WOOD TECHNOLOGIES AND USES OF EUCALYPTUS WOOD FROM FAST GROWN PLANTATIONS FOR SOLID PRODUCTS

Martín Sánchez Acosta
INTA – (National Institute for Agriculture Technology)
Experiment Station Concordia
Concordia, Entre Ríos, Argentina

Ciro Mastrandrea
INTA – (National Institute for Agriculture Technology)
Experiment Station Concordia
Concordia, Entre Ríos, Argentina

José Tarcisio Lima
Federal University of Lavras
Lavras, Minas Gerais, Brazil

Abstract

The forest plantations are replacing the native forest in the wood provision for industries. At world-wide level almost 50% of the provision comes from plantations (IUFRO, TAIPEI 2007), being much greater in the South Cone of South America. Specially in Argentina, Chile and Uruguay the plantations provide more than 85 % of the industrialized raw material.

The most important plantations in the South Cone are pines and eucalyptus, having the latter, highest growth (over 30 m3/ha/year, being able surpass 50 m3/ha/year). Eucalyptus initially was planted for energy, cellulose and boards, but in the last years has been adapted for solid uses, replacing in several cases native wood. For this reason, it began to have special importance in Brazil, Chile, Argentina, Uruguay and Paraguay the genetic, silviculture and technological properties uses of this wood.

The present paper shows the results of referred studies on technological properties of the fast growth eucalyptus wood, at usual cut ages, also the development in different uses in solid wood products, in the South Cone and other countries.

Keywords: solid products, forest products, eucalyptus wood, wood technology

Introduction

Forest plantations - objective

According to FAO (2007), the world-wide native forests cover 4,000 million ha, where as the afforestations are 140 million ha, (that is 3.5%). In the opening presentation of the last V IUFRO (2007) Commission Symposium (Forest products), it was emphasized that wood from these few forest plantations represent 50% of the raw material consumed by forest industries, and are increasing due to the environmental restrictions for cutting native forests.
This situation is more marked in the South Cone, where due to deforestation or the nonexistence of forests, like Argentina, Chile and Uruguay, where its industrial supply is more than 80% from plantations, and the emblematic case of Brazil where, in spite of, having 240 million ha of native forests the raw material coming from plantations represents approximately 60 % (Sánchez Acosta, 2008).

Fast grown plantations: the Eucalyptus

For this reason, plantations are being established to supply in the least possible time the required wood for the industries. In countries with good environmental conditions a particular fast grown plantation is being developed with diverse genus: *Populus, Salix, Pinus* and *Eucalyptus.*
Although the genus *Eucalyptus* has more than 600 species and varieties, those planted on commercial scale do not surpass the dozen. Among them we can mention *E. grandis*, (and its hybrids, as *"urograndis*"), *E. globulus, E. camaldulensis, E. tereticornis, E. viminalis, E. nitens, E. saligna* and *E. urophylla*, although at present, *E grandis* and *E.globulus* are the predominant in fast grown plantations.
These plantations offer the possibility of being easily certifiable with environmental certification as the FSC if the good practices are followed along the productive chain and even the custody chain. Today thousands of hectares of *Eucalyptus* are certified.
These plantations of *Eucalyptus* have presented, generally, high growth rate, but with the advance in genetics and the use of clones, nowadays in South America growth rates of 50 m^3/ha/yr are reached in commercial scale, and higher 70 m^3/ha/yr in small research plots. In Brazil, Argentina and Uruguay it is not rare to find one year-old trees surpassing 6 meters of height.

