SEEFOR SOUTH-EAST EUROPEAN FORESTRY

OPEN ACCESS
ISSN 1847-6481
eISSN 1849-0891

PRELIMINARY COMMUNICATION

DOI: https://doi.org/10.15177/seefor.18-10

Characterization of *Eucalyptus maidenii* Timber for Structural Application: Physical and Mechanical Properties at Two Moisture Conditions

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Citation: NOGUEIRA MCJA, DE ARAUJO VA, VASCONCELOS JS, DA CRUZ JN, VASCONCELOS JCS, PRATAVIERA F, CHRISTOFORO AL, LAHR FAR 2018 Characterization of *Eucalyptus maidenii* Timber for Structural Application: Physical and Mechanical Properties at Two Moisture Conditions. *South-east Eur for* 9 (2): 141-146. DOI: https://doi.org/10.15177/seefor.18-10

Received: 15 Mar 2018; **Revised:** 14 Jun 2018; 2 Jul 2018; **Accepted:** 6 Jul 2018; **Published online:** 7 Aug 2018

ABSTRACT

Background and Purpose: Eucalypt is an important raw material source of several industrial purposes. However, some eucalypt essences are still underutilized, possibly due to the lack of more embracing information about their properties. In this way, *Eucalyptus maidenii* species has presented a wide potential, and its lumber utilization is somewhat interesting. Nevertheless, a complete determination of its physical and mechanical properties, as carried out in this paper, certainly could encourage its popularization in construction.

Materials and Methods: *Eucalyptus maidenii* evaluation included two physical and fourteen mechanical parameters, regarding standard documents from Brazilian National Standards Organization (ABNT) and American Society of Testing Materials (ASTM). Thus, a simple comparison was established concerning the moisture content of wood samples, which were evaluated through two conditions: 30% as the initial level and a standard at 12%. All results were statistically evaluated by t-test. In sixteen parameters, 310 determinations were carried out.

Results: Half of mechanical properties presented significant changes in their resistances with the analysed moisture reduction. Modulus of rupture in static bending and in perpendicular compression, modulus of elasticity in perpendicular compression, strength in tangential cleavage, shear stress, and perpendicular and parallel hardnesses increased their resistances when the moisture content was reduced from 30% to 12%, that is, from green to dried standard stable point. Bulk density was also changed in the evaluated condition, decreasing to a smaller value. Volumetric mass density, modulus of rupture in parallel compression and in parallel and perpendicular tensiles, as well as modulus of elasticity in static bending and in parallel compression and tensile, and tangential toughness did not show any alteration in their values with this studied condition.

Conclusions: Lumber for civil construction needs to be suitable for efficient application, with air equilibrium, generally at 12% of moisture content as international normative documents require. As part of this, mechanical and physical properties/parameters were studied to characterize *Eucalyptus maidenii* wood regarding moisture content. The results obtained indicate the use of this essence from planted forests for structural purposes in construction.

Keywords: Maiden's Gum, wood density, strength modulus, cleavage, shear stress, hardness, toughness

INTRODUCTION

Eucalyptus maidenii F. Muell is commercially known as Maiden's Gum [1] or eucalypt maiden [2], as well as being widely recognized as "maidene eucalypt" in Latin American markets. This species occurs naturally in high-quality closed forests on sheltered slopes and gullies in good soils [1], among latitudes 34 and 39 S in altitudes from 230 to 915 meters, and its origin is along the Australian regions of southern New South Wales and northeastern Victoria [1, 3]. Maiden's Gum species is also found in Brazil [4, 5], Uruguay [6, 7], New Zealand [8-10], India [11], Portugal [5], Italy, Iberian Peninsula, Kenya, Malawi, Burundi [1], Tanzania [12], Uganda [13], Rwanda [14], etc. *Eucalyptus maidenii* is a tall to very tall forest tree usually 30 to 45 meters in height with a diameter of up to 2.5 meters, whose bark is smooth, whitish or cream, decorticating in strips to ground level, or sometimes with a short stocking of undecorticated rough bark [15]. Maiden's Gum trees could provide acid oils from their leaves [16] and their fruits [17] or medicines from their leaves [11], as well as extracts from their barks [18, 19]. Wood from Maiden's Gum has sapwood susceptible to *Lyctus* borer attack, and its light brown heartwood with pinkish to orange tints is hard, moderately strong and durable, coarse, uniform in texture, and with grain that is sometimes interlocked [1, 15]. *Eucalyptus maidenii* is usually applied for fuelwood [12], tannins [20], essential oils [20-22], pulp and paper [1, 8, 23], etc.

