TECHNICAL NOTE

Selected mechanical and physical properties of Chinese tallow tree juvenile wood

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Abstract

Chinese tallow tree is a noxious, invasive plant in the Southeastern United States. It is generally considered a nuisance and has no current commercial use. The objective of this research was to determine the moduli of rupture (MOR) and elasticity (MOE) of the stem wood of this species at different vertical sampling locations. Three Chinese tallow trees were felled and cut into bolts before sampling along the east and west radial directions. It was found that Chinese tallow tree has sufficient bending strength for low to medium structural uses. Tree, bolt, and sampling direction were all found to be significant sources of variation for the MOR and MOE data.

A major change has occurred in the species composition of the forests of the Southeastern United States. The Chinese tallow tree (*Triadica sebifera* syn. *Sapium sebiferum*) has become a serious invasive species throughout this region. A forest inventory from the 1990s revealed 1,035,000 forestland acres with at least 1.6 ft^2 basal area/ac (≥1.0 inch DBH/ac) in Chinese tallow tree for three regions: east Texas, Louisiana, and Mississippi. These Chinese tallow tree "occupied" forests contained 35,997,000 tons, or 2.562 tons/ac of woody biomass—an amount equivalent to 7.4 percent of the total tree biomass in these forests (Rudis 2003).

Because it grows rapidly, has seeds rich in oils, abundant flowers, and colorful fall foliage, it has been widely planted as a potential crop and as an ornamental (Jubinsky and Anderson 1996, Bruce et al. 1997). Chinese tallow tree has become naturalized from the Gulf Coast of Texas to the Atlantic Coast of North Carolina (Jubinsky and Anderson 1996, Bruce et al. 1997, Grace 1998). This invasive exotic species is currently considered noxious by the USDA Natural Resources Conservation Service (2008). A noxious organism is considered to have a harmful effect on the natural environment. It produces aboveground biomass at a significantly faster rate compared to most other tree species (Harcombe et al. 1993, Rockwood et al. 1993) and is able to quickly establish a dense stand.

One of the barriers to Chinese tallow tree utilization is the fear that the successful development of an industrial use for the species will encourage people to cultivate the already noxious species. Accordingly, most past research emphasis on this species has been on eradication, not utilization. The successful development of commercial uses for this species might be able to aid in underwriting the costs associated with its control/eradication.

The crooked stem prohibits the tree from being used for most conventional lumber applications. However, some recent studies have been initiated to better understand the basic properties of this species. Eberhardt et al. (2007) examined the chemical properties of the species. Previous studies have

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Table 1. — Mean physical and mechanical properties of Chinese tallow tree wood.

Tree no.	Total tree height (ft)	DBH[a] (in)	Bolt no.	No. samples	SG[b]	Green MC	Test MC[c]	MOR[d] (psi)	MOE[e] (x 10^5 psi)
						---------- (%) ----------			
1	42	10.1	1	14	0.62 (1.4)[f]	93.6 (4.3)	12.8 (1.4)	10,199 (5.8)	8.0 (3.5)
			2	11	0.61 (2.1)	75.3 (8.1)	12.5 (3.2)	11,727 (7.2)	11.8 (2.4)
			3	8	0.63 (3.1)	71.9 (6.1)	11.6 (3.3)	12,476 (6.1)	12.2 (4.5)
			4	5	0.66 (1.1)	73.6 (8.4)	10.9 (2.2)	12,009 (5.5)	11.9 (1.4)
			Mean		0.63	78.6	11.9	11,603	11.0
2	44	11.0	1	15	0.59 (2.1)	101.6 (6.1)	11.6 (4.3)	8,148 (5.9)	6.8 (3.5)
			2	13	0.57 (3.0)	88.3 (8.1)	12.4 (2.2)	10,324 (8.3)	9.5 (2.0)
			3	10	0.58 (1.0)	86.6 (7.3)	12.1 (3.8)	10,892 (8.2)	11.1 (3.3)
			4	8	0.59 (1.8)	82.4 (9.1)	11.9 (2.2)	10,669 (6.4)	11.1 (2.4)
			5	5	0.62 (0.76)	79.1 (8.7)	10.7 (1.8)	11,290 (8.5)	11.6 (1.2)
			6	4	0.60 (0.34)	78.9 (5.5)	10.7 (2.9)	11,350 (8.4)	11.9 (3.1)
			Mean		0.59	86.2	11.6	10,446	10.3
3	42	11.5	1	11	0.61 (0.89)	92.9 (8.4)	12.0 (1.9)	9,883 (8.7)	6.6 (2.2)
			2	9	0.62 (1.1)	75.8 (7.4)	11.9 (3.3)	8,789 (7.9)	8.5 (2.0)
			3	5	0.61 (0.87)	85.5 (6.8)	10.9 (2.0)	11,977 (9.6)	12.1 (1.8)
			Mean		0.61	84.7	11.6	10,216	9.1

