SUITABILITY OF THREE HYBRID POPLAR CLONES FOR LAMINATED VENEER LUMBER MANUFACTURING USING MELAMINE UREA FORMALDEHYDE ADHESIVE

Ramazan Kurt [a]

Experimental laminated veneer lumbers (LVLs) from rotary peeled I-214 (*Populus x Euramericana)* and two *Populus deltoides* I-77/51 and S.307-26 fast growing hybrid poplar clones were manufactured with a melamine urea formaldehyde (MUF) adhesive successfully. Two *Populus deltoides* clones that are grown in Turkey were used for the first time in LVLs manufacturing. The results showed that clone types affected physical and mechanical properties of LVLs. *Populus deltoides* clones had better physical and mechanical properties compared to *Populus x Euramericana* clone due to their higher density and fiber length values. S.307-26 clone had the highest and I-214 had the lowest properties among three hybrid poplar clones. The physical and mechanical properties of LVLs were higher than those of solid woods. This increase may be due to compaction factor (densification), manufacturing techniques, and the use of adhesives. The degree of contribution of solid wood properties to the LVLs' properties was explained by using a contribution factor. Two *Populus deltoides* clones were found to be more suitable for LVLs manufacturing compared to *Populus x Euramericana* clone.

Keywords: Hybrid poplar clones; Laminated veneer lumber (LVL); Melamine urea formaldehyde (MUF); Populus x euroamericana; Populus deltoides

*Contact information: a: Department of Forest Industry Engineering, Faculty of Forestry, Kahramanmaras Sutcu Imam University, 46060 Kahramanmaras TURKEY *Corresponding author: ramazankurt@yahoo.com*

INTRODUCTION

Laminated veneer lumber (LVL) is a well-known engineered wood product (EWP) that has been used since 1980's in many areas including in North America, Europe (especially Scandinavia), and the Far East. LVL may be defined as a lumber-like product, manufactured usually from rotary peeled veneers, glued parallel to the longitudinal axis of the member.

LVL proved their usefulness and efficiency in building construction as framing members such as girders, beams, joists (including I-joists), headers, lintels, and columns, as well as scaffold planks (Nelson, 1997) and panels. It can be manufactured in different sizes to suit architectural and structural aims if necessary. LVL has advantages over solid wood in strength, predictability of performance, available sizes, dimensional consistency, dimensional stability, treatability, and higher wood utilization rate (13% more than that of sawn wood's) (Nelson 1997).

Species, quality, durability, properties (mainly physical and mechanical properties) ease of treatment, seasoning, gluing, and finishing of wood materials are important factors to determine the suitability of wood for manufacturing LVL. The use of new manufacturing techniques, adhesives, and treatment processes have made fast growing and lesser known wood species possible to use including poplar clones in LVLs manufacturing, which enlarges the use of LVLs for structural and non-structural applications. Any tree species can be used as long as its physical and mechanical properties are acceptable for LVL manufacturing.

Douglas fir and southern pine are two common wood species that are used in LVL manufacturing in North America (Nelson 1997). Utilization of underutilized species such as aspen, poplar, and other soft hardwoods were reported in new engineered wood products plants, located in hardwood-producing areas (The Woodland Steward 1995). Utilization of poplar wood (Shukla et al. 1996; Wu et al. 1998; Nimkar and Mohapatra 2002; Uysal and Kurt 2005; Burdurlu et al. 2007; Kurt and Mengeloglu 2008) was reported in LVL manufacturing.

Hybrid poplars have better growth, form, adaptability, disease resistance, and fiber characteristics (Bannoun et al. 1984; Balatinecz and Kretschman 2001). In Turkey, poplar cultivation lands total 130000 ha, representing 0.64% of the total area of the country, 69.000 ha from of *Populus x Euroamericana* and *Populus deltoides* clones (Zoralioglu, 2003). The Poplar and Fast growing Forest Trees Institute of Turkey has been hybridizing different poplars for forest products industries. Two new hybrid *Populus deltoides* clones (I-77/51 and S.307-26) have been selected for this study due to their high growth performances, physical and mechanical properties (Tunctaner et al. 2004). Their properties were found to be higher than that of I–214 (*Populus x Euroamericana*) clones that supply almost half of the poplar production in Turkey (Zoralioglu and Kocer 1996).