Figure 1, 2. *Eucalyptus grandis*, fast growth plantations

1. *Eucalyptus grandis plantations* 2. *One year old trees Salta, Argentina*

The Eucalypts Wood

Fast grown Eucalyptus wood

The general belief is that fast grown wood presents lower density and poor quality. TINTO (1995) showed that in the case of *Eucalyptus grandis* the wood does not vary among trees of the same seed, some growing fast and others slowly. The wood density is given by the proportion of late wood and early wood within the ring. A very interesting characteristic is that the aspect of *Eucalyptus* wood resembles tropical hardwoods, therefore it can be commercialized in replacement of these or sometimes even as a forgery (it is not rare that it is sold as cedar or mahogany).
As average data, for commercial plantations in normal cut age (12 to 14 years) studies made at the INTI - CITEMA (National Institute of Industrial Technology - Center of Wood Technology) show physical and mechanical properties according to Table 1.

Table 1. Comparison of physical & mechanical values of fast growth species.

Species	***Density*** ***Kg/m3***	***MOE SB*** *Kg/cm2*	***CS rupture*** *Kg/cm2*	***MOE C*** *Kg/cm2*	***Janka H.*** *Kg/cm2 rd*	***Screw W*** *Kg/cm2 rd*
Eucalyptus grandis	*467*	*98345*	*342*	*150534*	*285*	*67*
Pinus elliottii	*439*	*61750*	*309*	*81400*	*256*	*27*
Pinus taeda	*430*	*83800*	*330*	*76050*	*303*	*30*
POPLAR 214 (Populus x euramericana cv I- 214)	*440*	*55500*	*287*	*84921*	*153*	*--*
POPLAR 63/51 (Populus deltoides cv I 63-51)	*420*	*68800*	*281*	*82500*	*130*	*--*
Eucalyptus dunnii	*795*	*116.093*	*330*	*121555*	*392*	

*Note: Density at 12 % m.c. MOE_b = modulus of elasticity in static bending CS = compression strength parallel t*o the grain, MOE C = modulus of elasticity in compression strength, Janka H = Janka hardness, Screw W: screw withdrawal Specimens sampled in the first 2.4 m long basal log ASTM d-143 Standar (Sánchez AcostaM, 1986, CITEMA 2003)

In Brazil, several studies, conducted by the group of Federal University of Lavras, amongst others, on *Eucalyptus* wood, originally cultivated for energy or pulp production, revealed values for solid wood as shown in Table 2 for basic density, in Table 3 for dimensional stability and in Table 4 for mechanical properties.

Eucalyptus was established in Brazil 104 years ago to provide fuel for trains. Later it was selected, planted and managed, both for charcoal and for pulp and paper. Only around 15 years ago this genus began to be employed widely for sawn timber production. Due to the lack of information, studies on the physical and mechanical properties of the fast grown *Eucalyptus* wood must be carried out to identify genetic material with better performance during processing and in use (Lima et al., 2005). It is important to report that these traits were not considered in the original process of selection. Most of the results, available on *Eucalyptus* wood produced in Brazil, were performed on clonal material planted for charcoal and pulp and paper. Amongst them, it has been possible to identify different sort of wood, some of them suitable for sawn timber utilization.

Table 2. Values of basic density found by various authors for Eucalyptus wood produced in Brazil (Lima et al., 2005).

Genetic Material	Age	Basic density ($g.cm^{-3}$)	Author
Wood originally planted for charcoal			
3 *E. saligna* clones	From 9 to 42-months-old	From 0.319 to 0.517	Lima, 1995
44 *Eucalyptus* genotypes	From 13 to 17-years-old	From 0.544 to 0.731	Caixeta et al., 2003
10 *Eucalyptus* hybrids	9-years-old	From 0.447 to 0.591	Moura et al., 2003
11 *Eucalyptus* clones	6-years-old	From 0.508 to 0.594	Souza et al., 2004
11 *Eucalyptus* clones	From 7.5 to 13.5-years-old	From 0.449 to 0.563	Mori et al., 2004
7 *Eucalyptus* clones	From 5.5 to 10.5-years-old	From 0.	Cruz *et al*., 2003
7 *Eucalyptus* clones	8-years-old	From 0.477 to 0.584	Padilha et al., 2006
Wood originally planted for pulp and paper			
5 *Eucalyptus* clones	8-years-old	From 0.420 to 0.560	Lima *et al*., 2000
7 *E. grandis* clones	From 0.5 to 7.5-years-old	From 0.347 to 0.570	Lima *et al*., 2001
7 *E. grandis* clones	2.5-years-old	From 0.446 to 0.511	Lima *et al*., 2001
5 *Eucalyptus* clones	12.9-years-old	From 0.530 to 0.658	Oliveira, 2001
4 *Eucalyptus* clones	2-years-old	From 0.412 to 0.472	Melo, 2004