Maiden's Gum wood presents some good mechanical properties [24] and for that reason is recommended for heavy construction [1], products from sawmills, posts and poles [3]. Due to the *Eucalyptus maidenii* structural potentiality as sawn wood, the study aimed to explore physical and mechanical properties of this wood species at two different stable moisture contents, 30% and 12%, evaluating its reduction effect in a point close to the fiber saturation and other with respect to normative documents for structural applications.

MATERIALS AND METHODS

The wood species studied here was *Eucalyptus maidenii*, whose logs were collected in two Brazilian cities in São Paulo State to generate the wooden samples used in the tests (Table 1). A universal testing machine was used to perform the evaluation of properties.

To evaluate *Eucalyptus maidenii* as structural lumber, sixteen physical and mechanical properties were performed with small clear specimens, whose selection was based on defect absence. This testing followed the prescriptions of Brazilian ABNT NBR 7190:1997 [25] and American ASTM D-143-14:2014 [26] standards for the following properties: density (bulk and volumetric mass); perpendicular and parallel compressions, perpendicular and parallel tensiles, and static bending (in modulus of rupture and elasticity parameters); shear stress; cleavage (tangential); hardness (parallel and perpendicular); and toughness (tangential). Tangential orientation was selected due to strength in parallel direction to growth rings, and supported by an observation by Stolf *et al.* [27] claiming that there is no significant difference between radial and tangential toughnesses for dicotyledonous trees.

Similarly to Lahr *et al.* [28] and Nogueira *et al.* [29] studies, the samples used in these sixteen tests were prepared and conditioned for stabilization in both moistures at green (30%) and standard point (12%) in the Laboratory of Wood and Timber Structures (LaMEM) at the School of Engineering of São Carlos from the University of São Paulo (USP-EESC), São Carlos, Brazil. Furthermore, 310 determinations (or repetitions) were carried out in the aforementioned sixteen physical-mechanical parameters for the evaluation of *Eucalyptus maidenii*.

Ultimately, the obtained results by property were statistically verified with the analysis of t-test according to the significance level of 5% (P-value<0.05) to investigate the moisture content influence in the observed sixteen physical-mechanical properties of *Eucalyptus maidenii* wood. Through the hypothesis formulation, a P-value higher than the significance level implies accepting the null hypothesis, whose means of the two groups of moisture are equivalent, or rejecting it otherwise when the means are not equivalent.

RESULTS

Physical properties of density were verified and the obtained results are described in Table 2 with their respective statistical analyses.

Apart from the physical properties, 14 mechanical parameters were demonstrated with their statistical analyses (Tables 3, 4, and 5). Table 3 showed modulus of rupture results.

TABLE 1. Aspects of the *Eucalyptus maidenii* origin.

Log Amount	Beam Amount (unit)	Age (year)	Diameter (m)	Brazilian Region
1	2	28	0.260	Rio Claro (SP)
2	2	28	0.255	Manduri (SP)
3	2	28	0.240	Rio Claro (SP)
4	2	28	0.230	Rio Claro (SP)
5	2	28	0.255	Rio Claro (SP)

Table 4 indicated the obtained results and statistical analysis for modulus of elasticity of *Eucalyptus maidenii* wood.