The selection of the most suitable adhesive for manufacturing LVL depends on the end use, exposure conditions, manufacturing conditions, present technology, equipment, dimensions, treatment, and design requirements (Kurt 2010). Usually phenolic adhesives (including phenol formaldehyde (PF) and phenol resorcinol formaldehyde (PRF)) are used in LVL manufacturing for structural applications in exterior conditions. On the other hand, urea formaldehyde (UF) adhesives are recommended for semi-structural and non-structural applications in interior conditions. The incorporation of melamine (melamine urea formaldehyde (MUF), melamine formaldehyde (MF) + UF) may be used to increase the resistance of UF adhesives against humidity, water, and weather due to three main reasons: the quasiaromatic ring structure of the melamine leads to stabilization of the C-N bonding between the amide group of the melamine and the methylol group; there is better hydrolysis resistance of the C-N bonding between the melamine ring and the methylol group; and buffer capacity of melamine causes slower decrease of the pH in the bond line (Dunky 2002). MUF adhesives can fulfill the requirements of class D4 in accordance to EN 204 (2001) and EN205 (1991) by giving good water and moisture resistance (Källander 2002).

The use of adhesives other than phenolic-based is important for semi-structural and non-structural applications of LVL. The MUF adhesive is the main candidate to meet water and moisture resistance requirements in interior conditions. The objective of this research is to determine the suitability of three hybrid clones; I-214, I-77/51, and S.307-26 for use in the manufacture of LVL with the MUF adhesive under laboratory conditions for semi and non-structural applications. Also, the effect clone type on selected physical and mechanical properties of LVL was determined. Two *Populus deltoides* clones (I-77/51 and S.307-26) clones were used for the first time for LVL manufacturing in Turkey. Furthermore, relationships between solid wood (SW) and LVL properties were determined. SWs' physical and mechanical properties values were taken from Kurt (2010).

MATERIALS AND METHODS

Wood Veneers

The LVLs were manufactured from rotary peeled veneers of *Populus x Euramericana* (I-214) and two hybrid *Populus deltoides* clones (I–77/51 and S.307-26) with dimensions of approximately 600 mm x 600 mm x 3 mm and moisture content of 6-8%. They were purchased from a plywood mill in Sakarya, Turkey.

Adhesive

A commercial MUF adhesive was used. MUF adhesive has a pH of 9.50 with a viscosity of 130 cps, a solid content of 54±2%, and density of 1.24 g cm^{-3} at 20^{o}C (Polisan 2010). The adhesive spreading rate was 200 g m^{-2}. The gram weight pick up was calculated according to procedures described in ASTM D899 (1994).

LVL Manufacturing

Experimental eight-ply LVLs were manufactured from three different hybrid poplar clones; I-214, I-77/51, and S.307-26 using MUF adhesives. After spreading adhesives to veneers surfaces', they were immediately assembled with their tight sides facing out on each veneer. Billets were pressed at 110 °C for 1 mm min^{-1} at a pressure of 1.2 MPa with their grain directions parallel to each other. LVLs were further cut in accordance with specific test dimensions. 50 mm Edges were trimmed off every LVL to prevent any effects related to use of edges on the properties. Thus, LVLs final dimensions were reduced to 500 mm x 500 mm x 20 mm.

Testing

Oven dry specific gravity (OD) and moisture content (MC) values of LVLs were determined in accordance with TS 2472 (1976a) and TS 2471 (1976b), respectively. Dimensions and shapes of OD and MC specimens are given in Table 1.

A glue bond quality (glueline shear strength) was determined according to procedures described in EN314-1 (2004). Specimens were modified as in an ELVE (European Laminated Veneer Engineering) final report (Anonymous 1997). The specimens' forms, dimensions and shapes are shown in Fig. 1 and Table 1. The bond quality was determined for three of seven gluelines, these being between 3/4, 4/5, and 5/6 layers. Specimens were conditioned at a relative humidity of 65±1% and a temperature of 20±3 °C for at least 14 days before testing.

