Prospects for the Utilization of Black locust Wood (*Robinia pseudoacacia* L.) coming from plantations in Furniture Manufacturing

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ABSTRACT

The recent years, interest is attracted in the utilization of black locust (*Robinia pseudoacacia L.*) timber large quantities that are expected to be harvested and enter the market the coming years, since this species was included in the proposed and financed species for cultivation by the European Union. This study was carried out to evaluate some basic mechanical properties of black locust of Greek and Hungarian origin, while beech wood of Greek origin was also included in this experiment, with a view to compare the results with a "similar to black locust" type of wood, referring to density and other characteristics, and additionally is a species extensively used in furniture construction. In particular, equilibrium moisture content, density, static bending strength, modulus of elasticity, impact bending strength and hardness of radial and tangential direction surfaces were investigated, while the results were also compared to other researchers corresponding values.

Key words: black locust, density, elasticity, hardness, impact bending, mechanical strength

1. INTRODUCTION

The previous years, black locust wood was included in the European subsidizing programme of tree species cultivation, aiming in the establishing of new plantations in many European countries. Additionally, the fast growth of this species especially in the first years, as well as the high calorific value of wood (Keresztesi 1988), has led to installation of pilot plantations of black locust for biomass production in many countries. As a result, large quantities of black locust wood will be harvested in the coming years and examination of the properties of the specific wood species would be very useful and crucial for the future utilization of wood in structures and furniture construction.

Black locust wood, because of its remarkable technical properties and physical strength that make it suitable for a large number of products, was widely used so far in pilings and some of the basic uses of sawn or round black locust timber were mine, poles and sleepers, and in smaller quantities machinery, wooden household objects, wooden ornaments, nails etc. (Keresztesi 1988, USDA 1932, Molnar 1995).

Black locust is also an important species with history of many years in many parts of the world. This species is suitable as an alternative crop for biomass and energy production (short rotation), due to its resistance to drought, fast growth and its ability to bind nitrogen (Stringer and Carpenter 1986, Naughton and Geyer 1978). Furthermore, it plays an important role in the protection of forests from erosion. In Hungary, black locust is used for the establishment of forest areas, protection blocks and "green" in urban and rural communities (Molnar 1995).

Concerning the field of timber and furniture construction, wood of black locust has gained in importance over several years. Specifically, the properties for the utilization of black locust wood can be summarized as follows.

Its wood is sufficiently hard and heavy, exhibits good mechanical properties, is dimensionally stable, can be treated satisfactorily with most gear and machinery, and is excellent in bending with steaming (So et al. 1980, Molnar 1995). The black locust wood is of high biological durability exhibiting excellent resistance to deterioration agents (microorganism attacks), which is attributed to extracts of heartwood (Erdtman 1953, Scheffer and Lachmund 1944), while it also presents excellent behaviour during impregnation (Handbook of Hardwoods, 1972). The chemical treatment would be important for the extended use and utilization of black locust in the future years, although its properties classify it into a species with less need of chemical treatments (chemical modification, impregnations, etc.), due to its high natural durability.

The color shades of black locust wood is red-green, yellow, golden yellow, yellowish brown and dark brown, but the color shade is possible to be changed with steaming (under normal or high pressure) to 1-2 atmospheres, to achieve more attractive yellow, brown or nearly black shades of approximately the same wood quality. More intense heat treatment enhances the color uniformity and machining of black locust wood and reduces also the shrinkage percentage, but reduces the mechanical strength as well. Treatment with hydrogen peroxide can effectively help the color uniformity of black locust, alleviating the main disadvantage of this wood species. Paints and finishes can be applied successfully, without any problems (Adamopoulos et al., 2007). The contact of wood with various adhesives can cause discoloration of wood (yellow areas), because of the interaction with the extractives, which determines the use and utilization of wood in structures. Solution to this problem could be the use of black locust wood in furniture items that are not apparent, such as frames of upholstered furniture etc. Generally, in the furniture industry black locust can find many applications. Additionally, the high frequency of small-diameter logs, poorly formed logs, inclusions of branches and rotten heartwood are the main drawbacks for the extended industrial utilization of this species and should be dealt with.

In the present research work, material of black locust of Greek and Hungarian origin and beech wood of Greek origin were used. Beech wood of Greek origin was included, with a view to compare the results with a "similar to black locust" type of wood, referring to density and other characteristics, and additionally is a species extensively used in furniture construction. In particular, Equilibrium moisture content, density, bending strength, modulus of elasticity, impact bending strength and hardness of radial and tangential direction surfaces were investigated, while the results were also compared to other researchers corresponding values.