[a]Diameter at breast height.
[b]SG based on green volume and ovendry weight.
[c]MC at time of bending tests.
[d]Modulus of rupture.
[e]Modulus of elasticity.
[f]Values in parentheses are COV (percent).

examined the potential of hydrothermal processing of Chinese tallow tree biomass for bio-based chemicals and energy (Shupe and Catallo 2006). Chinese tallow tree also can be used to produce composite panels with satisfactory mechanical properties for many applications (Lee et al. 2004, Shupe et al. 2006).

However, research is still lacking on the mechanical properties of Chinese tallow tree solid wood and such information is necessary to effectively use this species for composite panel production and other value-added uses. Therefore, the objective of this research was to determine the effect of different trees, bolts, and sampling directions on the modulus of rupture (MOR) and modulus of elasticity (MOE) of Chinese tallow tree stem wood.

Material and methods

Three Chinese tallow trees, with diameters at breast height (DBH) ranging from 10.1 to 11.5 in, were randomly selected from a mixed hardwood forest in Rapides Parish, Louisiana. The trees, harvested in August, were bucked into 8-ft-long bolts. No heartwood was visible on any of the log ends. A 15-in-long segment was cut from the bottom of each bolt and used for specific gravity (SG), moisture content (MC), and bending tests. The exact age of the trees was not determined. However, it is very likely that the trees were 10 to 20 years old because of their inherent rapid growth and size at time of harvest. Basic tree information, the number of bolts per tree, and the number of bending samples per disk, are shown in **Table 1**.

Bending samples (0.5 in^2 by 10 in) were cut along the east and west plane through the pith and coded according to location. Samples were then conditioned in an Aminco (Silver Spring, Maryland) conditioning chamber at 70 percent relative humidity and 110 °F to a target equilibrium MC of 12.0 percent. Samples were tested over an 8-in span in three-point static bending at a crosshead speed of 0.1350 in/min. in accordance with ASTM D143–83 (ASTM 1993). SG and MC were determined from 1.0 in^3 samples that were cut from the top 2 in of each segment. The SG samples were also cut along an east/west strip through the pith and labeled accordingly to location within the disk.

The experiment was considered a randomized complete block design. The data were analyzed by analysis of variance using SAS® (1989) to determine the effect of different trees, bolts, sampling direction on the MOR and MOE of Chinese tallow tree stem wood. Correlation coefficients between the dependent variables were also determined using SAS.

Results and discussion

Specific gravity

The mean mechanical and physical properties of the Chinese tallow tree wood samples are presented in **Table 1**. There was little variation in mean SG for each tree, which ranged from 0.59 to 0.61. The mean SG within a disk showed slightly more variability and ranged from 0.57 to 0.66. The SG data did not show any vertical trend (**Table 1**). This finding is in contrast with earlier research by Bendtsen and Senft (1986) on eastern cottonwood (*Populus deltoides* Bartr.). These researchers found eastern cottonwood SG to increase with age. There is a possible explanation for this difference. The SG data from Bendtsen and Senft (1986) is fairly constant from tree age 0 to 12 and only increases from age 14 to 30. While the exact age of our experimental Chinese tallow trees is unknown, it is very likely that the trees were 10 to 20 years old because of their inherent rapid growth and size at time of harvest. Therefore, the Chinese tallow tree data from this experiment would be largely juvenile wood and more appropriately compared to the 0 to 14 year data from Bendtsen and Senft (1986). In such a comparison, both data sets are in agreement.

Table 2. — Summary of analysis of variance (ANOVA) for modulus of rupture (MOR) and modulus of elasticity (MOE) of Chinese tallow tree wood.

	MOR	MOE
SOV	F value	F value
Tree (T)	**	*
Bolt (B)	**	**
Sampling direction (D)	**	*
T × B	**	NS
T × D	**	NS
B × D	*	NS
T × B × D	*	NS

Note: ** denotes significance at α = 0.01, and * denotes significance at α = 0.05.

Table 3. — Correlation coefficients (r) of experimental variables.

Variable	SG	MC	MOR	MOE
SG		−0.06	0.17	0.06
MC	−0.06		−0.06	−0.21*
MOR	0.17	−0.06		0.81**
MOE	0.06	−0.21*	0.81**	

Note: ** denotes significance at alpha = 0.01, and * denotes significance at α = 0.05.