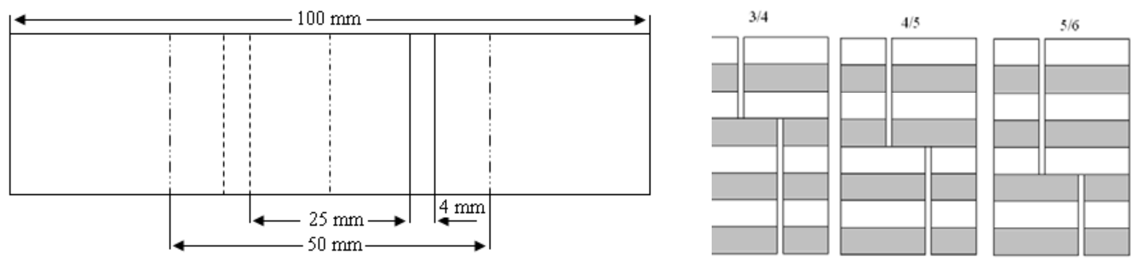
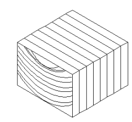
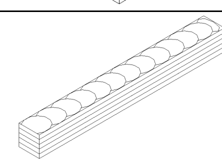
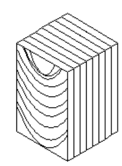
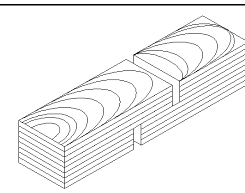


Fig. 1. Glue bond quality specimens' forms and dimensions

Table 1. Dimensions and Shape of Specimens for Specified Tests

Test	Dimensions (mm)	Shape
Oven-dry specific gravity (OD) Moisture content (MC)	20(t) x 30(w) x 30(l)	
Modulus of rupture (MOR) Modulus of elasticity (MOE)	20(t) x 20(w) x 360(l)	
Compression strength parallel to grain	20(t) x 20(w) x 30(l)	
Glueline shear strength	20(t) x 25(w) x 100(l)	

LVLs were tested flatwise to failure in bending under center point loading to determine modulus of rupture (MOR) and modulus of elasticity (MOE). The static bending test set-up is shown in Fig. 2. The span-to-depth ratio was 15, smaller than recommended value of 17-21 by ASTM D5456 (2003) due to limited dimensions of LVLs. According to Shukla and Kamdem (2009), using a slightly lower value of span to depth ratio does not have any known effect on the static bending strength tests. MOR, MOE, and compression strength (CS) (parallel to grain) were determined according to procedures described in TS 2474 (Anonymous 1976c), TS2478 (Anonymous 1976d), and TS 2595 (Anonymous 1977) respectively. The specimens were tested using a Zwick Roell (Z010) testing machine (Zwick, Germany). 10 replicates were used to test each property. Dimensions and shapes of MOR, MOE and CS specimens are given in Table 1.

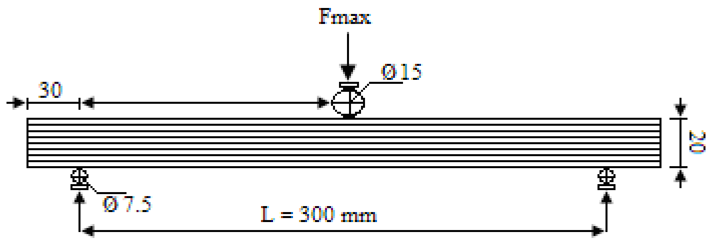


Fig. 2. The static bending test set-up

To explain the strength increases of LVLs compared to SWs' properties, an improvement rate (*IR*) and a compaction factor (*CF*) were calculated. To determine the effect of SWs' properties on LVLs' strength, a contribution factor (C_f) was calculated.

IR was calculated to determine the strength increase (MOR and MOE) of LVLs compared to SWs. *IR* can be expressed as,

$$IR\,(\%) = (\frac{P_L - P_S}{P_S}) * 100 \quad (1)$$

where, P_L is LVL strength and P_S is SW strength. High *IR* values indicate high increase in strength properties of LVLs compared to SWs.

CF was calculated according to Bao et al. (2001). *CF* can be expressed as,

$$CF = D_L / D_S \quad (2)$$

where D_L is LVL's OD and D_S is SW's OD. High *CF* ratios indicate higher densification. C_f was calculated in accordance with Bao et al. (2001). C_f can be expressed as,

$$C_f\,(\%) = (P_S / P_L)*100 \quad (3)$$

where P_S is SW's strength and P_L is LVL's strength. High C_f values indicate a large effect of SW properties on LVL, and low C_f indicate a low effect of solid wood properties (manufacturing and other factors may have additional effects). MOR and MOE values were used for the analysis, since the bending strength is considered to be the most important to LVL's structural performance (Bao et al. 2001).