2. MATERIALS AND METHODS

Experiments were carried out with black locust (*Robinia pseudoacacia* L.) of Greek and Hungarian origin and beech wood (*Fagus sylvatica* L.) of Greek origin, naturally dried for one year. Black locust wood was derived from several plantations of the two countries, while beech wood was obtained from Pertouli and Taxiarchis forest areas. The wood material of all species was cut on boards of 25 mm thickness x 50 mm width and was placed into a conditioned room at 20 ± 2°C temperature and 60 ± 5% relative humidity and allowed there to attain a nominal equilibrium moisture content (EMC). The wood of Greek black locust was found to have 0.781 g/cm^3 density and 10.45% EMC, while Hungarian black locust recorded density 0.750 g/cm^3 and EMC of 8.77%. Finally, the Greek beech wood was measured to have density of 0.722 g/cm^3 at 9.32% EMC.

The boards were visually evaluated for deformations and only those boards that were free of defects were selected for further mechanical tests processes. These boards were cut in final cross section dimensions for the measurement of mechanical properties, according to the respective standards (Density: ISO 3131:1975, Moisture Content: ISO 3130:1975, Static bending strength: ISO 3133:1975, Impact bending strength: ISO 3348:1975, Janka Hardness: ISO 3350:1975). For each property test 10-15 specimens were prepared and used. Specimens were weighed before the tests, dried in the oven at 103 ± 2°C for 24 hours and reweighed in order to estimate the mean test MC of the specimens, revealing that these values were very close to the previous measurements.

Bending tests were carried out on a Universal Testing Machine (SHIMADZU UH-300kNA), and the rate of crosshead-movement was adjusted at 5 mm/min, so that the maximum load was reached within 1.5 ± 0.5 min throughout the test. The static bending specimens were centrally loaded on radial surfaces (tangential direction), until a break of the specimen occurred. Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) values were measured during the bending strength tests procedure on the same specimens. Tests of impact bending strength and Janka hardness strength (radial and tangential) were accomplished on an Amsler Universal Wood Testing machine, adjusting the respective ancillary equipment on the machine.

The mechanical properties results were grouped and examined by one-way analysis of variance (ANOVA) comparing the differences of means at the 0.05 level.

3. RESULTS AND DISCUSSION

Based on the results of this research and the literature review that was carried out, it is easily concluded that the wood of black locust species has remarkable physical and mechanical properties that classify it in the wood species of high strength and those particularly suitable for use in furniture industry and woodwork. More specifically, some of the basic properties of wood species were examined in this experiment and the results of the tests are summarized and listed in *Table 1*.

Table 1. Mean values of Greek and Hungarian black locust and Greek beech wood properties

Property	Greek black locust	Hungarian black locust	Greek beech
Modulus of Rupture (N/mm^2)	109.88 (10.78)	173.02 (11.51)	119.55 (7.67)
Coefficient of Elasticity (N/mm^2)	10977.95 (1770.80)	18122.41 (2170.54)	13419.83 (995.07)
Impact bending strength (N/mm^2)	4.73 (1.02)	3.37 (0.76)	4.36 (0.83)
Radial Hardness (N/mm^2)	7.96 (0.39)	8.09 (0.38)	5.95 (0.27)
Tangential Hardness (N/mm^2)	8.08 (0.37)	7.48 (0.81)	5.96 (0.31)

Mean values of standard deviation in parentheses

According to the results of *Table 1*, the wood of black locust of Greek and Hungarian origin appears to have similar mechanical strength and behavior with beech wood, which is a species of similar density, used extensively in furniture manufacture. Hungarian black locust marked almost in all cases higher strength than Greek black locust, except for the cases of impact bending strength and tangential hardness. The results of modulus of elasticity (MOE) values, especially of Hungarian black locust wood were considered very satisfying, in comparison with the corresponding values of beech wood, which is a characteristic of particular importance for the construction of very high elasticity resistant connections, and wooden structures. Hungarian black locust MOE value was found to differ statistically significantly from the respective values of Greek black locust and beech wood. Radial and tangential hardness values of black locust of both Hungarian and Greek origin were found to be significantly higher compared to the corresponding values of beech wood. There were not particular statistically considerable differences between the hardness values of the two origins of black locust wood.