Table 5 showed the obtained results for the last five strength properties, that is, shear stress, tangential cleavage, perpendicular and parallel hardnesses, and tangential toughness of the studied *Eucalyptus maidenii* wood species.

All listed tests were performed, revealing the successful obtaining of sixteen studied properties (Tables 2 to 5).

TABLE 2. *Eucalyptus maidenii* wood densities.

Characteristics	MC (%)	n	M_D	sd	P-value
Bulk Density (g·cm^{-3})	30	10	1.19	0.08	0.0003
	12	10	0.92	0.16	
Volumetric Mass Density (g·cm^{-3})	30	10	0.71	0.15	0.6277
	12	10	0.74	0.12	

TABLE 3. *Eucalyptus maidenii* wood modulus of rupture.

Characteristics	MC (%)	N	M_R	sd	P-value
Parallel Compression (MPa)	30	10	43.8	6.4	0.0978
	12	10	48.3	5.0	
Perpendicular Compression (MPa)	30	9	1.7	0.3	0.0032
	12	10	3.7	1.6	
Parallel Tensile (MPa)	30	9	93.6	24.8	0.4731
	12	8	83.7	29.9	
Perpendicular Tensile (MPa)	30	9	3.8	1.2	0.2537
	12	9	4.8	2.2	
Static Bending (MPa)	30	10	92	21.5	0.0000
	12	10	225	27.4	

TABLE 4. *Eucalyptus maidenii* wood modulus of elasticity

Characteristics	MC (%)	N	M_E	sd	P-value
Parallel Compression (MPa)	30	10	15564.0	5710.7	0.6302
	12	10	14431.0	4561.4	
Perpendicular Compression (MPa)	30	9	169.1	27.7	0.0029
	12	10	368.0	156.1	
Parallel Tensile (MPa)	30	9	16845.1	2787.1	0.2735
	12	8	18932.2	4411.7	
Static Bending (MPa)	30	10	13620.5	3994.8	0.1344
	12	10	16024.4	2692.2	

TABLE 5. Other strength properties of *Eucalyptus maidenii* wood.

Characteristics	MC (%)	n	M_{OP}	sd	P-value
Shear Stress (MPa)	30	10	11.7	1.9	0.0010
	12	10	17.2	3.7	
Tangential Cleavage (MPa)	30	10	0.64	0.21	0.0000
	12	10	1.16	0.22	
Perpendicular Hardness (kN)	30	10	7.34	1.62	0.0078
	12	10	10.03	2.29	
Parallel Hardness (kN)	30	10	7.48	3.31	0.0449
	12	10	10.08	1.69	
Tangential Toughness (N.m)	30	10	15.3	5.6	1.0000
	12	10	15.3	5.6	

DISCUSSION

Bulk density results indicated a decrease of 22.69% or 0.27 g·cm^{-3} in this property when the moisture contents of *Eucalyptus maidenii* samples were reduced from 30% to 12%. In contrast, the volumetric mass density slightly increased to 4.05% (0.03 g·cm^{-3}) with this same situation of moisture content reduction. With the support of t-test for these densities, we verified the bulk density and rejected the null hypothesis of mean equality, because of changes in moisture content from 30% to 12% showed significant difference in the obtained means (P-value<0.05). However, volumetric mass density did not present this null hypothesis rejection, which is explained by the independence of these means in relation to this reduction (Table 2). Comparing it with literature for *Eucalyptus maidenii* species from New Zealand, McKinley *et al.* [10] obtained nominal densities for 11-year-old wood between 600 and 760. This range is close, but lower, to the range showed in this study. This was expected, because their samples were younger than those 28-year-old woods studied here, that is, almost three times older and thus lightly denser.