Statistical Analysis

Analysis of variance (ANOVA) was used to determine the effect of clone types on selected physical and mechanical properties of LVLs using the SAS statistical package program (SAS Institute 2001). The resulting F value was compared to the tabular F value at the 95% probability level. When there was a significant difference as a result of F tests, comparisons between means were made by the Bonferroni (Bon.) t-test. Statistical comparisons were made only between LVL specimens, since numbers of tested specimens were different for SWs.

RESULTS AND DISCUSSION

Results of the average OD, MOR, MOE, and CS tests including their standard deviations of LVLs are given in Table 2 along with the values of respective SWs of the same poplar species. The ANOVA (α=0.05) results indicated that the difference in mean mechanical properties values were observed when different clone types were used. The Bon. t-test result is given for each strength property separately.

The mean OD values of LVLs fell within a narrow range, between 0.42 and 0.48 g cm^{-3} (Table 2). The OD of LVLs' were higher than those of SWs' by 31.3%. This may be largely as a result of compressing veneers during pressing. The pressing process weakened the cell walls, where parenchyma cells were compressed (Sulaiman et al. 2009). High density of the MUF adhesive (1.24 g cm^{-3}) might also contribute to that situation (Shukla and Kamdem 2009) other than densification, since its density is higher than those of poplars'. The increase in OD of LVLs made from I-214 veneers was the highest among three different hybrid poplar clones. The ANOVA results showed that S.307-26 significantly had the highest OD compared to I-214 and I-77/51 clones ($p<.0001$). The OD of LVLs was higher than that of spruce (*Picea orientalis*) and fir (*Abies alba*) SWs (0.41 g cm^{-3}) (Bozkurt and Erdin 1997). According to the Bon. t-test results, there was a significant difference ($p<.0001$) between ODs of I-214, I-77/51, and S.307-26. Moisture content values were found to be 10 ± 2%.

Table 2. OD, MOR, MOE and CS of LVLs' and SWs'

Properties	LVL			SW[2]		
	I-214	I-77/51	S.307-26	I-214	I-77/51	S.307-26
OD[1] (g cm^{-3})	0.42 **C** (0.02)	0.44 **B** (0.01)	0.48 **A** (0.02)	0.32	0.37	0.38
MOR[1] (MPa)	75.1 **B** (11.3)	80.2 **AB** (4.7)	89.3 **A** (6.6)	48.5	59.8	61
MOE[1] (MPa)	6305 **B** (526.7)	6504 **B** (612)	7576.61 **A** (314.5)	4777.8	5442.6	6065.5
CS[1] (MPa)	46.3 **C** (1.4)	49.4 **B** (1.5)	54.3 **A** (2.1)	35.1	31.1	36.3

[1]; Number of specimens were 10 for LVLs and 30 for SWs. [2]; SWs' values are adopted from Kurt (2010). Bonferroni t-test (Bon) groupings are given in capital letters; means with the same letter are not significantly different. Standard deviations are given in parenthesis.

Mean glueline shear strength between 3/4, 4/5, and 5/6 layers of LVLs fell within a wide range between 3.2 and 6 MPa (Table 3). The results showed that the adhesive provided good bonding through the thickness of LVL. The results also proved that the adhesives sufficiently cured in the cores of the LVL, since there were no differences between 4/5 (core/middle glueline) and/or 3/4 and 4/5 gluelines shear strength values. I-77/51 and S.307-26 clones had similar shear strength values. Shear strength values of LVLs made of *Populus deltoides* clones were comparable to that of LVL made from high quality birch and alder veneers with a phenol based adhesive (Anonymous 1997). There was a strong relationship between the density and glue line shear strength values. Thus high density veneers produced high strength. Similar results found in ELVE (European Laminated Veneer Engineering) final report (Anonymous 1997). F tests were performed for each clone types' gluelines separately. F test results of I-214 (p<.0264) and I-77/51 (p<.0472) showed that mean shear strength values of LVLs' were affected by the gluelines and thus their Bon. groupings were different. The Bon. t-test result showed that there was a significant difference between gluelines of I-214 and I-77/51.

