantation grown kamarere is shown to have a 30% lower basic density than values quoted for Papua New Guinea material (Eddowes 1977). Similarly Cown *et al.* (1983) showed that increasing the rotation length of Caribbean pine from 5 up to 15 *y* increased basic density by approximately 35%. In contrast, longer rotations used for the production of high-value timbers such as teak and mahogany produce wood of similar density to that from traditional sources. Therefore it is critical for foresters to consider wood density prior to selecting a species for the plantation production of utility timbers. As a general rule it is recommended that, for a species to be acceptable in utility timber plantations, naturally grown trees should have at least a medium-high density (> 550 $kg\ m^{-3}$ basic density). Not only is average density important to the end user of timber but so too is evenness of density. Use of shorter rotations and the accentuation of radial and vertical density profiles can result in significant within-tree density variation. For example, when the range of density is expressed as a percentage of average basic density, yemane and mahogany show variations of approximately 60 and 75% respectively.

By selecting species with desirable patterns of density variation, foresters can play an important role in improving those wood properties and processes influenced by wood density. Wood density should not only be considered in selecting a species for afforestation but also in selecting the seed source, and in subsequent tree improvement programmes. Too often these programmes are based on tree vigour and form alone, without regard to wood density and other critical wood properties.

Growth stress

There are generally higher levels of growth stress in logs from plantation grown trees than in older logs from natural forests, and smaller log size further accentuates the detrimental effect of this problem. Of the tropical hardwoods evaluated, kamarere, cedar, and cadamba are severely affected by growth stress. All the other hardwood species develop only moderate levels of stress. Growth stress is important because it can cause brittle heart in the central portion of the tree (*e.g.* in kamarere) for which there is no solution. Release of growth stress during sawmilling can cause low recovery and timber which is poorly sized, distorted, and end split. In addition, stress commonly causes end splitting of logs during logging, transport and storage, and this degrade further reduces yields from plantation trees. There is no single solution to the problems posed by growth stress, and processors of plantation logs must adapt their normal handling, storage and processing procedures to minimise the degrade in each processing step. Logs should be handled with care and kept in lengths as long as possible until immediately prior to sawmilling. Designs currently applied to the sawing of small softwoods are inappropriate for sawing small hardwoods. For example, use of multi-saw resaws to rip slabs of plantation hardwood will result in distortion of the sawn timber. The saw-dry-rip procedure which is widely used in Australian eucalypt sawmilling (Ryder 1985) and also American hardwood mills (Layton *et al.* 1986) is appropriate to sawing of tropical plantation hardwoods. Relaxation of residual stress during drying in full-width slabs allows the multi-ripping of dry slabs without subsequent distortion of the timber. It also facilitates removal of any drying degrade. Haslett (1988) has a full discussion on options for sawing plantation hardwoods.

Internal decay

Discolouration and internal decay have been found in all the hardwood species evaluated but are most prevalent in kamarere and yemane. Sawing trials have shown that the major causes of decay are, firstly, damage to the stem and root buttresses, and, secondly, poor branch shedding characteristics which cause decay around knots. Damage to the stem and roots must be minimised as it creates opportunities for fungal infection. In view of this, mechanised commercial thinning of species such as teak and mahogany needs particular care to protect the considerable investment in final crop trees. Compared with slower grown natural trees, fast grown plantation hardwoods appear to have more unfavourable branch shedding characteristics. Rapid diameter growth in plantation trees tends to entrap the branches and prevent shedding, thereby allowing the branch to die and creating a pathway for fungal infection. Consideration should be given to include pruning of crop trees, particularly high-value long rotation species.

Natural durability and preservation

With the exception of teak and cedar, all the plantation species evaluated have lower resistance to decay than from natural stands. Plantation forestry increases the need for protection of the sawn timber in use, both through increased attention to appropriate timber usage (*e.g.* restricting non-durable timbers to protected interior uses) and correct design and building construction. Alternatively, processors will need to treat these timbers with preservatives. For protected internal uses, diffusion treatment with boron chemicals will provide adequate protection against insects and decay. However, for exterior uses a fixed preservative such as copper-chrome-arsenate (CCA) will be required, although because of poor penetration and uneven distribution of preservatives, hardwoods are generally difficult to pressure-treat successfully. Plantation timbers with their higher sapwood proportions, and often a more permeable heartwood, can be easier to treat than timber from natural stands. For example, heartwood of older kamarere is highly resistant to pressure treatment, whereas plantation material has a wide treatable sapwood and also has heartwood which gives reasonably uniform treatment, so that after treatment the timber may be used in exterior non-ground contact uses.