Modulus of rupture results indicated increases of 9.32% or 4.5 MPa in the parallel compression, 54.05% (or 2 MPa) in perpendicular compression, 20.83% (1 MPa) in perpendicular tensile, and 59.11% (133 MPa) in static bending when the moisture contents of *Eucalyptus maidenii* samples were reduced from 30% to 12%. Even in this moisture content reduction, the parallel tensile presented a decrease of 10.58% (9.9 MPa). By the t-test analysis, we observed the perpendicular compression and static bending means and rejected the null hypothesis of equality means, whereas their means indicated significant difference when the moisture content was reduced from 30% to 12% (P-value<0.05). In contrast, parallel compression, and parallel and perpendicular tensiles did not reject the null hypothesis, i.e., their means did not present significant difference with the moisture decreasing (Table 3). In their study for 11-year-old *Eucalyptus maidenii* wood, McKinley *et al.* [10] reached two times lower modulus of rupture in static bending, likely due to this younger age and lower density.

Modulus of elasticity results indicated increases of 11.02% or 2087.1 MPa in parallel tensile and 54.05% (or 198.9 MPa) in perpendicular compression when the moisture contents of *Eucalyptus maidenii* samples were reduced from 30% to 12%. In such modulus, the moisture reduction caused decreases of 7.85% (1133 MPa) in parallel compression, and 15.00% (2403.9 MPa) in static bending. The t-test analysis applied in these modulus of elasticity showed only perpendicular compression which showed a significant difference in its means when the moisture content was reduced from 30% to 12%, due to the null hypothesis rejection (P-value<0.05). Successively, static bending, and parallel compression and tensile did not reject this null hypothesis, and due to these properties did not present significant differences in their means (Table 4). Thus, as compared to McKinley *et al.* [10], for 11-year-old *Eucalyptus maidenii* wood also at 12% of moisture content, the obtained results were one fifth higher than their modulus of elasticity in static bending, certainly, on account of the difference of age and density found in the two studies that focused on this particular species.

When the moisture content was reduced to 12% (dried and standard point), other strength property results indicated increases in tangential cleavage, shear stress, and parallel and perpendicular hardnesses in the amount of 44.83% (0.52 MPa), 31.98% (5.5 MPa), 25.79% (2.60 kN), and 26.82% (2.69 kN), respectively. Tangential toughness remained stable with the same value. The application of t-test in tangential cleavage, shear stress, and perpendicular and parallel hardnesses showed that these properties rejected the null hypothesis of mean equality, in other words, their moisture content revealed significant differences in their means when moisture content was reduced from 30% to 12% (P-value<0.05). Only modulus of tangential toughness did not present this significant difference in its means with this moisture reduction (Table 5).

In a study about the evaluation of *Eucalyptus urophylla* var. *maidenii* clones, Beltrame et al. [24] studied wood mechanical properties at 12% of moisture content. From values of rupture and elasticity modulus (both in static bending and parallel compression), and shear stress obtained by Beltrame *et al.* [24], it could be verified that this clone is mechanically similar to traditional *Eucalyptus maidenii* timber studied here. McKinley *et al.* [10] evaluated hardness of *Eucalyptus maidenii* 11-year-old wood, but did not evaluate shared specific direction, that is, parallel or perpendicular. In both cases, the obtained hardness was superior to that showed in their study, likely, due to their younger wood samples with lower densities.

Regarding those results that showed no effect with moisture content reduction, that is, volumetric mass density (Table 2), tensile strength parallel to fibers (Table 3), modulus of elasticity at parallel compression to fibers (Table 4), and tangential toughness (Table 5), these situations occurred possibly due to the grouped consideration of wood samples from five different farms (Table 1), that is, four forestry areas at Rio Claro city and another at Manduri city, both in São Paulo state, Brazil. This grouping was considered regarding of the exact age and eucalypt species from these five distinct plantations from the same Brazilian state region. However, such regard revealed three negative impacts and a neutral result (toughness), in contrast to other twelve positive effects verified with moisture reduction by this grouping.