Table 3. Mean Shear Strength Values (MPa) between 3/4, 4/5, and 5/6 Gluelines

Clone Group	Gluelines		
	3/4	4/5	5/6
I-214	3.2 (0.8) **B**	4 (0.4) **AB**	4.1 (0.8) **A**
I-77/51	5.5 (0.6) **A**	5.8 (0.9) **A**	5.3 (0.4) **A**
S.307-26	5.5 (0.6) **AB**	6 (0.8) **A**	5.3 (0.4) **B**

Bon. groupings are given in capital letters; means with the same letter are not significantly different. Standard deviations are given in parenthesis.

MOR, MOE, and CS values of LVLs ranged from 75.1-89.3, 6305-7576.6, and 46.3-54.3 MPa, respectively (Table 2). Coefficient of variations (COV) of MOR, MOE and CS values were generally under 10%. Low percentage of COV indicated that variability of mechanical properties was low. The mechanical properties of LVLs were higher than those of the SWs of the same poplar clones, as expected. *IR*s' of MOR and MOE, were up to 54.7% and 32% respectively, compared to SWs' MOR and MOE (Table 4). *CF*s of I-214, I-77/51, and S.307-26 were 1.3, 1.2, and 1.3, respectively (Table 4). A higher *CF* of I-214 corresponded to a higher *IR* of MOR and MOE (Table 4). *CF* results and their relationships to MOR and MOE were similar to the study of Bao et al. (2001). Fiber lengths may also be used to explain the strength increase of LVLs, since they affect the maximum load capacity (i.e. MOR) (De Boever et al. 2007). The fiber length of I-214, I-77/51, and S.307-26 were found to be 0.82, 0.87, and 0.87 mm respectively (Kurt 2010). Higher MOR and MOE values of two *Populus deltoides* clones corresponded to higher fiber lengths compared to that of I-214 clone's.

LVLs made of I-214 had the lowest and S.307-26 had the highest MOR, MOE, and CS values. F test results of MOR (p<.0018), MOE (p<.0001), and CS (p<.0001) showed that mean mechanical strength values of LVLs' were affected by the clone types, and thus their Bon. groupings were different. Bon. t-test results showed that there was a significant difference between I-214 and S.307-26 in MOR values, between I-214/ I-77/51 and S.307-26 in MOE values, and between I-214, I-77/51, and S.307-26 in CS values. The MOR and CS of LVLs were higher than that of two commonly used species for LVLs manufacturing; fir (*Abies alba*) and spruce (*Picea abies*) (Bozkurt and Erdin 1997). MOR, MOE, and CS values were comparable to commercial LVLs design values published by Canadian Construction Materials Centre (CCMC) (2006).

Table 4. Compaction Ratio (*CF*), Contribution Factor (C_f) and Improvement Rate (*IR*) of SWs' vs LVLs' MOR and MOE

Wood and Clone	Compaction Ratio	MOR		MOE	
		C_f (%)	I (%)	C_f (%)	I (%)
SW I-214 vs LVL I-214	1.3	64.7	54.7	75.8	32
SW I-77/51 vs LVL I-77/51	1.2	74.5	34.2	83.7	19.5
SW S.307-26 vs LVL S.307-26	1.3	68.4	46.3	80.1	24.9

In MOR and MOE, the C_f was the highest in I-77/51 and lowest in I-214 (Table 4). A comparison of the MOR and MOE among the three poplar clones showed two types of relationships; higher MOR/MOE values of SWs corresponded to high C_f and associated with higher LVLs' MOR and MOE values, as in two *Populus deltoides* clones (I-77/51 and S.307-26), and lower MOR/MOE values of SWs corresponded to low C_f and associated with lower LVLs' MOR and MOE values, as in I-214 (Table 4). The use of adhesive and the manufacturing technique also played important roles in the strength increase (Bao et al. 2001). In addition, it is possible to control manufacturing processes (such as drying, gluing, and pressing) and reduce variations in LVL (Liu and Lee 2003). This will give a great control to the manufacturer.