Table 2 Mean values of black locust mechanical properties derived from the literature

Property	Pollet et al. (2012)	Wagenfuhr and Schreiber (1989)	Nemeth et al. (2000)	Sell and Kropf (1990)	Stringer (1992)	Forest products laboratory (1987)
MOR (N/mm^2)	138 (20)	103-169	152	118-145	-	136.4
MOE (N/mm^2)	15700 (2100)	9000-13600	12631-13384	11000-15700	14413	-
Rad. Hardness (N/mm^2)	6.66 (1.4)	-	-	9.5	-	-
Tang. Hardness (N/mm^2)	6.13 (0.95)	-	-	-	-	-

Mean values of standard deviation in parentheses

Our results could be compared to the corresponding strength results of some previous researches, referring to black locust wood in *Table 2*. Except for those, comparisons that have been implemented by the researchers Adamopoulos *et al*. (2007) between juvenile and mature wood specimens of similar densities (0.667-0.894 g/cm^3 and 0.682 - 0.892 g/cm^3, respectively) showed that juvenile wood of black locust had a statistically significant lower mean MOR (138.78 N/mm^2), MOE (13,936 N/mm^2), Pure MOE (18,125 N/mm^2), MOE of dynamic strength (16,813 N/mm^2) and toughness strength (155.25 KJ/m^2) than the mature wood (148.29 N/mm^2, 14,747 N/mm^2, 19,498 N/mm^2, 17,635 N/mm^2 and 181.27 KJ/m^2, respectively).

Furthermore, the results of the present research were compared to a previous research of us (Vassiliou *et al*., 2016), where the same wood material was used (Greek and Hungarian black locust, Greek beech) and evaluated the strength of the corner and middle joint types of mortise-tenon, and double dowels, using PVAc and PUR adhesive. According to the findings, the strength of black locust joints of both Greek and Hungarian origin, was proved very high, reaching the strength levels of beech wood joints and exceeded them in the case of PUR adhesive presence. PVAc adhesive provided better strength results, in comparison with PUR adhesive, as regards to both joint types, while mortise-tenon joint in combination with PVAc, provided the best strength results for all wood species. They referred also that Greek and Hungarian black locust joints were characterized by very high MOE values reaching the elasticity level of beech wood. These findings comply with those of the present research, since black locust, as well in this research, revealed similar strength with that of beech wood and in case of Hungarian origin black locust the mechanical strength exceeded the one of beech wood, in all cases with the exception of impact bending strength.

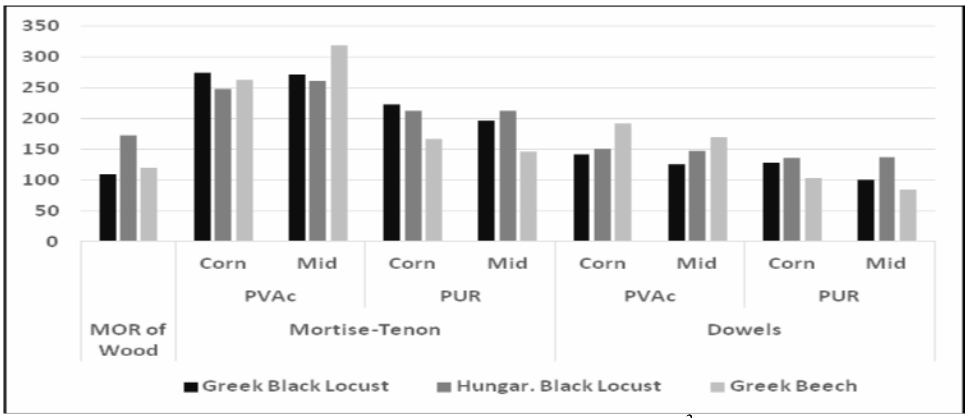

Figure 1 Configuration of the mean values of Modulus of Rupture (N/mm^2) of Greek, Hungarian black locust and Greek beech wood specimens and the respective strength values of Mortise-Tenon and double Dowels joints constructed with the same species (Vassiliou et al. 2016)

Figure 1, that depicts the result of the comparison between the static bending strength values of the three species (Greek, Hungarian black locust and Greek beech wood) and the joints that were constructed with these species, revealed that the joints in most cases demonstrated higher strength than the plain wood specimens, which is strongly influenced by the joint type and adhesive type and less by the wood species. PVAc is better to be used in combination with beech wood, whereas PU showed better strength results in black locust wood. In most cases corner joints marked higher strength compared to the respective middle joints. Generally, Hungarian black locust revealed higher strength both in plain wood specimens and in most cases of joint specimens.

Therefore, the furniture manufacturers should be aware and take into account that black locust wood may be used in many applications in furnishing and could replace other species which have traditionally been used so far. For example, it is suitable for flooring and decks, due to its high hardness, as well as wooden wall coverings, beams and bridge supports with the adhesion of black locust products, pallets, sleepers, stakes, poles in vineyards, sawn timber for fences, barrels of wine, structural purposes (in laminated wood constructions), and also what may not be used otherwise, could be utilized in the production of particleboards, fiberboards, OSB boards or in firewood/ fuel production.