According to Lima et al (2005) it can be observed in Table 2 that basic density varies from a minimum of 0.319 g/cm^3 to a maximum of 0.731 g/cm^3. Normally, wood formed in early stages of tree development is of low basic density. It has been shown in Brazil that *Eucalyptus* for solid wood production must be around 20-years-old. However, this assertive is based on the properties that older genetic material attains at age 20 years rather than the intrinsic wood characteristic. New material, propagated by cloning has shown wood characteristics and performance both during the processing and utilization that give good reason for its selection and plantation. From the papers of the several authors (Table 2) it is possible to verify that wood grown for pulp and paper shows lower basic density than that grown for charcoal production. It has to be mentioned that the genetic material listed on Table 1 does not represent the overall material cultivated to produce charcoal or pulp and paper in Brazil. Some of these materials were selected to evaluate their potentiality to be used as solid wood producers. In this aspect, it has been generally accepted that materials originally selected for pulp and paper is more suitable for furniture, while material selected for charcoal is more adequate for construction application.

Eucalyptus wood is recognized as having high dimensional instability caused by the variation of moisture content. In Brazil, only recently (from approximately 15 years ago) assessment of this characteristic was carried out in a wide approach. In recent studies, several authors (Table 3), most of them working with *Eucalyptus* clones, determined linear and volumetric shrinkage of this wood. The tangential shrinkage presented values from 6.8% to 14.3%. The radial shrinkage presented values from 3.3% to 8.6%, while the volumetric shrinkage changed from 10.8% to 21.9%. From these results was possible to find genetic material able to be used as solid wood. In addition is possible to affirm that the Coefficient of Anisotropy, i.e. the rate of tangential shrinkage over radial shrinkage, also presents wide amplitude. The higher this index is from the value of one, the higher will be the propensity of the wood to present warping, cracking and splitting during drying (Lima et al., 2005).

Table 3. Values of dimensional stability for Eucalyptus wood produced in Brazil.

Genetic material	**Age**	**Dimensional stability**					
		TS%	**RS%**	**LS%**	**CA**	**VS%**	**Author**
44 sup. *Euc* genotypes	13 to 17	7.6 to 11.8	5.0 to 8.3	0,16 to 0,44	1,30 to 1,91	12.2 to 19.0	Caixeta et al., 2003
20 *Euc* clones	13 to 17	6.8 to 14.3	4.3 to 8.6			11.1 to 21.9	Oliveira, 2005
Euc grandis (one tree)	25	6.6 to 8.3	3.3 to 4.0			10.8 to 12.8	Gomes et al.,2006
10 *Euc.* clones	9	7.8 to 13.7	4.6 to 7.2			11.6 to 20.0	Moura et al., 2003
11 *Euc.* clones	6	8.2 to 11.8	3.8 to 6.3		1.6 to 2.4	12.8 to 18.0	Souza et al., 2004
13 *Euc.* clones	10	7,0 to 11.9	4.0 to 6.8			11.0 to 17.9	Rodriguez, 2007
7 *Euc,* clones	5.5 to 10.5	9.5	4.5		2.2	13.8	Cruz et al, 2003

TS% - Tangential shrinkage; RS% - Radial shrinkage; LS% - Longitudinal shrinkage; VS% - Volumetric shrinkage; CA – Coefficient of Anisotropy