Bendtsen and Senft found the juvenile/mature transition to be approximately 17 to 18 years of age for cottonwood. The juvenile/mature transition was not determined in this study.

Choong et al. (1989) showed an increase in SG from tree heights from 0 to 12 ft for unextracted tupelo-gum (*Nyssa aquatica* L.) estimated to be between 55 to 75 years of age. The correlation coefficient (*r*) between SG and tree height was 0.66. The exact relationship during early tree growth was not reported and may be different than the overall relationship reported.

Moisture content

There was also little variation in mean MC for each tree, which ranged from 78.6 to 86.2 percent. The mean MC within a disk showed more variability and ranged from 71.9 to 101.6 percent. All of the trees showed a decrease in green MC as tree height increased (**Table 1**). Although many previous researchers have examined the effect of season (i.e., month) on green wood MC, fewer have looked at the effect of tree height on green MC. Previous research on two yellow-poplar (*Liriodendron tulipifera* L.) trees has shown that tree height has an inconsistent effect on green MC (Shupe et al. 1995a). In general, wood MC decreased for wood samples near the pith whereas wood samples near the bark showed a fairly constant MC as tree height increased. The combined data for both trees and the different wood types showed an insignificant correlation between MC and tree height. This finding is consistent with data from a single eastern cottonwood tree (42 cm DBH) from Shupe et al. (1995b) who reported an insignificant correlation between apparently juvenile and mature wood samples. However, Shupe et al. (1995c) did find a statistically significant ($\alpha = 0.05$) correlation of $r = -0.32$ between MC and tree height for outer-, middle-, and corewood of two sweetgum trees (*Liquidambar styraciflua* L.).

MOR and MOE

The mean MOR of the experimental trees ranged from 10,216 to 11,603 psi. The mean MOE of sampled trees ranged from 9.1 by 10^5 to 11.0 by 10^5 psi (**Table 1**). All three primary sources of variation (tree, bolt, and direction) were significant sources of variation for both MOR and MOE (**Table 2**). The interactions were also significant for MOR but not for MOE (**Table 2**). The mechanical properties tended to increase with increasing height and were well correlated to each other (**Table 3**).

The mean MOR data from this test was comparable to the value reported for eastern cottonwood (8,500 psi) by *The Wood Handbook* (USDA Forest Serv. 1987). Bendsten and Senft (1986) found the MOR of plantation-grown eastern cottonwood to range from 2,600 to 4,860 psi from age 1 to 26. Both Chinese tallow tree and eastern cottonwood tree are generally considered low density and low value hardwoods. In fact, the Chinese tallow tree MOR data compares favorably to popular species such as Southern red oak (10,900 psi in the dry condition) and yellow-poplar (10,100 psi in the dry condition) (USDA Forest Serv. 1987).

The MOE data from this experiment was substantially less than that reported for eastern cottonwood reported in *The Wood Handbook* (13.7 by 10^5 psi in the dry condition) (USDA Forest Serv. 1987). The data from *The Wood Handbook* is based on mature wood, which is widely known to possess greater mechanical properties than fast-growing juvenile wood. The Chinese tallow tree data does compare favorably to plantation-grown eastern cottonwood. Bendsten and Senft (1986) found the MOE of plantation-grown eastern cottonwood to range from 1.39 by 10^5 to 7.37 by 10^5 psi from age 1 to 26. Similarly, Roos et al. (1990) found mature wood to yield 15 and 18 percent greater mean values for SG and MOR, respectively. However, mature wood values were 31 percent greater than juvenile wood for MOE.

Based on the age and growth rate of our trees, it is likely that the samples were comprised of high percentages, if not total, of juvenile wood. Although SG is statistically related to the mechanical strength of wood, it was found to not be a reliable indicator of the presence or extent of juvenile wood in red alder (*Alnus rubra*) (Evans et al. 2000). A similar scenario may be true for Chinese tallow tree. Moreover, several studies have indicated that juvenile wood has a greater effect on MOE than on MOR (Pearson 1984, Bendtsen and Senft 1986, Bendtsen et al. 1988).

Conclusions

This study was undertaken to determine selected mechanical properties of Chinese tallow tree wood. It was found that the SG and MOR are comparable with low-medium strength domestic woods, particularly eastern cottonwood. However, the MOE values of Chinese tallow tree are substantially less than those of most domestic hardwood species. The MOR of the species should allow for its utilization for a number of low to medium strength secondary applications such as pallets, furniture, paneling, etc. Additional research is needed to determine the dimensional stability of this species in order to better determine its utilization potential.

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