Timber grade recoveries

Because of their tree and branching form, plantations of mahogany and cedar can give good yields of full length decorative grade timber [55-70% by volume being clears or containing only small tight knots (Cown *et al.* 1989)]. However, because of frequency of knots and associated decay, the other species have given much lower grade recoveries. If timber from the medium quality shorter rotation species is to be successfully marketed for decorative uses, such as furniture, then implementation of a short clear cuttings grade will be essential. The timber which the furniture industry requires is generally in lengths of 0.3 to 2.1 *m* which can be met adequately from a cuttings grade rather than full length clears. Production of a clear cuttings grade will raise the usage potential of a timber species such as yemane which at 14 *y* yielded only 15% full length clearwood, but just over 60% by volume of clear-cuttings of 0.6 *m* or longer (Haslett unpublished data). Clear cuttings could be used in short furniture components or alternatively they could be finger jointed.

As well as lower grade recoveries we can also expect lower conversions from plantation logs because of their smaller diameter and the greater impact of growth stress.

Conclusion

Tropical plantation forests are capable of providing both utility and high value decorative timbers provided the species are correctly chosen and grown, and that the timber is correctly processed. Care is needed in selecting a new plantation species because frequently timber from young plantations is significantly different from that grown in natural forests. These differences are particularly pronounced where short rotations of less than 20 *y* are used. The differences in the wood properties of plantation grown species will also affect processing and potential uses of their timbers. Of the timbers discussed in this paper, mahogany appears to offer the highest potential for the production of high-value decorative timber. Despite a rotation of only 30 to 35 *y* its wood properties are virtually identical to older material grown in Central America. Plantation trees exhibit good form and when sawn they yield high grades of timber which are exceptionally easy to process. Caribbean pine is thought to be the "best" of the short rotation utility timber species as it is easy to saw, dry, and treat and the timber has good strength properties. Because of the presence of growth stress, which will neccessitate specialised sawing equipment and sawing procedures, the utility hardwoods are more difficult to process than Caribbean pine. Despite this, if correctly processed, short rotation hardwoods such as yemane and kamarere have the potential to produce utility timber for local markets.

Acknowledgements

Funding for the evaluations came from the Overseas Development Assistance Programme of the Ministry of External Relations and Trade (MERT), New Zealand. Their support is gratefully acknowledged. The data given in this paper represent the work of many sections of the Wood Technology Division of FRI.

References

COWN, D.J., Mc CONCHIE, D.L. & KIMBERLEY, M.O. 1989. A sawing study of Fijian large-leaf mahogany. *Commonwealth Forest Review* 68(4): 245-261.

COWN, D.J., McCONCHIE, D.L. & YOUNG, G.D. 1983. Wood properties of *Pinus caribaea* var. *hondurensis* grown in Fiji. *New Zealand Forest Service, FRI Bulletin No. 17.*

EDDOWES, P.J. 1977. *Commercial timbers of Papua New Guinea.* Hebamo Press, Port Moresby, Papua New Guinea.

HASLETT, A.N. 1988. A guide to handling and grade-sawing plantation-grown eucalypts. *Ministry of Forestry, New Zealand, FRI Bulletin No. 142.*

HASLETT, A.N. & YOUNG, G.D. 1990. Plantation grown tropical timbers. 1. Wood property and processing evaluation procedures to improve usage. *Journal of Tropical Forest Science* 3(2): 131 - 139.

LAYTON, T.F. SMITH, W.R. & MAEGLIN, R.R. 1986. An evaluation of the saw, dry and rip process to convert red alder into studs. *Wood Science and Technology* 20: 185-200.

RYDER, A. 1985. Slab cutting increases grade recovery and profit. *Australian Forest Industries Journal* 51(11): 25-27.