The results presented in (Table 3) can be considered as average in magnitude according to the classification proposed by Durlo and Marchiori (1992). According to these authors, example of other Brazilian species that produce timbers present volumetric shrinkage as follow: *Cedrela fissilis* (Cedro) - VS = 15.7%; *Araucaria angustifolia* (Brazilian Pine)- VS = 17.6%; *Bowdichia* (Sucupira)- VS = 22.4%. This suggests that fast grown *Eucalyptus* wood cultivated in Brazil, in terms of that important property, dimensional stability, may be used as solid wood, both for furniture and building material.

Table 4 Values of mechanical properties found by various authors for Eucalyptus wood planted in Brazil (Lima et al., 2005)

Genetic material	**Age**	**Mechanical characteristics**					**Author**
		CS	MOE_c	MOR	MOE_b	JH	
Wood originally planted for charcoal							
10 *Euc.* hybrids clones	9	49 to 61	6978 to 11943	89 to 116	15491 to 19947		Moura et al., 2003
44 *Eucalyptus* genotypes	13 to 17			97 to 143	13924 to 24015		Caixeta et al., 2003
7 *Eucalyptus* clones	5.5 to 10.5	40 to 52	6590 to 8993	78 to 108	8768 to 19670		Cruz *et al*., 2003
7 *Eucalyptus* clones	8	45 to 57	7357 to 9521	91 to 115	6139 to 7576	4290 to 5962	Padilha *et al*, 2005
Wood originally planted for pulp and paper							
26 *Eucalyptus* clones	8	42 (B); 45 (T)		67(B) 67(T)	7660 (B) 8338 (T)		Lima *et al*., 1999
26 *Eucalyptus* clones	8			90(B) 91(T)		4784 (B) 4260 (T)	Lima *et al*., 2000
5 *Eucalyptus* clones	8	49 to 69	8367 to 11221				Lima *et al*., 2000
4 Euc. Clones and one progeny	12,9	51 to 62		99 to 111	6932 to 7914	5501 to 7404	Oliveira *et al*., 2001
4 *Eucalyptus* hybrids clones	2	49 (ft) 54 (st)	7374 (ft) 8057 (st)	92(ft)	99 (st)		Mello, 2004

Note: CS = compression strength parallel to the grain, MPa; MOR = modulus of rupture in static bending, MPa; MOE_b = modulus of elasticity in static bending, MPa; MOE_c = modulus of elasticity in compression strength, MPa; JH = Janka hardness, N). (B)- specimens sampled in the first 3 m long basal log; (T)- specimens sampled in the second 3 m long basal log. (ft) Flat terrain; (St) Sloped Terrain.

Amongst these properties, compression strength, static bending and hardness are some of the great importance. In contrast to wood density, information on the variability of the mechanical properties of *Eucalyptus* wood has been little studied by wood scientists or those involved in tree breeding. Needless to say, knowledge of the wood mechanical properties is required to define the utilization of wood in applications such as furniture and building material. Despite this requirement, characteristics related to the strength and elasticity of wood are also fundamental, both to the structural stability of trees and safety of manufactured wood products (Lima et al., 2005).

Table 4 presents a summary of various results found for mechanical characteristics of *Eucalyptus* wood, found by several authors. This wood is from trees planted to serve the requirements of the pulp and paper and steel industries. Also, this wood is from fast grown young *Eucalyptus* with high proportion of juvenile wood. It can be noted in this table that trees originally planted for charcoal produce wood slightly stronger than those for pulp and paper. However, it seems that the differences in terms of mechanical properties are not meaningful.