CONCLUSIONS

1. The potential use of hybrid I-214, I-77/51, and S.307-26 poplar clones for LVLs manufacturing were determined. Experimental LVLs were manufactured from rotary peeled hybrid poplar clones veneers with the MUF adhesive successfully.
2. LVLs' physical and mechanical properties were better than those of SWs. Strength increases were explained by *CF* and *IR*. *CF* of I-214, I-77/51, and S.307-26 were 1.3, 1.2, and 1.3, respectively. IR of MOR and MOE were 34.23-54.68%, and 19.51-31.96 respectively. The effect of SWs' properties on LVLs properties was explained by C_f. C_f values of MOR and MOE were 64.65-74.50 and 75.78-83.67 respectively. Effects of manufacturing technique, and LVL technology were also found important to explain the strength increase of LVLs compared to SWs.
3. Clone types affected physical and mechanical properties of LVLs. LVLs made of S.307-26 had the highest and I-214 had the lowest OD, MOR, MOE, and CS values among three different hybrid poplar clones. Two *Populus deltoides* clones; I-77/51 and S.307-26 performed similarly. Their fiber length and density values were higher than that of I-214 clone. They may be more suitable for LVL manufacturing than I-214 clone, since they performed better.
4. Strength properties values of LVLs were comparable to that of commonly used softwoods (i.e. poplar (*Populus nigra*), fir, spruce). The utilization of hybrid poplar could be expanded by using them for value-added applications, i.e. LVLs.

ACKNOWLEDGMENTS

This research was supported by Turkish Scientific and Research Council (TUBITAK) under project number 1060556. Technical supports from Mr. Kagan Aslan, Muhammet Cil, Mehmet Ercan and staff of The Poplar and Fast Growing Forest Trees Institute of Turkey are appreciated.

REFERENCES CITED

Anonymous. (1997). "An investigation and evaluation of laminated veneer lumber (LVL) manufactured from European hardwoods," Copernicus ELVE (European Laminated Veneer Engineering) Project Final Report.

ASTM D899. (1994). "Standard test method for applied weight per unit area of liquid adhesive," American Society for Testing Materials, Philadelphia.

ASTM 5456. (2003). "Standard specification for evaluation of structural composite lumber products," American Society for Testing Materials, Philadelphia.

Balatinecz, J. J., and Kretschman, D. E. (2001). "Properties and utilization of poplar wood," In: *Poplar culture in North America*, Dickmann, D. I., Isebrands, J. G., Eckenwalder, J. E., and Richardson, J. (eds.), NRC Press, Ottawa, 277-291.

Banoun, F., Morgan, D., Viart, M., and Zsuffa, L. (1984). "The poplar - A multi-purpose tree for forestry development," *Unasylva* (FAO) 36(3), 23-33.

Bao, F., Fu, F., Choong, E. T., and Hse, C. (2001). "Contribution factor of wood properties of three poplar clones to strength of laminated veneer lumber," *Wood Fiber Sci.* 33(3), 345-352.

Bozkurt, Y., and Erdin, N. (1997). *Wood Technology*, Istanbul University Publication No: 3998, Istanbul.

Burdurlu, E., Kilic, M., Ilce, A. C., and Uzunkavak, O. (2007). "The effect of ply organization and loading on bending strength and modulus of elasticity in laminated veneer lumber (LVL) obtained from beech (*Fagus orientalis L.*) and Lombardy poplar (*Populus nigra L.*)," *Constr Build Mater* 21, 1720-1725.

CCMC. (2006). "Microllam™ evaluation report," Canadian Construction Materials Centre, Institute for Research in Construction, National Research Council of Canada, Ottawa.

De Boever, L., Vansteenkiste, D., Van Acker, J., and Stevens, M. (2007). "End-use related physical and mechanical properties of selected fast-growing poplar hybrids (*Populus trichocarpa x P. deltoides*)," *Ann. For. Sci.* 64, 621-630.

Dunky, M. (2002). "Chemistry of adhesives," In: *Wood Adhesion and Glued Products: Wood Adhesives State of the Art Report*, Dunky, M., Pizzi, T., and Van Leemput, M.), COST Action E13., 3-29.

EN314-1. (2004). "Plywood-Bonding quality Part 1: Test methods," European Standardization Committee, Brussels.

EN204. (2001). "Classification of thermoplastic wood adhesives for non-structural applications," European Standardization Committee, Brussels.