There are cases, such as the one reported by Duarte [30], that the rupture can occur in fragile mode, resulting in a lower influence of moisture content in each studied mechanical property. In addition, eventual grain deviations are very common in eucalypts such as in maidenii [31]. Therefore, these two situations can be acceptable explanations to the observed negative effects, considering that specific property improvements were not captured by statistical analysis in view of these possible anatomical factors and rupture types from testing.

By adding value to forests by means of timber production used in prefabricated components employed in low-rise timber buildings, the reduction of wood utilization from native areas is required, for example, aiming at positive effects from forest management, which include the environment, the landscape, and the reduction of hydrogeological hazard [32]. At the same time, the popularization and correct utilization of wood, particularly those species available in planted forests, such as *Eucaliptus* spp, should be intensified [33].

Thereby, the study demonstrated that clear timber without perceptible defects of *Eucalyptus maidenii* species could be efficiently applied for lumber-based products and raw materials for construction, furniture and other structural uses, because its mechanical properties efficiently complied with the studied structural stress strengths at standardised moisture content. Popularization and correct use of wood from planted forests [32], such as *Eucalyptus maidenii*, according to Fragiacomo *et al.* [33], can contribute to the reduction of wood utilization from native areas, offering positive effects on the environment.

CONCLUSIONS

According to the results on clear pieces without perceptible defects, *Eucalyptus maidenii* wood species achieved required goals for its efficient utilization in structural applications, whereas woods from five forestry areas in São Paulo state were considered.

This forestry essence is raw material easily obtained from planted forests, and such eucalypt species demonstrated improvements in half of their mechanical strengths studied, when these properties were submitted to moisture reduction from 30% of fibre saturation point to 12% of air equilibrium prescribed by international normative documents for wood application in civil construction.