Comparison with other fast grown species

A significant proportion of raw material available for solid utilizations, in the short and medium term, will come from forest plantations. For this reason it is interesting to show the comparison between the most abundant genus: *Pinus, Populus,* and *Eucalyptus*, where the latter has the highest values. Also, although in certain cases the density is similar, the strength values are greater in *Eucalyptus*, which shows a high strength/density relation. The *Eucalyptus dunni* is a new undeveloped commercial species, but it shows a high growth and is the exception because it has high density. INTI - CITEMA has published the comparative average, showed in Table 1.

Uses at international level

The plantations of *Eucalyptus* outside of their zone of origin, Australia and surrounding areas, have been directed towards mainly for energetic, cellulosic uses, or board elaboration. This means that, in most of cases there was little interest in properties which are important for solid wood, as mechanical or dimensional stability, for example. An exception to this is Argentina where, since the beggining of the introduction, *Eucalyptus* has been planted mainly for pole production and sawn wood, for boxes and pallets manufacture.
In the last years, the lack of native wood caused an increase in *Eucalyptus* sawn wood for solid uses (furniture, carpentry, floors, etc) and veneers to produce plywood. This has been accompanied by genetic improvement which is beginning to use parameters related to these uses.

Solid Uses :

The solid uses can be divided in:

- *Round wood*: tree trunks, big or small poles that come directly from the plantations: Poles, furnitures, logs for houses.

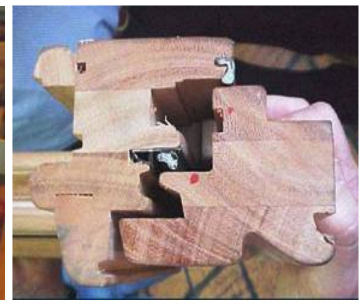
Figures 3, 4, 5 *Eucalyptus grandis* round wood – logs uses

3. Euc. Log house in INTA 4. Furniture 5. Tourist log house

- *Sawn wood*:
  Green; for rustic uses like boxes, pallets, bins, plank mouldings and scaffolds.
  Dryed: like raw material for remanufacture: moldings, T & G, carpentry.
- *Engineered products*
  Blanks - blocks - glued laminated wood

Figure 6,7,8 *Eucalyptus grandis* glue products





6. Edge glue panel 30 mm *7- Laminated glue beams* *8 . Window frame*

- *Veneers:*
  Rotative veneers: to make plywood (phenolics – ureics – Overlays , etc)
  Slice veneers: decorative uses

Figure 9, 10, 11. Eucalypts veneers



9. "Plakimbre" decorative plywood *10. Overlay plywood* *11. Slice Hybrid veneer*

- *Remanufactures*
Use in furniture, doors, windows, frames, house parts etc.

Figure 11, 12, 13 - Pieces & Furnitures of *Eucalyptus grandis*



11. Pieces of furniture 12- Beds 13 – Brazilian furnitures

Figure 14 , 15 *Eucalyptus grandis* Parts and Houses


14 ceiling E. grandis *15. INTA E. grandis house*

- *Small wooden objects.*

Figure 15 , 16 Artistic objects


15. Brazilian *E. grandis* handcrafts 16. FSC certified Eucalypts products

Substitution – complementation

The use of these fast grown woods is widely justified for low value uses, where in some cases native wood is still being used, as is the case of pallets, boxes, packages, and rural goods. Also, the use in products of greater value, with certain degree of reprocessing, offer the possibility of complementation or substitution of native wood, protecting them. A typical case is the current exportation of *Eucalyptus* wood to countries of Southeast Asia, which produce furniture with designs similar to those of *Tectona grandis* (Teka wood) which has certain cutting restrictions. These products are even re-exported, and in certain cases, with the FSC environmental certification.

The present time - The future

At present, the percentage of uses as solid wood is still small, but year to year it is increasing. This increase goes along genetic improvement, better silvicultural practices, and industrialization technologies. However, their terms cannot be much accelerated. Undoubtely, restrictions to cut native forests will be greater each time, and wood consumption will continue to increase, reason why the role of forest plantations, and in particular, of *Eucalyptus* will be more important.

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