EN205. (1991). "Adhesives. Wood adhesives for non-structural applications. Determination of tensile shear strength of lap joints," European Standardization Committee, Brussels.

Källander, B. (2002). "Introduction," In: *Wood Adhesion and Glued Products: Glued Wood Products State of the Art Report*, (Johansson, C. J., Pizzi, T., and Van Leemput, M. (eds.), COST Action E13, pp. 1-6.

Kurt, R., and Mengeloglu, F. (2008). "The effect of boric acid / borax treatment on selected mechanical and combustion properties of poplar laminated veneer lumber," *Wood Res-Slovakia* 53(2), 113-120.

Kurt, R. (2010). "Possibilities of using poplar clones and boron compounds to manufacture fire resistant laminated veneer lumber," Turkish Scientific Research Council, Project No:106O556 progress report.
Liu, Y., and Lee, A. W. C. (2003). "Selected properties of parallel strand lumber made from southern pine and yellow poplar," *Holzforschung* 57, 207-212.
Nelson, S. (1997). "Structural composite lumber," In: *Engineered Wood Products: A Guide for Specifiers, Designers, and Users*, Smulski, S. (Ed.), PFS Research Foundation, Madison, 147-152.
Nimkar, A. U., and Mohapatra, K. P. (2002). "Three decades of research on properties and utilization (*Populus deltoides*). A review," *Indian Forester* 128(11), 1254-1261.
Polisan. (2010). "Application guide for the melamine urea formaldehyde adhesive," Polisan Chemical Corporation, Kocaeli.
SAS. (2001). "SAS/Sat Release 8.2", SAS Institute, Cary, NC, USA.
Shukla, K. S., Anil, N., and Ravindra, S. (1996). "Laminated veneer lumber (LVL), from *Populus deltoides*," *J. Tim. Dev. Assoc. India* 42(3), 30-35.
Shukla, S. R., and Kamdem, D. P. (2009). "Properties of laboratory made yellow poplar (*Liriodendron tulipefera*) laminated veneer lumber: Effect of the adhesives," *Holz Roh Werkst* 67, 397-405.
Sulaiman, O., Salim, N., Hashim, R., Yusof, L. H. M., Razak, W., Yunus, N. Y. M., Hashim, W. S., and Azmy, M. H. (2009). "Evaluation on the suitability of some adhesives for laminated veneer lumber from oil palm trunks," *Mater Design* 30, 3572-3580.
The Woodland Steward. (1995). "Engineered wood products," The Woodland Steward, Purdue.
TS 2472. (1976a). "Wood, determination of density for physical and mechanical tests," Turkish Standard Institution, Ankara.
TS 2471. (1976b). "Wood, determination of moisture content for physical and mechanical tests," Turkish Standard Institution, Ankara.
TS 2474. (1976c). "Wood, determination of ultimate strength in static bending," Turkish Standard Institution, Ankara.
TS 2478. (1976d). "Wood, determination of modulus of elasticity in static bending," Turkish Standard Institution, Ankara.
TS 2595. (1977). "Wood, determination of ultimate stress in compression parallel to grain," Turkish Standard Institution, Ankara.
Tunctaner, K., As, N. and Ozden, O. (2004). "Investigation into growth performances, some technological wood properties and suitability to paper production of some poplar clones," Turkish Republic, Ministry of Environment and Forest, Poplar and Fast Growing Forest Trees Research Institute Technical Bulletin No. 196, Izmit.
Uysal, B., and Kurt, S. (2005). "Dimensional stability of laminated veneer lumbers manufactured from using different adhesives after the steam test," *GU J. Sci.* 18(4), 681-691.
Wu, Z., Furuno, T., and Zhang, B. Y. (1998). "Properties of curved laminated veneer lumber made from fast-growing species with radiofrequency heating for use in furniture," *J. Wood Sci.* 44(4), 275-281.

Zoralioglu, T., and Kocer, S. (1996). "Mechanization techniques for poplar development in Turkey," *Biomass Bioenerg* 10(5/6), 261-265.
Zoralioglu, T. (2003). "Some statistical information concerning poplar wood production in Turkey," First International Conference on The Future of Poplar Culture, Italy.

Article submitted: June 18, 2010; Peer review completed: July 12, 2010; Revised version received and accepted: July 15, 2010; Published: July 15, 2010.