REFERENCES

1. FAO 1981 Eucalypts for planting. 2nd ed. Food and Agriculture Organization of the United Nations, Rome, Italy, 677 p. URL: http://www.fao.org/3/a-ac459e.pdf (15 March 2018)
2. MAIDEN JH 1922 The forest flora of New South Wales. 1st. ed. 7 (61-70). University of Sydney Library, Sydney, Australia
3. FERREIRA M 1979 Escolha de espécies de eucalipto. *IPEF* (47): 1-30. URL: http://www.almanaquedocampo.com.br/imagens/files/Eucal%C3%ADpto%20escolha%20de%20esp%C3%A9cies.pdf (15 March 2018)
4. SCHUMACHER MV, CALDEIRA MVW 2001 Biomass estimation and nutrient content of a *Eucalyptus globulus* (Labillardière) subspecie *maidenii* plantation (*in Portuguese with English summary*). *Ciencia Florestal* 11 (1): 45-53. DOI: https://doi.org/10.5902/19805098494
5. DOMINGUES RMA, SOUSA GDA, SILVA CM, FREIRE CSR, SILVESTRE AJD, PASCOAL NETO C 2011 High value triterpenic compounds from the outer barks of several Eucalyptus species cultivated in Brazil and in Portugal. *Ind Crops Prod* 33 (1): 158-164. DOI: https://doi.org/10.1016/j.indcrop.2010.10.006
6. PÉREZ CA, WINGFIELD MJ, ALTIER NA, SIMETO S, BLANCHETTE RA 2011 *Puccinia psidii* infecting cultivated *Eucalyptus* and native Myrtaceae in Uruguay. *Mycol Prog* 10 (3): 273-282. DOI: https://doi.org/10.1007/s11557-010-0698-x
7. SOTERO M, MONZA J 2007 Micropropagation of *Eucalyptus maidenii* elite trees. *Agrociencia* 11 (1): 81-89
8. KIBBLEWHITE RP, JOHNSON BI, SHELBOURNE CJA 2000 Kraft pulp qualities of *Eucalyptus nitens*, *E. globulus*, and *E. maidenii* at ages of 8 and 11 years. *N Z J For Sci* 30 (3): 447-457
9. STACKPOLE DJ, MCCONNOCHIE RM, DUNGEY HS, LOW CB, BURDON RD, KENNEDY SG 2013 Comparative performance of *Eucalyptus bicostata*, *E. globulus*, *E. maidenii* and *E. pseudoglobulus* on three northern New Zealand sites. *N Z J For Sci* 43 (6): 1-10. DOI: https://doi.org/10.1186/1179-5395-43-6
10. MCKINLEY RB, SHELBOURNE CJA, LOW CB, PENELLUM B, KIMBERLEY MO 2002 Wood properties of young *Eucalyptus nitens*, *E. globulus*, and *E. maidenii* in Northland, New Zealand. *N Z J For Sci* 32 (3): 334-356
11. PRABHU S, VIJAYAKUMAR S, YABESH JEM, RAVICHANDRAN K, SAKTHIVEL B 2014 Documentation and quantitative analysis of the local knowledge on medicinal plants in Kalrayan hills of Villupuram district, Tamil Nadu, India. *J Ethnopharmacol* 157: 7-20. DOI: https://doi.org/10.1016/j.jep.2014.09.014
12. ALLEN JC 1985 Wood energy and preservation of woodlands in semi-arid developing countries. *J Dev Econ* 19 (1-2): 59-84. DOI: https://doi.org/10.1016/0304-3878(85)90039-2
13. NYEKO P, MUTITU EK, DAY RK 2009 *Eucalyptus* infestation by *Leptocybe invasa* in Uganda. *Afr J Ecol* 47 (3): 299-307. DOI: https://doi.org/10.1111/j.1365-2028.2008.01004.x
14. NSABIMANA D, KLEMEDTSON L, KAPLIN BA, WALLIN G 2009 Soil CO_2 flux in six monospecific forest plantations in Southern Rwanda. *Soil Biol Biochem* 41 (2): 396-402. DOI: https://doi.org/10.1016/j.soilbio.2008.12.004
15. BOLAND DJ, BROOKER MIH, CHIPPENDALE GM. HALL N, HYLAND BPM, JOHNSTON RD, KLEINIG DA, MCDONALD MW, TURNER JD 2006 Forest trees of Australia. 5th ed. Csiro Publishing, Collingwood, Australia, 768 p
16. TIAN LW, ZHANG YJ, WANG YF, LAI CC, YANG CR 2009 Eucalmaidins A–E, (+)-oleuropeic acid derivatives from the fresh leaves of *Eucalyptus maideni*. *J Nat Prod* 72 (9): 1608-1611. DOI: https://doi.org/10.1021/np900290s
17. TIAN LW, ZHANG YJ, QU C, WANG YF, YANG CR 2010 Phloroglucinol glycosides from the fresh fruits of *Eucalyptus maideni*. *J Nat Prod* 73 (2): 160-163. DOI: https://doi.org/10.1021/np900530n
18. SANTOS SAO, VILLAVERDE JJ, FREIRE CSR, DOMINGUES RM, PASCOAL NETO C, SILVESTRE AJD 2012 Phenolic composition and antioxidant activity of *Eucalyptus grandis*, *E. urograndis* (*E. grandis×E. urophylla*) and *E. maidenii* bark extracts. *Ind Crops Prod* 39: 120-127. DOI: https://doi.org/10.1016/j.indcrop.2012.02.003
19. LUIS Â, NEIVA D, PEREIRA H, GOMINHO J, DOMINGUES F, DUARTE ÂP 2014 Stumps of *Eucalyptus globulus* as a source of antioxidant and antimicrobial polyphenols. *Molecules* 19 (10): 16428-16446. DOI: https://doi.org/10.3390/molecules191016428
20. BALACS T 1997 Cineole-rich *Eucalyptus*. *Int J Aromather* 8 (2): 15-21. DOI: https://doi.org/10.1016/S0962-4562(97)80020-3