4. CONCLUSIONS

In recent years, and mainly because of our increasingly growing needs in timber and wood products worldwide, more researches on the utilization of black locust wood have begun to be implemented. Generally, black locust is an important species with history of many years and the interest for this species is constantly increasing also because of its suitability for various other uses beyond the timber production. As a consequence of its exceptional technical properties, this species is expected in the future to contribute to the creation of high added value products, given the vigorous technological development occurring (informatics, design, machinery, logistics etc.) and is expected to be a species with high demand in wood industry.

As a result, the utilization enhancement of black locust wood should be one of the priorities of management of the wood quantities that will be harvested in Greece in the coming years. A significant part of black locust wood, which will be produced from the plantations established the previous years in Greece through the European support and development programs of plantations in our country, could be used in furniture construction and especially the upholstered furniture frames, eliminating the drawback of the color unevenness of this wood, as well as other structures. In this way, part of the imported high-strength timber commonly used would be replaced by this species and there would be less logging pressure in forests in our country and worldwide for larger quantities of durable and of high-quality wood.

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REFERENCES

Adamopoulos, S.; Passialis, C.; Voulgaridis, E. (2007): *Strength properties of Juvenile and Mature wood in Black locust (Robinia pseudoacacia L.).* Wood and Fiber Science 39 (2): 241-249.

Erdtman, H. (1953): *Ueber einige Inhaltstoffe des Kernholzes der koniferenordnung Pinales*. Holz Roh-Werkstoff 11: 245-251.

Forest Products Laboratory (1987): *Wood Handbook: Wood as an engineering material.* U.S. Dep. Agric. Agric. Handb. 72.

Handbook of Hardwoods (1972): *2nd Edition. Revised by R.H. Farmer*. Princes Risborough Laboratory, London.

Keresztesi, B. (1988): *The Black Locust. Forestry Monograph-Series of the Agricultural Science Department of the Hungarian Academy of Sciences*. Ed.B. Keresztesi. Budapest. pp 197.

Molnar, S. (1995): *Wood properties and utilization of Black Locust in Hungary*. Drevarsky Vyskum 1: 27-33.

Nemeth, R.; Feher, S.; Keszlen, I.; Babiak, M.; Cunderlik, S. (2000): *Static and dynamic strength properties. Final report of the project activities.* Technology for high quality products from black locust. Inco-Copernicus project No PL 96-4144, Brussels.

Naughton, G.G.; Geyer, W.A. (1978): *Wood as supplemental fuel to generate steam*. In Proc. 2nd Central Hardwood For. Conf. (P.E. Pope, ed.), 107-122, West Lafayette, IN.

Pollet, C.; Verheyen, C.; Hébert, J.; Jourez, B. (2012): *Physical and mechanical properties of black locust (Robinia pseudoacacia) wood grown in Belgium*. Canadian Journal of Forest Research, 2012, 42(5): 831-840.

Scheffer, T.C.; Lachmund H.G. (1994): R*elation between hot-water extractives and decay resistance of black locust wood.* J. Agric. Res. 68(11): 415-426.

Sell, J.; Kropf F. (1990): *Proprietes et caracteristiques des essences de bois.* Union Suisse en faveur du bois, Le Mont, Suisse.

So, W.T.; Park, S.J.; Kim, J.K.; Shim, K.; Lee, K.Y.; Hyun, J.W.; Lee, H.S.; Kang, S.K., Jo, J.M. (1980): *On wood properties of imported (introduced) species grown in Korea. Wood properties of Pinus stobus, Pinus silvestris, Pinus banksiana, Picea abies and Robinia pseudoacacia*. Res. Rep. For. Res. Inst. S. Korea 27:7–31.

Kang, S.K.; Jo J.M (1980): *On wood properties of imported (introduced) Species grown in Korea. Wood properties of Pinus stobus, Pinus silvestris, Pinus banksiana, Picea abies and Robinia pseudoacacia.* Res. Rep. For. Res. Inst. S. Korea 27: 7-31.

Stringer, J.W. (1992): Wood properties of black locust (Robinia pseudoacacia L.): physical, mechanical, and quantitative chemical variability. Proceedings:International Conference on Black Locust: Biology, Culture and Utilization. June 17-21, 1991. East Lancing, Michigan, USA.

USDA (1932): *American Woods.* United States Department of Agriculture,
Forest Service, Washington.

Vassiliou, V.; Barboutis, I.; Kamperidou, V. (2016): *Strength of corner and middle joints of upholstered furniture frames constructed with black locust and beech wood*. Wood Research 61 (3):2016.

Wagenfuhr, R.; Schreiber, C. (1989): *Holzatlas.*VEB fachbuchverlag Leipzig pp.422-424.