21. GUNDIDZA M, CHINYANGANYA F, MAVI S 1993 Antimicrobial activity of the essential oil from *Eucalyptus maidenii*. *Planta Med* 59 (1): 705-706. DOI: https://doi.org/10.1055/s-2006-956515
22. ROH HS, LEE BH, PARK CG 2013 Acaricidal and repellent effects of myrtacean essential oils and their major constituents against *Tetranychus urticae* (Tetranychidae). *J Asia Pac Entomol* 16 (3): 245-249. DOI: https://doi.org/10.1016/j.aspen.2013.03.001
23. RENCORET J, GUTIÉRREZ A, DEL RIO JC 2007 Lipid and lignin composition of wood from different eucalypt species. *Holzforschung* 61 (2): 165-174. DOI: https://doi.org/10.1515/HF.2007.030
24. BELTRAME R, PERES ML, DELUCIS RA, FREITAS DL, GATTO DA, HASELEIN CR 2015 Longitudinal growth stress and mechanical properties of wood from *Eucalyptus* spp. clones (*in Portuguese with English summary*). *Matéria (Rio J)* 20 (4): 1061-1074. DOI: https://doi.org/10.1590/S1517-707620150004.0108
25. ABNT NBR 7190 1997 Design of wooden structures (*in Portuguese with English summary*). Brazilian National Standards Organization, Rio de Janeiro, Brazil
26. ASTM D143-14 2014 Standard test methods for small clear specimens of timber. American Society of Testing Materials, West Conshohocken, USA.
27. STOLF DO, BERTOLINI MS, ALMEIDA DH, SILVA DAL, PANZERA TH, CHRISTOFORO AL, LAHR FAR 2015 Influence of growth ring orientation of some wood species to obtain toughness. *REM: Rev Esc Minas* 68 (3): 265-271. DOI: https://doi.org/10.1590/0370-44672014680018
28. LAHR FAR, NOGUEIRA MCJA, DE ARAUJO VA, VASCONCELOS JS, CHRISTOFORO AL 2017 Physical-mechanical characterization of *Eucalyptus urophylla* wood. *Eng Agric* 37 (5): 900-906. DOI: https://doi.org/10.1590/1809-4430-Eng.Agric.v37n5p900-906/2017
29. NOGUEIRA MCJA, ALMEIDA DH, VASCONCELOS JS, ALMEIDA TH, ARAUJO VA, CHRISTOFORO AL, LAHR FAR 2018 Properties of *Eucalyptus umbra* wood for timber structures. *International Journal of Materials Engineering* 8 (1): 12-15. DOI: https://doi.org/10.5923/j.ijme.20180801.03
30. DUARTE BB 2017 Influência de componentes químicos em propriedades mecânicas da madeira (*in Portuguese with English summary*). PhD thesis, School of Engineering of São Carlos, University of São Paulo, São Carlos, Brazil, 127 p
31. NOGUEIRA MCJA 1991 Indicações para o emprego de 16 espécies de eucalipto na construção civil (*in Portuguese with English summary*). MSc dissertation, School of Engineering of São Carlos, University of São Paulo, São Carlos, Brazil, 150 p
32. DE ARAUJO VA, GARCIA JN, CORTEZ-BARBOSA J, GAVA M, SAVI AF, MORALES EAM, LAHR FAR, VASCONCELOS JS, CHRISTOFORO AL 2017 Importance of wood from planted forests for manufacturing industry (*in Portuguese with English summary*). *Pesq Flor Bras* 37 (90): 189-200. DOI: https://doi.org/10.4336/2017.pfb.37.90.824
33. FRAGIACOMO M, RIU R, SCOTTI R 2015 Can structural timber foster short procurement chains within Mediterranean forests? A research case in Sardinia. *South-east Eur For* 6 (1): 107-117. DOI: https://doi.org/10.15177/seefor.15-09